A STUDY OF ALGEBRA 1 STUDENTS' USE OF DIGITAL AND PRINT TEXTBOOKS

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

A STUDY OF ALGEBRA 1 STUDENTS' USE OF DIGITAL AND PRINT TEXTBOOKS

Presented by Amanda Thomas,

a candidate for the degree of Doctor of philosophy,

and hereby certify that, in their opinion, it is worthy of acceptance.

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Professor Barbara J. Dougherty

Professor James E. Tarr

Professor David Bergin

Professor Joi L. Moore

For my children who give me purpose for all that I do.

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Appreciation is a wonderful thing:

It makes what is excellent in others belong to us as well. –Voltaire

Four years ago, I applied for the doctoral program in mathematics education at the University of Missouri because it was within an hour of my hometown. It didn't take long before I realized my good fortune to be part of such an esteemed community of scholars. It is with utmost appreciation that I acknowledge the faculty members, colleagues, friends, and family who supported me throughout my doctoral study.

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A STUDY OF ALGEBRA 1 STUDENTS' USE OF DIGITAL AND PRINT TEXTBOOKS

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ABSTRACT

The dissertation study described here examines Algebra 1 students' use of print and digital mathematics textbooks within the classroom setting. Following the emergence of digital textbooks in U.S. schools, the study responds to a critical need to understand not only the potential of innovative digital instructional materials, but also the actual implementation of new textbook media within mathematics classrooms. Whereas prior studies relating to printed textbook use have focused on teachers, consideration of students' digital textbook use confronts the claim that these products are more engaging and motivating. Examining both print and digital textbook use allows for comparison between how students use Algebra 1 textbooks presented in two formats.

Activity theory frames the study, functioning as a tool to understand how students use textbooks within the context of the mathematics classroom. This case study employed qualitative methods to investigate how students in two Algebra 1 classrooms, taught by the same teacher, used corresponding print and digital formats of a commercially published Algebra 1 textbook. Daily observations and video recordings, a series of student interviews, weekly teacher interviews, and artifacts of student work depict student use of the two textbook formats throughout a chapter focusing on linear functions. Data analysis focuses on clips of student textbook use, recorded from students' perspectives using head-mounted video cameras. These clips are supported with data from stimulated recall interviews in which students elaborated on their textbook use.

Findings indicate that students used a small proportion of the textbook resources and features available to them, both in the class using print format and in the class using digital format. Although variation existed among students in both classes, students tended to view the textbook primarily as a source for homework exercises and rarely attended to worked out examples and text within lessons. Furthermore, students' textbooks use was predominantly teacher-directed regardless of the textbook format. However, the two classes differed with respect to their engagement with the classroom community while using their textbooks. Students in the class using print textbooks tended to engage with the teacher and peers while using their textbooks, while the class using the digital format remained mostly silent as students used their textbooks. One of most notable findings in the study occurred in the class using digital textbooks. Although the digital textbook included a variety of interactive features, those features were among the least used. Nonetheless, students in both classes expressed preferences for digital formats.

Implications of the study suggest that strategic use of textbooks, regardless of format, is not automatic for students and that classroom teachers play an important role in how their students use their Algebra 1 textbooks. In order to capitalize on the potential that digital textbooks offer for integrating mathematics curriculum with technological learning tools, students must not only understand how to use these powerful resources, but also have a motive to engage more deeply with the mathematical content conveyed in the materials

I. INTRODUCTION

Rationale

For many years, mathematics textbooks have been a stable component in school mathematics classrooms, providing guidance for millions of teachers and students (Reys, Reys, & Chavez, 2004). As the Center for the Study of Mathematics Curriculum (CSMC) research framework indicates (see Figure 1.1), teachers serve as mediators of the textbook curriculum such that students experience the teacher's implemented mathematics curriculum. Accordingly, a number of researchers have considered the relationship between the textbook curriculum and teacher-implemented curriculum. Yet, students also use and interact with the textbook curriculum every time they open up a mathematics textbook. This study focuses on this relationship between mathematics students and the textbook curriculum, with particular attention to student use of two forms of a textbook (printed and digital) used in two different Algebra 1 classes taught by the same teacher.

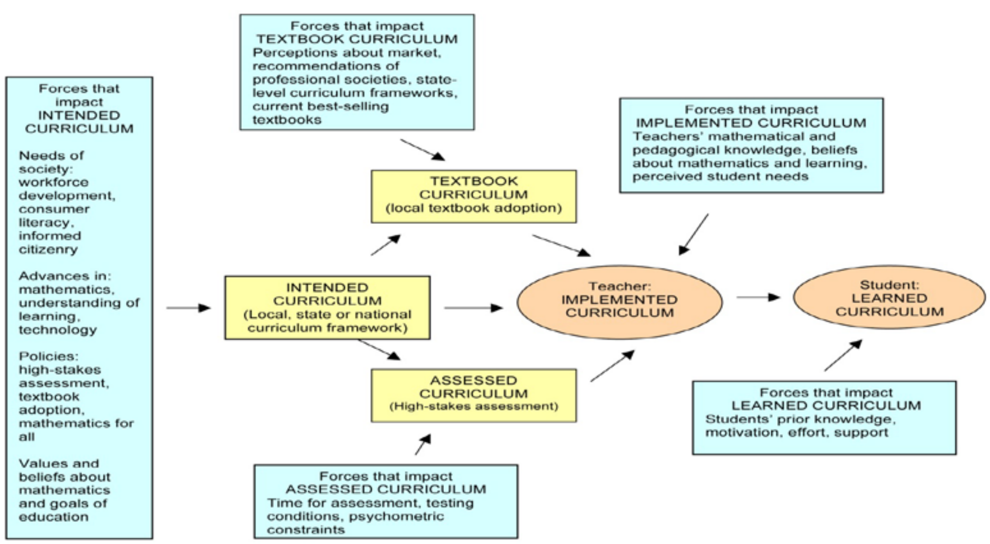


Figure 1.1. CSMC Research Framework

Statement of the Problem

Consideration of students' use of print and digital mathematics textbooks is important and timely as digital textbook options are quickly emerging for K–12 education. In higher education, digital textbooks have gained popularity in recent years with sales in U.S. higher education growing 44.3 percent to $267.3 million in 2011 (Herff Jones, 2012). Digital textbooks are also gaining popularity for K–12 students. A national survey indicated that approximately one-third of high school students and one-fourth of middle school students accessed textbooks via electronic devices in 2010, while over half of students, parents, and administrators would like to empower digital content with online or digital textbooks (Project Tomorrow, 2010). On Digital Learning Day, February 1, 2012, U.S. Secretary of Education, Arne Duncan, promoted digital textbooks by challenging U.S. schools to transition to digital textbooks in the next five years.

Proponents of digital textbooks have suggested that this new medium will revolutionize textbooks by adding interactivity, customizability, and flexibility to engage and motivate students in ways that are not possible on the printed page (Apple, Inc., 2012). While digitization may transform the mathematics textbook medium, it is unclear to what extent that transformation will result in higher quality materials. Tarr, Reys, Barker, and Billstein (2006) proposed that mathematics textbook quality considerations include mathematical content emphasis, instructional focus, and teacher support, criteria which digitization may or may not impact. Presently, there exists a dearth of research to support or negate optimistic claims about how digital textbooks might impact the quality of textbooks or the ways in which students experience the school mathematics curriculum.

Theoretical research in mathematics education has considered how virtual, dynamic representations might change the learning experience. Shaffer and Kaput (1999) argued that from a cognitive evolutionary perspective, “the ability to externalize manipulation of formal systems changes the very nature of the cognitive activity” (p. 97). They contended that in this new ‘virtual culture,’ mathematics education should capitalize on creating and modifying representations and making sense of the world.

Extending Kaput’s theories on dynamic representation, Moreno-Armella, Hegedus, and Kaput (2008) proposed five stages in the evolutionary transition from static to dynamic representations. These stages are *static inert, static kinesthetic/aesthetic, static computational, discrete dynamic, and continuous dynamic.* In the first stage, inscription or print is ‘fused’ to the media on which it is presented. This characterizes traditional printed textbooks. The second stage, static kinesthetic/aesthetic, allows users to inscribe upon the media with eraseability, such as chalk or colored pencils. The static computational stage refers to “a static representation of the user’s input or interaction with the [computational] device” (p. 103). The fourth stage, discrete dynamic, allows for co-action between the user and the media environment with discrete user inputs represented on the medium in malleable ways. The final stage of dynamic representation, continuous dynamic, involves a medium that is sensitive to continuous user inputs through time and space. For instance, digital textbooks on tablets could potentially detect movement of the surface or allow students to provide continuous inputs by dragging or using sliders via the touch screen. While printed representations of mathematics would be categorized in the static inert stage, digital textbooks enabled by touch screen devices allow the curriculum to provide continuous dynamic representations.

Considered from this perspective, an affordance of digital mathematics textbooks is the dynamic, networked, virtual representations they enable. Digital textbooks also afford opportunities to integrate the content of mathematics textbooks with instructional technologies. This study helps to establish a basis of research regarding how students use and interact with both printed and digital textbooks, also providing insight as to whether claims about increased student engagement with digital textbooks hold true in the context under consideration.

Theoretical Framework

In this study, learning is viewed as a social activity that involves cultural tools (Vygotsky, 1978) including print and digital textbooks. From the sociocultural perspective on learning, "human action is viewed from the perspective of how it inherently involves cultural tools, and these cultural tools shape practices and what the cognitive consequences of participating in those practices will be" (Hatano & Wertsch, 2001).

A number of studies related to curriculum and technology use in mathematics education have been conducted from a sociocultural perspective. Remillard (2005) identified studies from a sociocultural perspective for which she described curriculum use as "participation with" the text. This characterization of curriculum use is also useful for considering students' use of mathematics textbooks, particularly digital textbooks with which students can interact in a dynamic way. A sociocultural lens was also explicitly identified in a study of teacher and student use of technology in secondary mathematics classrooms in Australia (Goos, Galbraith, Renshaw & Geiger, 2003). Furthermore, Roschelle (2003) acknowledged learning with wireless Internet learning devices as a social activity.

> Mobile devices participate in a network that is overlaid in the same physical space in which students and teachers participate socially in teaching and learning, so two distinct kinds of participation are occurring at the same time and in the same space: the normal social participation in classroom discussion (for example) and the new informatic participation among connected devices. (p. 261)

Activity Theory

The sociocultural psychology of Vygotsky is reflected in activity theory (Leont'ev, 1974; Engeström, 1987; Cole & Engeström, 1993; Nardi, 1996) which functions as a tool for understanding how individuals interact with cultural artifacts in social contexts (Nardi, 1996). The unit of analysis is activity or an activity structure, which can occur over a varied period of time and involve multiple actions. Activity is a complex series of actions, guided by a specific purpose, during which a subject engages in a sequence of processes, mediated by artifacts and directed at objects or tasks, resulting in outcomes. Wertsch (1994) suggested that mediated action is a nonreductionist, manageable unit of analysis and described mediational means as "carriers" of sociocultural patterns and knowledge. He suggested that mediated action involves tension between these "carriers" and the unique contextualization of mediational means in concrete actions.

Activity theory is commonly utilized to guide studies of human computer interaction and educational technology use (see, for example, Bottino, Chiappini, Forcheri, Lemut & Molfino, 1999; Stevenson, 2008; Karasavvidis, 2009). Even and Schwarz (2003) applied activity theory to illustrate the contrast between interpretations of a mathematics lesson from two different theoretical perspectives, cognitive science and sociocultural theory. Of specific relevance to this study, Rezat (2006) proposed activity theory as a worthwhile perspective for modeling the use of mathematics textbooks among students and teachers.

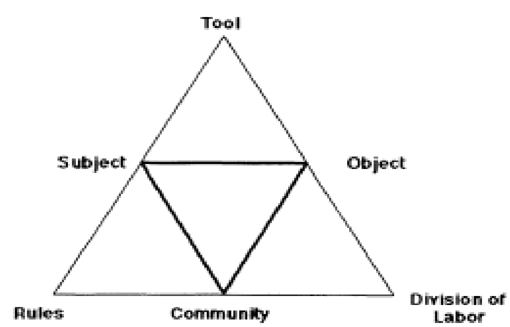


Figure 1.2. Engeström's (1987) Triangular Model of Activity

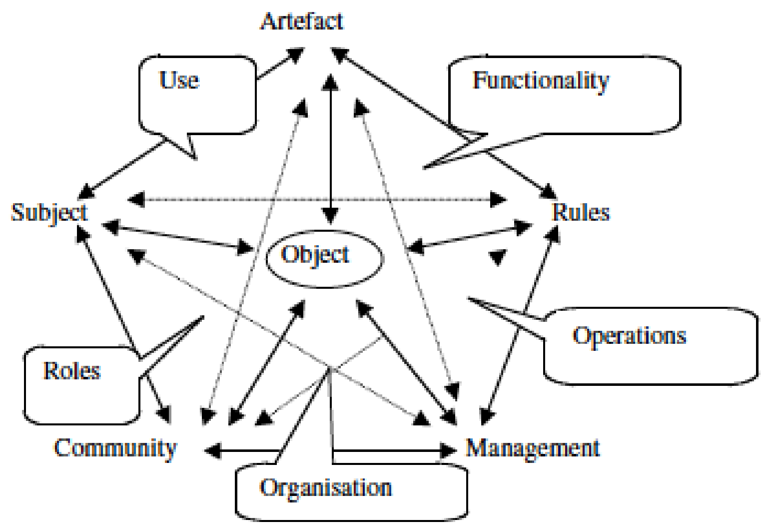


Figure 1.3. Activity Pentagon and Aspects of Action (Stevenson, 2008)

Activity theory is traditionally represented as a triangular model (see Figure 1.2), but this study considered a topologically equivalent pentagonal model developed by Stevenson (2008), shown in Figure 1.3. Both models include the same seven interconnected elements: subject, rules, community, division of labor/management, tool/artifact, and object. What is not visually apparent in either model is the relationship of objects with the seventh element, outcomes. In three dimensions, this relationship would extend from the object orthogonally to the page. Table 1.1 summarizes these elements and how they are embodied in this study.

Table 1.1.

Elements of an activity system and examples.

	Brief description	Examples within this proposed study
Subject	Person or group of persons.	Algebra 1 students
Rules	Conditions that enable and constrain the activity (Stevenson, 2008)	Teacher's curricular decisions, classroom norms, digital infrastructure, specific to the task
Community	Human social context of the activity	Teacher and students in each Algebra 1 classroom
Division of labor/management	Organization of processes related to the goal (Roschelle, 2003)	Roles and relationships among students and the teacher.
Tool/artifact	Mediators of sociocultural patterns and knowledge (Wertsch, 1994)	Digital and print textbooks
Object	Task designed to produce outcomes (Stevenson, 2008)	Mathematics tasks and exercises
Outcome	Skill, knowledge, or understanding	Algebra 1 learning objectives

In a study of mathematics teachers in England using digitally based activities for computers and interactive whiteboards, Stevenson (2008) developed a model of pedagogy based on activity theory, using the pentagonal representation to make more explicit the relationships between rules and artifacts, rules and management, and management and artifacts. The pentagonal model was particularly appropriate for the study of print and digital textbook use because Stevenson extended the model to include five facets of an action and how they relate to objects and outcomes, as shown in Figure 1.3. The facets of an action include roles, organization, use, functionality, and operations; the following descriptions are summaries of definitions offered by Stevenson (p. 840).

> *Roles* shape the relationships between teachers and learners, such as simple roles during lecture and more complex roles during discussion.
>
> *Organization* relates to the grouping and management of teachers and learners during an activity.
>
> *Use* includes how individuals or groups employ artifacts such as print or digital textbooks in practice.
>
> *Functionality* identifies the potential uses for artifacts made possible by designers and available to subjects.
>
> *Operations* refer to the physical availability and distribution of artifacts and their management within the context of the activity.

The *use* aspect is the specific focus of this study. Rather than acting as a prescriptive tool, activity theory provided a general structure for understanding textbook use in context. This framework drew attention to the complexity and components involved in using textbooks, including attention to the social aspect of the classroom community. It was particularly useful to employ activity theory for this exploratory study because there was little prior research regarding student use of either print or digital textbooks from which to build.

Research Questions

The purpose of this study is to investigate student use of print and digital mathematics textbooks in two Algebra 1 classrooms (one using only print textbooks and the other using only digital textbooks) taught by the same teacher. The specific research questions guided investigation of student use of each textbook medium as well as a comparison of use between the two media specific to the content of an Algebra 1 class. Thus, the overarching research question included a number of sub-questions.

Main Research Question: What is the nature of students' use of mathematics textbooks?

1. How do students in an Algebra 1 class use their printed textbooks?
2. How do students in an Algebra 1 class use their digital textbooks?
3. How does student use of digital textbooks compare with student use of printed textbooks in two Algebra 1 classes taught by the same teacher?

Definition of Terms

Content Curation

The term 'content curation' refers to "finding, organizing, and sharing the best and most relevant content on a specific issue online" (Jim, 2012).

Digital textbook

'Digital textbook' refers to more than just an image of a textbook on a digital device. The definition of 'digital textbook' is taken from legislation in Florida that reads, "Text-based or image-based content in a form that provides the student with various interactive functions that can be searched, tagged, distributed, and used for individualized and group learning that includes multimedia content such as video clips, animations, and virtual reality; and that has the ability to be accessed at any time and anywhere" (Florida State Senate, 2011). This study focuses on the digital version of Houghton Mifflin Harcourt's Algebra 1 Common Core Edition (2012). The digital version of the textbook is enabled via the HMH Fuse: Algebra 1 CC application (or 'app') for iPad (Burger, et al., 2012b).

Electronic textbook/e-textbook

Although the terms 'digital textbook' and 'electronic textbook' are sometimes used interchangeably, there is an important distinction to be made for the purposes of this study. An electronic textbook lacks the interactivity of a digital textbook. In this study, an electronic textbook refers to an image of a print textbook (e.g., pdf, epub format) that is rendered on an electronic device (e.g., computer screen, ebook reader).

Open education resources (OER)

Open education resources, or OERs, refers to tools and resources created in collaboration among a group of people, that can be modified at anytime, by anyone, and are made available to educators free of charge (Szeto, 2009).

Printed mathematics textbook

Printed mathematics textbook refers to a collection of content, contexts, activities, and exercises, adopted by a school or district and used by teachers and students to organize and sequence mathematics content, conveyed statically using print media. This study focuses on one particular printed textbook, Algebra 1

Common Core Edition, published by Houghton Mifflin Harcourt (Burger et al., 2012a).

Web 2.0

Web 2.0 was a term first coined in 2004 to characterize the transition to not only read, but read and write on the internet using more participatory, collaborative, and distributed practices such as social networks and participatory media (Greenhow, Robelia, & Hughes, 2009).

Significance of Study

Publishers, policy makers, and school administrators have touted digital textbooks as innovative, motivational, and engaging for 21st century learners (Apple, Inc., 2012; Fletcher, Schaffhauser, & Levin, 2012; Foughty & Keller, 2011; Houghton Mifflin Harcourt, 2012). This study is among the first to research these claims, examining the nature of students' textbook use within mathematics classrooms.

Prior studies of mathematics textbook use have considered only teacher use of print textbooks. This study builds upon existing studies of teachers' mathematics textbook use, extending the notion of textbook use to include how students use their mathematics textbooks. Consideration of both print and digital textbook use by students will further contribute to the field's understanding of the role mathematics textbooks play in students' mathematical learning experiences.

II. REVIEW OF RELATED LITERATURE

To date, little research has focused specifically on classroom use of digital textbooks for K–12 mathematics education. Given the paucity of research on use of digital mathematics textbooks, this review of literature draws upon reports and studies regarding digital textbooks, mathematics curriculum materials use, mathematical technology use, and the intersection of mathematics curriculum and technology tools. Digital mathematics textbooks have the potential to coordinate the use of curriculum and mathematical tools together on a single computing device. Thus, examining research regarding these individual components of a digital mathematics textbook environment helps to frame further study of the use of digital mathematics textbooks.

Digital Textbooks

The Emergence of Digital Textbooks

Although research literature specific to digital textbooks is very limited, print and news media sources have devoted considerable attention to this emerging textbook medium in recent years. In January 2012, digital textbooks were highlighted nationally by Apple's announcement of iBooks2, partnerships with textbook publishers to provide inexpensive, interactive digital textbooks for K–12, and authoring tools that allow virtually anyone to create their own digital textbooks with interactive widgets (Apple, Inc., 2012).

A number of sources, ranging from educational researchers to journalists and commentators, have expressed opinions about the potential affordances and constraints of digital textbooks for K–12 education. Researchers at the Florida State

University PALM Center authored a whitepaper describing a number of benefits and limitations of digital textbooks, particularly in Florida (Mardis, Everhart, Smith, Newsum, & Baker, 2011). They suggest that digital textbooks: increase opportunities to learn, promote good teaching, enable differentiation, promote improved technology integration, make financial sense, improve local control over curriculum, protect children's health and safety, and protect the environment. Among the potential drawbacks of digital textbooks, Mardis et al. warned that digital textbooks may compromise comprehension and engagement, exclude visually-impaired learners, perpetuate socioeconomic gaps in education, and be limited by the lack of internet connectivity in schools. They also suggest that teachers are not prepared to use digital content effectively and that digital textbooks will not resolve flaws in traditional curricula materials. As indicated by the works cited in the white paper, the points raised by Mardis et al. are supported by anecdotal cases, media reports, market research, and research related to, but not directly focused on, digital textbooks in classrooms.

Another white paper on the topic authored by Herff Jones (an educational publishing company and retailer of education-related products such as yearbooks, class rings, and graduation regalia) described "e-textbooks" as an opportunity to leverage technology to take learning into the 21st century (2012). In addition to describing Apple's recent venture into the digital textbook marketplace, the paper highlights the increasing appeal of digital textbooks and e-book readers among some educators and school district personnel. The report raises concerns about the costs of tablets to enable Apple-only digital textbooks and the impact of iBooks

Author. In particular, the need for content curation was highlighted; that is, there is a need to organize and evaluate existing content. The authors suggest that iBooks Author may flood the market with content rather than help to identify the best quality content. Referring to Wikipedia-like “crowdsourcing” approaches to identify high quality digital textbooks, the authors quote Donahoo (2012), “Education is not the type of activity you want directed by a popularity contest” (p. 7).

Project Tomorrow provided another public perspective on digital textbooks in K–12 education. Since 2003, the nonprofit education organization has annually conducted the *Speak Up* survey that polls K–12 students (n = 294,399), parents (n = 42,267), and educators (n = 42,619) about the role of technology for learning in and out of school. The 2010 findings from K–12 students and parents indicated that, while a minority of K–12 students uses digital textbooks, a majority of both parents and students identify digital textbooks as a component of their idealized school (see Figure 2.1).

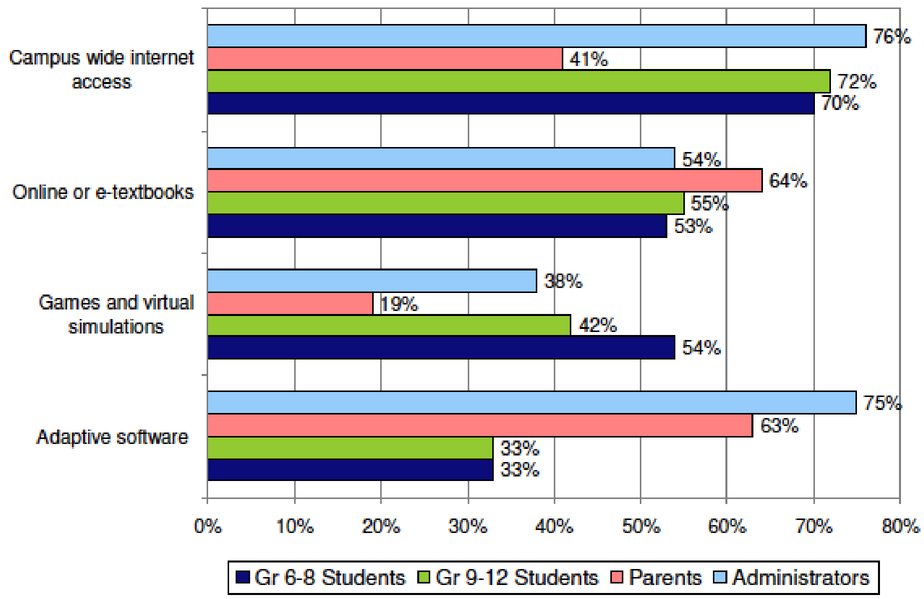


Figure 2.1. Ultimate School: Empowering Digital Content (components of idealized school). (Project Tomorrow, 2011, p. 16)

In their 2012 report, *Out of Print: Reimagining the K–12 Textbook in the Digital Age*, the State Educational Technology Directors Association (SETDA) asserted, "It is not a question *if* the reimagining of the textbook will permeate all of education, only a matter of how and how fast" (Fletcher, Schaffhausen, & Levin, p. 6). SETDA described a number of student learning benefits when students can access increasingly available quality digital content through affordable computing devices. The benefits of digital content include the ability to keep materials up to date without reprinting or redistributing print materials; accessibility at any time, anywhere, online and offline; customization and personalization to meet individual students' needs; and "digital content can be far richer and engaging, including not only text, but also high-definition graphics, video clips, animations, simulations, interactive lessons, virtual labs, and online assessments" (p. 1).

The SETDA report outlined digital textbook opportunities while acknowledging the limitations of present digital content.

> The educational environment isn't exploiting digital content for all of the benefits that can accrue for today's learners. The gap is widening for what we do in our lives–how we communicate, work, learn, and play–and how we're educating our kids. (p. 5)

The report described the motivational appeal of digital textbooks, "As Tom Woodward, assistant director of Instructional Technology at Henrico County Public Schools in Virginia, notes, 'Much of the power [of digital content] comes from using things people actually like, things they'd use of their own free will'" (p. 14).

In addition to identifying benefits, opportunities, and shortcomings of digital textbooks, the SETDA report identified interrelated policy challenges and issues related to shifting from print to digital instructional materials. These issues and brief descriptions are summarized in the report as follows.

- Sustainable funding for devices. Without easy access to devices, students cannot take full advantage of the digital content (and these same devices can and should be leveraged for other educational ends, including online assessment and access to online learning).
- Robust internet connectivity. States need to plan for and implement a network and internet infrastructure sufficient to enable pervasive, simultaneous use of devices for instruction, assessment, and school operations.
- Up-to-date policies and practices. In addition to state policy changes, local districts need to examine their policies and practices to jettison those that inhibit the use of digital content and look for initiatives and incentives to encourage its use.
- Prepared educators. Colleges of education need to prepare teachers to use digital content, and districts need to provide opportunities for sustained professional learning, including online access to communities of practice.
- Intellectual property and reuse rights. A key benefit of digital content is its flexibility, but content should be licensed as to take advantage of the flexibility and encourage sharing and customization.
- Quality control and usability. If digital content is vetted at the local level and

tagged in such a way as to make it easy to find and use in a variety of situations, it saves teachers time and helps them to personalize learning in their classrooms.

- State and local leadership buy-in. Leadership is a key factor in changes in state policy and it is no less important at the local level. Leaders provide the necessary vision and support to enable successful implementation planning. (Fletcher, Schaffhauser, & Levin, 2012, p. 2)

The next section describes developments in public policy at local, state, and national levels relating to digital and electronic instructional materials and textbooks.

Digital Textbooks and Public Policy

Szeto (2009) provided a status report regarding open source digital textbooks (a type of open education resource) for secondary schools highlighting electronic, static representations of printed text. She noted public policy as an influence on digital textbooks for K–12 and specifically identified the California Learning Resource Network digital textbook initiative – an initiative of Governor Schwarzenegger, which encouraged school districts to adopt open source textbooks as a cost-cutting measure.

In 2008, California became the first closed-adoption state to consider free, online textbooks for state approval. (As a closed-adoption state, California officials evaluate textbooks and provide a list of textbooks approved for adoption in K–12 schools throughout the state.) As one of the earliest and largest initiatives to legitimize digital content for K–12 schools, The California Digital Textbook Initiative reviewed a number of online, open source textbooks across multiple disciplines for alignment with California content standards. This review led to approval of seven digital mathematics textbooks for use in California public schools (California

Learning Resource Network (CLRN), 2009). Included on the approved list were one algebra II textbook, four calculus textbooks, one geometry textbook, and one trigonometry book. Since then, the California Learning Resource Network has continued to review and add book titles for courses such as linear algebra, probability and statistics, advanced probability and statistics, trigonometry, and calculus (CLRN, 2010a and CLRN, 2010b). Presently, California school districts can choose from nineteen different free digital textbooks across a range of secondary mathematics courses.

Early in 2011 Florida SB 2120, the annual K–12 education funding legislation, mandated districts to spend at least half their textbook budgets on digital materials by 2015-16. Whereas the California digital textbook initiative was intended as a cost-saving measure, Florida's digital textbook legislation earmarks half of existing district textbook budgets for the purchase of digital instructional materials, providing resources for the purchase of materials beyond open education resources (OERs).

Other U.S. states are beginning to consider or incorporate digital textbooks and tablets into K–12 classrooms, if only in a few districts or grade levels. In 2012, Alabama began considering a bill that would provide resources to purchase tablets for all high school students (Baggett, 2012). Through the Classroom Innovation Grant for Mathematics, several schools in Indiana piloted digital mathematics curricula. Reactions among Indiana teachers have been mixed although some conclude that, "Students have generally expressed that they have enjoyed their math classes more than they have in the past" (Foughty & Keller, 2011, p. 66). Elsewhere, individual districts such as Joplin, Missouri (Hefling, 2012); Clark County, Nevada (Takahashi, 2011); Moorseville, North Carolina (Tulenko, 2011); and the San Diego Unified School District (Kucher, 2012) have begun implementing their own digital textbook initiatives.

A 2012 SETDA report described some of the state-level initiatives related to digital textbooks taking place in 22 states at the time. Figure 2.2 indicates these states and the types of digital textbook policy innovations that they have undertaken. State policy has generally fallen into three categories: redefining textbooks to provide flexibility for adoption and funding of digital materials, launching digital textbook initiatives, and launching OER initiatives. The map displays the extent of state policy initiatives relating to transitioning from print to digital educational resources.

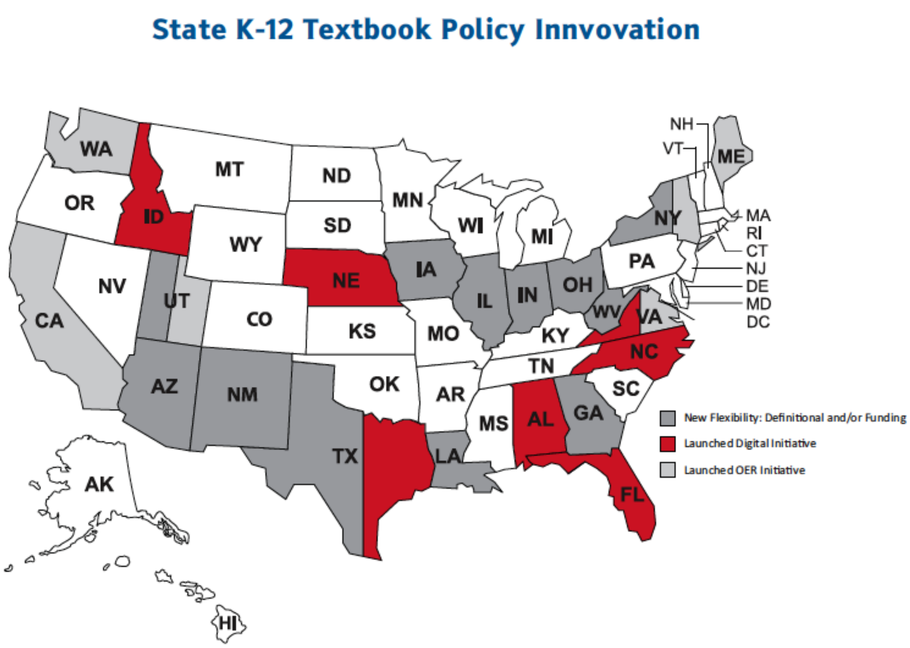


Figure 2.2. State K-12 Textbook Policy Innovation (Fletcher, Schaffhauser, & Levin, 2012)

The U.S. federal government has also advocated for digital textbooks in K–12 schools. On the first Digital Learning Day on February 1, 2012, the Federal Communications Commission (FCC) released the Digital Textbook Playbook, to "advance the conversation toward building a rich digital learning experience" (Digital Textbook Collaborative, 2012, p. 3). Informed by considerations of broadband access and the Department of Education's National Educational Technology Plan (2010), the Digital Textbook Playbook was developed by the Digital Textbook Collaborative, a joint effort of industry stakeholders and school nonprofit leaders. The playbook draws from the Digital Learning Imperative report from the Alliance for Excellent Education (2012) in defining and conceptualizing digital learning.

On Digital Learning Day, U.S. Secretary of Education Arne Duncan challenged U.S. educators and policy makers to transition to digital textbooks within five years. This goal coincides with the South Korean digital textbook initiative to replace printed textbooks with digital alternatives by 2015 (Knapp, 2011). Under the South Korean initiative, the Ministry of Education plans to transfer all printed textbooks to digital form by 2015 to leverage the features of digital textbooks described in Table 2.1. Early reports concerning the Korean digital textbook initiative indicated resistance during piloting of digital textbooks. One report indicated, "Education leaders here worry that digital devices are too pervasive and that this young generation of tablet-carrying, smartphone-obsessed students might benefit from less exposure to gadgets, not more" (Harlan, 2012). This tension underscores the need for research that examines the benefits, drawbacks, and interactions when digital textbooks are implemented in K-12 classrooms.

Table 2.1

Comparison Between Digital Textbook and Printed Textbook (KERIS, 2010, p. 25)

Descriptions	Digital Textbook	Printed Textbook
Learning Place	Online + Offline	Offline
Media	Various Digital Devices	Printed media
Type of Data	Multi-media Data	Flat, Linear Data
Learning Method	Learner-centered Self Leading Study	Teacher-centered Teaching Activities
Interaction	Multi-direction Exchange among Teachers, Students and Textbooks	Single-direction Teaching-Learning Activities
Linkage among Texts	Linked among Subjects	Difficult to link related data among Subjects
Data Conversion	Prompt Conversion	Conversion Impossible
Learning by Study Level	Implementation of Learning by Study Level Customized to Learner	Difficult to customize to Learner's Level or to implement one-to-many Learning

Research on the Impact/Effect of Digital Textbooks

Design research in mathematics education. Mathematics education scholars have primarily addressed the issue of digital textbooks from the perspective of design research. For instance, the Concord Consortium, a nonprofit educational research and development organization, has projects underway to develop "deeply digital textbooks" for K–12 mathematics and science which exploit five advantages of networked digital media: interactivity, assessment, currency, plasticity, and community (Dorsey, 2009).

Researchers in the U.S. and Israel have documented the positive effects of the *Time to Know* digital curriculum (Walters & Richards, 2009; Rosen & Beck-Hill, 2012). The *Time to Know* digital curriculum and teaching platform was launched in 2007 and incorporates a full fourth and fifth grade digital mathematics curriculum in an online learning environment. Walters and Richards (2009) found that fifth-grade mathematics students who used *Time to Know* for two years had significantly higher gains in test scores than a comparison group who did not use the digital mathematics curriculum. They found the opposite among students who used the curriculum for only one year, but attributed the negative result to errors in pre-test administration. In a mixed methods comparative study, Rosen and Beck-Hill (2012) found that students using *Time to Know* outperformed control group students in both grades 4 and 5. Findings also indicated that attendance and motivation increased among students using *Time to Know,* while disciplinary issues decreased.

Researchers at the SRI Center for Technology and Learning developed *Dynabook*, a digital textbook focusing on proportional reasoning for preservice teachers. Roschelle, Courey, Patton, and Murray (in press) suggested that the specific term, dynabook, be used to refer to "those books that support activities of both reading and writing, allow students to engage deeply with powerful ideas, and extend their benefits to a diversity of learners" (p. 7). The *Dynabook* project was designed using the Universal Design for Learning (UDL) framework to take advantage of digital media for engaging students around big mathematical ideas. *Dynabook* incorporates interactive features such as mathematical modeling tools, challenging questions with options to respond using multiple representations, as well as highlighting, note taking, and search features. Research surrounding Dynabook has focused on pilot tests in order that the product and design might be continually improved to meet three stated goals:

1. support and reward the candidates engaging more deeply in mathematical thinking themselves;

2. encourage candidates to draw connections among related concepts of proportionality;

3. develop teacher candidates' awareness of potential student misconceptions and instructional options they could choose to support student development of more robust ideas about proportionality. (p. 14)

Another example of digital textbook design research is that of mathematics education blogger and Stanford University doctoral candidate, Dan Meyer. Meyer's publicly available digital mathematics tasks for middle grade and secondary mathematics students do not comprise a complete curriculum. Rather, they are designed to motivate students' mathematical learning using real-life settings and often take advantage of digital videos, graphic features or other electronic tools. Meyer's work is based on five design principles for digital experiences (Meyer, 2012):

1. Show, don't tell.
2. Introduce the task as early and concisely as possible.
3. Climb the entire ladder of abstraction.
4. Crowdsource patterns.
5. Prove math works.

The first principle, show don't tell, refers to presenting problems in a manner that compels students to want to figure out solutions. The second principle suggests that exposition of tasks be minimized. This is usually accomplished with multimedia such as video clips of someone shooting a basketball, stopping as the ball is mid-air, begging the question, "Will it hit the hoop?" (Meyer, 2010). This grounding of problems in real-world contexts prompts students to 'climb the ladder of abstraction' toward more formal mathematical representations. The fourth principle often involves technology by 'crowdsourcing patterns' so that students can work collaboratively or gauge their progress by reaching consensus as a group. The fifth principle, 'prove math works' provides concrete resolution to the problem that was originally posed and solved via mathematical reasoning. For instance, students can view the resolution of the basketball video and see an image of the basketball going in the basket, with an overlay of the graph of a quadratic function to model the ball's trajectory, as shown in Figure 2.3.

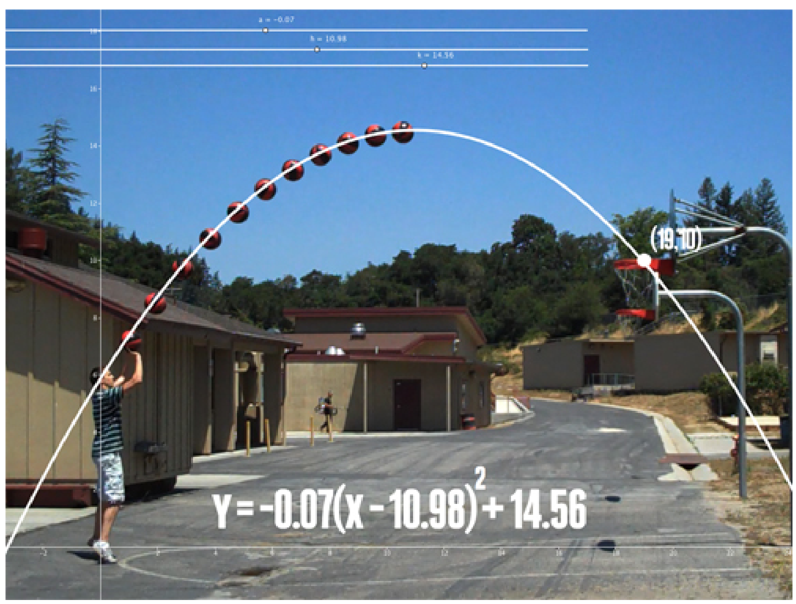


Figure 2.3. Will it Hit the Hoop? (Meyer, 2010)

Tasks and design patterns such as these are particularly relevant at a time when tools such as iBooks Author enable locally authored digital mathematics curriculum materials. As teachers are encouraged to select and/or create their own digital curriculum materials, it is increasingly important that they have access to robust design principles and tools such as those provided by Meyer.

While projects such as those described above contribute to the field's repertoire of robust digital mathematics curriculum designs, such exemplars have not all been studied in clinical settings and have not been taken to scale. Further research is needed that considers not just the types of digital textbook products that are possible, but how various products (commercially-published, open access, and other models) are implemented in ecological settings. At this point, there is little research that captures how students or teachers engage with these new media or the effects on motivation or learning. Beyond lightening backpacks and potentially saving money, how are teachers' and students' experiences with digital textbooks different from experiences with print textbooks?

Digital textbooks as assistive devices. One of the affordances of digital textbooks is their potential to serve as assistive devices for students with special needs. Special education researchers have considered how electronic and digital textbook supports impact students with special needs. For instance, Anderson-Inman and Horney (2007) examined digital and electronic textbooks and proposed the typology for supported electronic textbooks shown in Table 2.2.

This typology describes the features of electronic and digital textbooks, without regard to the specific content matter. Such descriptors contribute to understanding of digital mathematics textbooks and provide a basis on which mathematics educators might add features such as modeling applets, spreadsheets, graphing utilities, text editors, and others specific to the content of mathematics textbooks.

Horney and Anderson-Inman are also principal investigators of the Mathematics eText Research Center at the University of Oregon (MeTRC). The purpose of MeTRC is to coordinate research regarding mathematics eText supports for students in grades 4-9 with print disabilities (Horney, 2010). MeTRC is presently coordinating five research projects including Curriculum Conversion and Implementation, Accessible Curriculum Online, Accessible Assessment, Accessible Middle School Algebra, and Accessible Computer Algebra System (http://metrc.uoregon.edu/). Results of these ongoing studies are not yet available.

Table 2.2.

E-textbook Typology (Anderson-Inman & Horney, 2007)

Resource	Description	Examples
Presentational	Enables the text and accompanying graphics to be presented in varying ways, hence customizable to meet the needs of individual learners.	Font size and style, text and background color, line, and page length, page layout and juxtaposition with other pages, graphics in relationship to text.
Navigational	Provides tools that allow the reader to move within a document or between documents.	Within-document links, across-document links, embedded menus, links from other resources such as Table of Contents, Glossary, Bibliography
Translational	Provides a one-to-one equivalent or simplified version that is more accessible or familiar to the reader; may focus on a word, phrase, paragraph, picture, or whole document; may be of same or different modality or media.	Synonyms, definitions, digitized or synthesized text-to-speech, alternate language equivalents (Spanish), video of American Sign Language translations, simplified version at lower reading level, text descriptions for images, captions and video
Explanatory	Provides information that seeks to clarify the what, where, how, or why of some concept, object, process, or event.	Clarifications, interpretations, or descriptions that point to causes, operations, components, mechanisms, parts, methods, procedures, context, or consequences: list of influencing factors
Illustrative	Provides a visual representation or example of something in the text; designed to support, supplement, or extend comprehension of the text through illustrations or examples.	Drawings, photos, simulations, video, photos, reenactments, sounds, music, information that something is representative of its type ("…is a typical example of…")
Summarizing	Provides a summarized or condensed way of viewing some feature of the document.	Table of contents, concept map, list of key ideas, chronology, timeline, case of characters, abstract
Enrichment	Provides supplementary information that is not strictly needed to comprehend the text, but adds to the readers' appreciation or understanding of its importance or historical context.	Background information, publication history, biography of the author, footnotes, bibliography, influence on other writers
Instructional	Provides prompts, questions, strategies, or instruction designed to teach some aspect of the text or how to read and interpret the text.	Tutorials, self-monitoring comprehension questions, annotations, instructional prompts, study guides, embedded study strategies, online mentoring, tips for effective reading
Notational	Provides tools for marking or taking notes on the text to enable later retrieval for purposes of studying or completing assignments.	Electronic highlighting, bookmarking, margin notes, outlining, drawing; ways to gather and group these notes for postreading review
Collaborative	Provides tools for working or sharing with other readers, the author, or some other audience.	Threaded discussion, online chat, e-mail links, podcasts, blogs

Digital and electronic textbook pilots. A small number of studies have examined the effects of digital and electronic textbooks in pilot programs, mostly at the college level where digital and electronic textbooks present an opportunity for cost savings to students. At the K–12 level, commercial publishers have piloted their products in classrooms and released reports of the digital textbooks' effectiveness.

Weisberg (2011) examined how undergraduate students used five electronic textbook devices. During each semester for two years, students were divided into six groups. All groups had access to the course's print textbook and five groups were loaned devices. Groups in each semester class were assigned one of the six textbook devices: Amazon Kindle, Sony eReader Touch, Apple iPad, enTourage eDGe, CourseSmart, and paper textbook.

Data sources included surveys, student papers, weekly journals, anecdotes from classroom discussions, observations of student behavior, and learning assessments such as quizzes and exams. Findings from the first semester indicated that, based on their experiences throughout the semester, 71% of students would use their computer as a digital textbook as a secondary textbook in the future, whereas 29% would use a tablet as their primary textbook source and 54% would use the tablet eTextbook as a secondary device. Among students with eReaders, 26% would use an eReader textbook as their primary textbook source and 65% would use this device as a secondary source for accessing their textbook. The author found no differentiation among the six groups with regard to performance on assessments. During the study, approximately 70% of students reported using their assigned eTextbook device to complete reading assignments more than half of the time, suggesting that although all students had access to the print book, most used the electronic version the majority of the time.

While this study provides insights as to college students' willingness to use various devices to access electronic versions of printed textbooks, it did not examine the nature of students' print or electronic textbook use or their perceptions thereof. In a pilot program among college students in an elective computer information technology course, Systems Analysis, Sloan (2012) employed questionnaires to examine students' perceptions of usefulness, ease of use, and the extent to which they enjoyed using the eTextbook. Students were provided iPad 2 tablets and CourseSmart access to "a digitized version of the printed textbook with 'page-fidelity'" (p. 90).

Sloan (2012) considered students' perceptions of both the eTextbook and the iPad device on which it was displayed. She found that while many students had little experience with eTextbooks prior to the study, their perceptions of usefulness, ease of use, and enjoyability increased during the study. At the end of the study, most students found the eTextbooks easy and enjoyable to use and almost all expressed a desire to use eTextbooks in other courses. Regarding the iPad devices, students initially indicated that they found Apple computers and devices easy and enjoyable to use, and they found Apple devices more useful than Apple computers. These perceptions did not significantly change throughout the pilot study. Sloan also compared average final course grades of the pilot class with those of students in the previous two semesters the course was offered. The average grade increased slightly, indicating that the use of the iPad and eTextbooks did not have a negative impact on students' grades. At the conclusion of the study, 64 students reported a preference for eTextbooks, 14 preferred print textbooks, and 18 expressed no preference.

At the K–12 level, publishers Pearson and Houghton Mifflin Harcourt conducted pilot studies of their digital mathematics textbook series. Pearson released a summary of a longitudinal, randomized control trial involving the middle grades digital mathematics curriculum, *digits*. Houghton Mifflin Harcourt (HMH) conducted a yearlong pilot of the HMH Fuse Algebra 1 digital textbook for iPad. Both publishers reported positive results of their digital products.

Pearson (2012) reports on a longitudinal randomized control trial conducted by third-party evaluator, Gatti Evaluation, Inc. This study examined a sample of 94 classrooms and 2109 sixth and seventh grade students in four states who used the *digits* middle grades mathematics curriculum, which is accessed on computers via internet. The study found that students in both sixth and seventh grade achieved statistically significant gains as measured by the Group Mathematics Assessment and Diagnostic Evaluation (GMADE). When compared to students using other math textbooks, peers using the other textbooks significantly outperformed sixth grade students using *digits*. In the seventh grade, students performed similarly regardless of the mathematics textbook series. The authors attributed these findings to disparities between standards alignment, limited training prior to *digits*, and moderate fidelity of implementation during the first year of the pilot. Whereas *digits* aligned with the *Common Core State Standards for Mathematics*, other mathematics programs were presumably aligned to prior state standards.

Student surveys indicated that 58% of students who used *digits* had an overall positive attitude about using the program, 89% of students felt the online homework was helpful in their learning, and 80% liked how the digital hosts (virtual characters in the digital textbook who provided verbal explanation) explained math content (Pearson, 2012). Likewise, teachers responded positively to the *digits* program. Some of the teachers reported that the digital curriculum decreased lesson preparation time, decreased time spent grading, and made lesson planning easier. Teachers reported higher levels of student engagement and attentiveness and liked the strong focus on vocabulary and writing, intervention lessons, leveled homework for learners, and immediate remediation for students via online homework.

During the 2010-11 school year, Houghton Mifflin Harcourt partnered with Riverside Unified School District in California to pilot the HMH Fuse Algebra 1 app for iPad. For each of two teachers, one section of Algebra 1 was randomly selected to use HMH Fuse: Algebra 1, while the other sections used the corresponding print textbook. In addition to the HMH Fuse app, students were given full access to the iPad and allowed to use Wi-Fi features for both educational and personal purposes.

The two teachers involved in the study reported that their students using HMH Fuse were more engaged and motivated. Students also reported using the HMH Fuse: Algebra 1 app outside of class. One of the teachers reported that HMH Fuse: Algebra 1 allowed him to ‘flip’ his class, with his students learning and doing independent work at home and doing and discussing problems during class time. Both teachers reported increased student performance among those who used HMH

Fuse. California state test results indicated that students who used HMH Fuse outperformed students at the same school who used the corresponding print book, with 78% of HMH Fuse users scoring proficient or advanced and 59% of non-Fuse students in the same school scoring proficient or advanced (HMH, 2012). The report concluded that using the HMH Fuse app increased students' Algebra achievement and changed students' behavior inside and outside of the classroom. According to the study, administrators, teachers, students, and parents had positive perceptions of HMH Fuse: Algebra 1.

Pilot studies indicated some positive perceptions and results when digital and electronic textbooks were used in place of print textbooks. However, these studies involved either non-mathematics, college-level classes or evaluation of publishers' products at the K–12 level. No independent research studies were found that considered digital textbook use in K–12 mathematics classes.

Mathematics Curriculum Use

Consideration of how digital textbooks are used in mathematics classrooms must also take in to account previous research on use of print textbooks. Although both teachers and students are the primary users of textbooks within mathematics classrooms, relatively little research has focused on students' use of mathematics textbooks. Thus, this review of literature also draws upon research regarding teachers' use of mathematics textbooks. The following two sections describe research on teacher and student use of mathematics textbooks and curriculum materials.

Teacher Use of Mathematics Textbooks

Studies on mathematics textbook use have tended to focus on how teachers use curriculum materials. In a 2005 review, Remillard identified four conceptions of teachers' curriculum use that repeatedly appeared in the research literature: following or subverting the text, drawing on the text, interpreting the text, and participating with the textbook. These conceptions were guided by various theoretical and epistemological influences, and also represented different conceptions of curriculum materials, the role of the teacher, and the teacher−curriculum relationship.

Subsequent studies have continued to examine teachers' use of mathematics textbooks and materials. Herbel-Eisenmann, Lubienski, and Id-Deen (2006) presented a case study of Jackie, an eighth grade teacher who taught two eighth grade advanced mathematics classes with two distinct types of textbooks. In one class Jackie taught using a traditional Algebra 1 textbook and in the other she and her students used an integrated mathematics I textbook (Core Plus). Findings indicated that the textbook used in each class influenced Jackie's pedagogy. In the integrated class, Jackie tended to use graphing calculators, group work, and extended-time for problem solving whereas she spent most of her time in the traditional algebra class lecturing. This case study contributes to the field's understanding of how the particular textbook a teacher uses can influence his or her pedagogy.

Nicol and Crespo (2006) employed qualitative methods to describe how four Canadian preservice elementary teachers interacted with the district-adopted mathematics textbook. The preservice teachers played a strong role in helping "decide what and how to teach mathematics to their students during the practicum setting" (p. 342). The four teachers demonstrated three different approaches to using textbooks: adhering, elaborating, and creating. These approaches were compatible with the conceptions of use identified by Remillard (2005), and described the preservice teachers' roles and relationships with their primary teaching resource, the textbook.

Citing both Remillard (2005) and Nicol and Crespo (2006), Sherin and Drake (2009) proposed a framework for identifying how teachers across disciplines read, evaluate, and adapt curriculum, before, during, and after instruction. The framework is intended to capture individual teachers' curriculum use strategies and the authors present results of a study in which the framework was used to identify patterns of reform-based mathematics textbook use among ten elementary teachers. Findings indicated that nearly all of the teachers read the lessons in the textbook before instruction. However, there was great variation among teachers in terms of when and to what extent they evaluated and adapted lessons in the textbook. The framework enabled the researchers to identify each teacher's individual curriculum use strategy, and observations indicated that teachers consistently maintained these strategies during 78 to 100 percent of observations, thus supporting the plausibility and validity of the framework.

Choppin (2011) examined use of the *Connected Mathematics Project* textbook series among three experienced middle school teachers. He describes teachers' goals for instructional sequences, the extent to which they followed the textbook's recommended practices, and the specific ways in which they used teacher resources. While teachers tended to use all the tasks within the textbook, they made adaptations that ranged from infrequent and minor to frequent and major. Choppin asserted, "The results show that the teachers' understanding of the curriculum resources impacted how they used those resources and that the teacher with the most profound understanding showed the greatest impact" (2011, p 349).

Examining mathematics curriculum use among 15 professors and instructors at the college level, Mesa and Griffiths (2012) used Rabardel's model of instrument use (Vérillon & Rabardel, 1995) to characterize three ways in which textbooks mediate college mathematics instruction. They found that the textbook served as a mediator between instructor and the design of the instruction, between the instructor and other persons (including students), and reflexively, between the instructor and self. They also found that instructors' curriculum use differed according to whether they perceived their students as 'math students' or 'undergraduate students'.

Across this review of the literature regarding teacher use of textbooks, it is evident that textbook use is complex and can vary among teachers and grade levels.

Student Use of Mathematics Textbooks

Few studies have considered student use of mathematics textbooks. The *2012 National Survey of Science and Mathematics Education* found that 81% of middle and high school mathematics classes used commercially published textbooks, with 55% of middle school classes and 65% of high school classes using a commercially published textbook most of the time. Two-thirds of surveyed teachers estimated that more than half of their mathematics instructional time was spent using instructional materials (Banilower et al., 2013). This survey indicates that textbooks are a prominent component in U.S. mathematics classrooms.

Tyson-Bernstein and Woodward (1991) documented the ubiquitous nature of U.S. textbook use, noting the importance of aesthetics and factors not related to content quality in the textbook selection process. Emphasis on visually engaging aspects of textbooks was assumed to be important for enticing students to open and read textbooks. Yet, there is little research to document what features actually do entice students to use their textbooks nor is there literature to detail the ways in which students engage with their textbooks.

Lester and Cheek (1997) surveyed a sample of 44 rural high school students using open-ended questions to determine textbook availability and student preferences. They asked students to indicate frequency of textbook use using a Likert-type scale. Findings indicated that 77% of students reported using their mathematics textbook almost every day of the week, more than any other high school textbook. They found that mathematics textbooks were the most used and least favorite among textbooks across six content areas. This lends credence to the importance of studying student reactions to mathematics textbooks, in particular.

Most of what is available regarding students' opinions and usage of textbooks is in the context of undergraduate textbook use. Besser, Stone, and Nan (1999) used surveys of convenience samples of 568 students at two large universities to study student interaction and impressions about textbooks in communications courses. Findings indicated that students liked bold or italic keywords, end-of-chapter summaries, glossaries, and chapter introductions and generally found graphic aspects the least important aspect of texts. A study of 3200 chemistry students and 23 instructors at nine U.S. institutions found that students valued textbook features such as in-chapter example problems, end-of chapter problem sets, written text, and the solution manual (Smith & Jacobs, 2003). Simulations, examples of real world applications or situations and the study guide were the lowest-rated features among the sampled students.

These studies suggest that, among undergraduates, the textbook features that are most (and least) valued differ according to discipline.

Weinberg, Wiesner, Benesh, and Boester (2012) studied undergraduate students' self-reported use of mathematics textbooks in entry-level mathematics classes. Data sources included a survey of 1156 students at three universities, textbook-use journals from nine students, and structured interviews with an additional eighteen students. The authors generated a list of nine reasons why students might use parts of the textbook and three conditions in which students used their textbooks outside of class. Students used parts of their textbooks for the following purposes:

1. Read for better understanding.
2. Make sense of definitions or theorems.
3. Look up definitions or theorems.
4. Rephrase/summarize text (for notes, homework, etc.).
5. Read the homework problems to see what ideas come up most frequently.

6. Use the answers to exercises to check homework.
7. Use extra problems and answers to exercises to check understanding of problems that weren't assigned.
8. Read or copy homework problems to complete homework assignments.
9. Look up answers without solving the problems. (p. 156)

Outside of class, students used their textbooks for the following purposes: preparing for class; doing homework (or other graded assignments); and, studying for exams. The authors also identified five primary beliefs students have about their textbook:

1. A textbook should explain the "big ideas" of the course.
2. A textbook should explain the "underlying concepts" of problems.
3. A textbook should give examples to explain the material.
4. A textbook should give examples that can be used to complete homework.
5. A textbook should highlight important equations and definitions (Weinberg et al., 2012, p. 157).

Among students who reported using their textbooks, 89.4% reported using textbook examples, 79.9% used homework problems, 71.8% used homework solutions, and 63.3% used the chapter test most often. Only 24.7% of respondents reported using the chapter introduction and 29.2% reported using the chapter summary. Text within the chapter was most often used for completing homework and studying for exams, reported by 85.2% and 83.6% respectively among students who used the textbook. Only 18% of students who used the textbook used the chapter text to prepare for class. Ninety percent of students who reported reading the text in their textbook used it to understand the material, look up definitions, and make sense of definitions, with 68% using it to rephrase or summarize content. Nearly all students reported using worked examples in their textbooks.

The features of textbooks that students most valued were: highlighting important definitions and equations, giving lots of examples to help understand material, and giving lots of examples to use on the homework. The least valued feature of the textbook was material that explained the big ideas of the course and underlying concepts of problems. The authors found that, although instructors requested that students use their textbooks to read the chapter text, look up definitions, read examples, and complete homework, most students tended to focus primarily on homework problems within the textbook. Weinberg et al. (2012) concluded that students expect their textbooks to provide them with clear examples similar to what they might encounter on homework and exams, rather than relying on their textbooks to increase their conceptual understanding. The authors posited that students' textbook use tendencies might reflect students' perceptions of mathematics as "a collection of techniques to be memorized and applied, a subject in which there is one correct answer and one way to obtain the answer" (p. 167).

Although some studies have noted students' preferences for particular textbook features, only one study indicated how students use their mathematics textbooks and this was at the collegiate level. As many K–12 schools transition to digital textbooks that offer more customizable interfaces than printed mathematics textbooks, it is important to consider how not only teachers, but also students, interact with their mathematics textbooks and the outcomes of those interactions.

Technology and Mathematics Education

Digital textbooks have the potential to merge the content of mathematics textbooks with mathematics technology tools and other educational technologies. In addition to considering research that explicitly focused on the intersection of technology and mathematics curriculum, this review also surveys many of the component technologies that could potentially be incorporated in digital mathematics textbooks. Summaries of research regarding mathematical tools, including graphing calculators, dynamic geometry environments, and graphing calculators help to frame what one might expect from digital mathematics textbooks incorporating similar features. Because digital textbooks are enabled by devices with capabilities well beyond the textbook, research about one-to-one computing, Web 2.0 tools, and mobile devices is also described.

Technology and mathematics curriculum

In 1997, Kaput and Roschelle described how interactive technologies such as *SimCalc MathWorlds* could make complex mathematical ideas accessible to more students by removing the barrier of extensive prerequisite algebra knowledge. In addition to the potential of technological tools to change how students experience mathematics, Kaput and Roschelle (1997) proposed that interactive mathematical technologies could open up space in the curriculum for new mathematics that students would need for the future. Referring to SimCalc, Dede (2000) writes:

> Curricular strategies and learning experiences such as these are not intended to eliminate the need for eventual use of formal notations for some students, and perhaps some formal notations for all students. Rather, SimCalc's purpose is to provide a substantial mathematical experience for the 90% of U.S. students who do not have access to the mathematics of change and variation, as well as to supply a conceptual foundation for the 10% who will need to learn more formal calculus (p. 289).

The impact of *SimCalc* on student learning of advanced middle school mathematics was evaluated in two randomized controlled experiments and one quasi-experiment. Roschelle et al. (2010) found that replacing units with an integrated approach involving SimCalc interactive representational technology, paper curriculum, and teacher professional development resulted in statistically significant main effects for student learning in diverse contexts. Based on these studies, the authors recommended that "less emphasis should be placed on the value of technology alone and more on interventions that deeply integrate professional development, curriculum materials, and software in a unified curricular activity system" (p. 874).

Schwartz (1999) expanded upon how mathematical technology can support three of the purposes for education identified by John Dewey: assisting the personal growth and development of individuals, preparation of people for the world of work, and transmission of culture. Schwartz proposed that mathematics curriculum be structured as a matrix of mathematical objects and mathematical actions and that technology be employed to enhance students' experiences, thereby better serving society's purposes for education.

> In my view enabling a person to have such idiosyncratic, self-driven, creative mathematical experiences is the key to changing the way the subject is perceived and thus the ways in which it can help us, as a society, to address our educational goals (Schwartz, 1999, p. 107).

The Object × Action structure proposed by Schwartz has commonalities with the NCTM (2000) content and process standards and the *Common Core State Standards for Mathematics* (CCSSI, 2010) structure of content standards and standards of mathematical practice, with content standards corresponding to mathematical objects and process standards/mathematical practices corresponding to mathematical actions. Schwartz's assertion that new technologies can help shape the mathematics curriculum is particularly salient when considering digital mathematics textbooks that can directly embed and incorporate a variety tools within the curriculum, rather than simply supplementing the printed curriculum.

Mathematical Technology Tools

Regarding the impact of educational technologies on mathematics learning, a three year longitudinal study of secondary mathematics classrooms in Australia, by Goos, Galbraith, Renshaw, and Geiger (2003) examined technology-related interactions involving computers, graphing calculators, and a device that projected screen output for whole class viewing. Their study was explicitly guided by sociocultural theory. The authors suggest that individual cognitive reorganization occurred when students interacted with technology in a semiotic system in which their thinking was qualitatively transformed. Discussing the introduction of new cultural tools such as in the context of technology-enabled distance learning, Wertsch (2007) echoed this perspective, “we should be on the lookout for qualitative transformation of that action rather than a mere increment in efficiency or some other quantitative change” (p. 105).

Much of the mathematics education research regarding technology use has focused on particular tools and software such as computer algebra systems (CAS), dynamic geometry environments (DGE), and graphing calculators. For each of these tools there exists a large body of research that is beyond the scope of this review. However, since individual mathematical tools can be embedded within a digital mathematics textbook, it is important to consider some of the main findings from research on these tools.

Computer Algebra Systems (CAS). A number of researchers have studied the implementation of computer algebra systems (CAS) in secondary classrooms. Most of these studies have been situated in high school calculus (Heid, 1988) or high school algebra-focused courses (Heid et al., 1988). In spite of objections by many that CAS may threaten pencil-and-paper manipulations and calculations in school mathematics (Heid 1997), studies of CAS use generally note increased conceptual understanding without decreased manipulative skills.

Dynamic Geometry Environments (DGEs). Dynamic geometry software is another technology tool that has been studied at length in mathematics education. Most studies have been at the middle and high school levels and focused on use of DGEs for proofs and proving geometry concepts (e.g., Connor, Moss & Grover 2007;

Laborde 2000; Marrades & Gutiérrez 2000). Research involving DGEs have also emphasized the ability to 'drag' and construction versus drawing using formal geometrical knowledge (e.g., Hölzl, 1996, Hollebrands, Laborde, & Sträβer, 2007).

Graphing calculators. Perhaps one of the most commonly used mathematical technology tools in secondary mathematics classrooms, graphing calculators, provide students and teachers opportunities to simplify, solve, and investigate equations and inequalities with symbolic, numeric, and graphical representations. Numerous studies have focused on graphing calculator use in high school mathematics, resulting in various characterizations of these tools. Doerr and Zangor (2000) described five modes of use for the graphing calculator in two precalculus classes taught by the same skilled teacher. Their work indicates that graphing calculators play the role of computational tool, transformational tool, data collection and analysis tool, visualizing tool, and checking tool.

Among Doerr and Zangor's modes of use, the graphing calculator as a transformational tool that changed the nature of the mathematical task was perhaps the most noteworthy. In a meta-analysis of 54 research studies on calculators (not specifically graphing calculators) Ellington (2003) found that calculators did not hinder mathematical skill development, as some critics have alleged. A review of literature specific to graphing calculators (Penglase & Arnold, 1996) supported this notion.

Educational Technologies

In addition to technologies that are specific to mathematics, more general educational technologies such as computers, communication tools, and mobile devices can also play an important role in the mathematics classroom. These devices and tools can be used to enable or enhance digital textbooks, thus warranting consideration in this review of literature. The following sections describe research regarding one-to-one computers, Web 2.0 tools such as wikis, and mobile technologies in terms of K–12 use.

One-to-one computing. When digital mathematics curricula are embedded in a computer or tablet, the result is a one-to-one ratio of students and computers. Many school districts have implemented one-to-one computer initiatives in the past and, in 2002 Maine became the first state to implement a statewide one-to-one computer initiative (State of Maine, 2001). In response, studies have examined one-to-one computer usage in mathematics classrooms, mostly in the middle and elementary grades.

Garthwait and Weller (2005) used a case study design to examine one-to-one computer implementation during the first year of the Maine Learning Technology Initiative. They found that teachers' beliefs about teaching and learning resulted in technical issues and educational issues that differed among classrooms. This study emphasized the importance of teachers in implementing new tools and approaches in the classroom. Similarly, Donovan, Hartley, and Strudler (2007) used the Concerns-Based Adoption Model (Hall & Hord, 2001) to examine 17 seventh-grade teachers' (including but not limited to mathematics teachers) concerns during early implementation of one-to-one laptop computers. They found that concerns were mostly personal in nature, relating to how laptop computers impacted their responsibilities and challenges as teachers. Few teachers expressed concerns about the best way to use the laptops to meet students' needs. Thus, while one-to-one laptop initiatives may be aimed at meeting the needs of 21st century learners, teachers' implementation of these initiatives may emphasize factors other than students' needs.

Mouza (2008) considered both teacher and student implementation and use of one-to-one laptops in an urban, low income, high minority school. Comparing qualitative and quantitative data from three one-to-one elementary classrooms with non-laptop classrooms in the same school, the researcher found that one-to-one technology environments enhanced motivation and engagement, classroom interactions, student empowerment, and resulted in academic gains in mathematics.

A 2006 review of research on one-to-one computing by Penuel identified 46 articles that reported research on one-to-one computing in K–12 schools, not all specific to mathematics classrooms. This synthesis revealed four goals of one-to-one initiatives including improving academic achievement, increasing equity, increasing economic competitiveness, and transforming instructional quality. In terms of classroom use, students used laptops mostly for administrative and word processing purposes, basic skills practice, and Internet browsing. Teacher beliefs about implementation of the initiative were mostly personal and focused on management concerns, and how laptops impacted themselves or classroom management. Few studies reported teacher beliefs related to student learning. A number of studies also reported the importance of ongoing support and professional development for teachers' successful implementation and use of one-to-one laptops. While the synthesis of research indicated that one-to-one initiatives could improve students' technological literacy, there was less evidence that one-to-one initiatives resulted in improved student achievement in core subjects such as mathematics.

Web 2.0 technologies. Greenhow, Robelia, and Hughes (2009) claim that "Web 2.0 technologies enable hybrid learning spaces that travel across physical and cyber spaces according to principles of collaboration and participation" (p. 247). In considering future research on learning with Web 2.0 technologies, they recommend that learner participation, creativity, and online identity formation be considered in combination with support, desired competencies, teaching practices, and policies. This recommendation can also be applied to the implementation of digital textbooks and technological devices that enable social, collaborative Web 2.0 technologies. Specific to mathematics education, Gadanis and Geiger (2010) describe how Web 2.0 technologies and an increasing presence of social theories of learning in mathematics education research literature can lead to a reconceptualization of learning mathematics as performance within a Web-based social environment. This conceptualization of mathematical learning corresponds to recommendations of Greenhow et al. (2009) to focus on learner participation with Web 2.0 technologies.

Referring to synchronous, asynchronous, and social networking tools, Hodges and Hunger (2011) highlight some of the possibilities of Web 2.0 technology for communicating mathematics. The authors identify blogs, wikis, course management systems, and a Facebook app that make it possible to communicate mathematical expressions and symbols on the Web. They also acknowledge that while there do exist Web 2.0 tools that make symbolic mathematical communication possible, communicating mathematics on the Web is not as easy as communicating with regular text. Thus, incorporation of Web 2.0 tools in mathematics classrooms requires that students learn new ways to render mathematical expressions digitally and will likely require support and guidance from the teacher in ways that communicating with regular text do not.

The work of Reich, Murnane, and Willett (2012) focuses on the quality and use of Wikis in K-12 public schools with particular attention to equity and opportunities to learn 21st-century skills. Of 255 wikis that were examined in this study, 13% were found to support mathematics. The authors found that wiki usage fell in to one of four categories: 40% were trial wikis and used for teacher resource sharing, 34% were used for teacher content-delivery, 25% were used for individual student assignments and portfolios, and 1% were used for collaborative student presentations and workspaces (p. 7). These results were not disaggregated by subject matter but do indicate that the collaborative potential of Web 2.0 technologies is not well developed.

It remains to be seen whether digital textbooks, either with Web 2.0 applications embedded or on devices that also enable Web 2.0 apps, can help learners and teachers to move toward what Gadanis and Geiger (2010) describe as “learning mathematics as performance” in a Web-based social environment. That is, as a student engages or “performs” in a Web-based social environment centered on mathematics, such performance is an embodiment of what it means to learn mathematics.

Mobile devices. While digital curricula and the tablets on which they are conveyed are fairly new, some studies have examined the use of mobile computing devices in mathematics classrooms. Swan, Hooft, Kratcoski, and Unger (2005) found that students in six K–8 science classes who used mobile computing devices experienced more personalized learning experiences and extended learning beyond the classroom. Results also suggest that the devices increased student motivation, and the quality, and quantity of student work.

In a project that studied the value of Wireless Internet Learning Devices (WILDs) in mathematics classrooms, Roschelle (2003) suggested that existing knowledge about computer-supported collaborative learning is insufficient for characterizing the complexity of classrooms with WILDs.

> Mobile devices participate in a network that is overlaid in the same physical space in which students and teachers participate socially in teaching and learning, so two distinct kinds of participation are occurring at the same time and in the same space: the normal social participation in classroom discussion (for example) and the new informatic participation among connected devices. (p. 261)

Kaput (2000) described the complexity and wealth of possibilities that could result from network-based activity frameworks that integrate social structure and mathematical structure. For example, he described how connected mobile technologies could alter participation and communication in whole class, small-group, and individual activities in the mathematics classroom. In addition to outlining some of the research that is needed regarding the impact of mobile devices, Kaput (2000) described the need to build a framework capable of describing uses that would help to distinguish between effective and ineffective practice.

Summary

While existing literature provides insight as to how teachers use printed curriculum materials, there exists a substantial gap with regards to how K–12 students use mathematics textbooks or what features and aspects of mathematics textbooks are important to students and/or support student learning. Although mathematics textbooks are a mainstay in U.S. classrooms, we know surprisingly little about the specific role of textbooks for students. Yet research on teachers' use of mathematics textbooks points to complex roles and relationships between teachers and textbooks. While teachers use mathematics textbooks for different purposes than students, there is no reason to believe that the roles and relationships between students and textbooks are any less complex. Research on student use of mathematics textbooks is becoming particularly salient as schools adopt digital textbooks that aim to motivate and engage students in ways that printed textbooks have not.

Digital mathematics textbooks create new opportunities to connect and capitalize on mathematics content, educational technology, mathematical tools, and social connectivity. Although each of these areas has been the focus of research individually, we know little about how they might interact to support student engagement and learning. Recent policy initiatives focused on digital textbooks in the US and internationally emphasize the relevance of this emerging medium for school use. Concurrently, there is an increase in available devices to empower digital textbooks (iPads, tablets, and smartphones), mathematics textbooks are being revised to align to the *Common Core State Standards* (CCSSI, 2010), digital infrastructure is expanding to provide increased network connectivity, and school districts are seeking cost-effective solutions to meet accountability standards. What appears to be a 'perfect storm' for the rise of digital mathematics textbooks, also provides an opportunity for increased research activity to examine new curriculum delivery formats and tools that will likely play an important role in the mathematics classrooms of the future.

III. Methodology

Design of the Study

The research design for this study is an instrumental case study as described by Stake (1995) and Creswell (2007). This design is particularly useful for gaining insight into a general question by studying a particular, purposefully chosen case. For this study, I examined the activity of one teacher and students in the two sections of Algebra 1 that she teaches; one section used printed textbooks and the other section used the same textbook in digital format. Such a design yielded insight as to how students used print and digital textbooks and how use differed between the two media in this particular context. The instructional context was one chapter from the Algebra 1 course, chosen because, although the content and learning objectives were the same across formats, the digital textbook format included features with the potential to alter student learning opportunities. The chapter used during this study focuses on linear functions and the embedded mathematical tools in the digital textbook provided opportunities for multiple representations of these functions.

Context of the Study

Pilot Study at the Research Site

During the spring 2012 semester, I conducted a pilot study at the site where the main study took place. The pilot study did not focus specifically on digital textbooks, but examined students' use of iPads to support mathematics instruction. Data sources included ten classroom observations in an AP Statistics class, two interviews with the AP Statistics teacher, hereafter referred to by the pseudonym

Mrs. Rogers, and interviews with four of the six students in the observed class. Students in this class used a print textbook designed for addressing AP Statistics content. As noted, they also had access to an iPad. Preliminary results from the pilot study indicated that, while the teacher encouraged iPad use in her classroom and students frequently used their iPads during class, students tended to use their iPads independently and for administrative, non-mathematical purposes or for performing basic calculations. The teacher expressed her desire to integrate the iPads in ways that would take advantage of mathematical and communication tools.

Mrs. Rogers and the four students who were interviewed expressed their wishes for digital mathematics textbooks. While Mrs. Rogers desired to integrate the iPads into her practice and connect the iPad to the print textbook material, she was limited by lack of planning time, knowledge, and internet connectivity at her rural home. She verbally encouraged students to use their iPads for her class, but did not often incorporate activities that explicitly required this technology. She indicated that digital textbooks would be a way to more fully take advantage of the opportunities afforded by the iPads.

It is from the pilot study that I became familiar with the school and teacher where the digital textbook study took place. During informal conversation with the teacher, she expressed a desire for her mathematics classes to pilot digital textbooks because, as mathematics department head, it was a direction she wanted to take the mathematics department at the school. Following the conversation, the teacher sought and received preliminary approval from school administrators to use digital textbooks in her Algebra 1 class the next school year. Limited funding prevented immediate school-wide transition to digital mathematics textbooks.

Research Site

The school in which this study took place, hereafter identified by the pseudonym Morrison Day School, is a small, non-religious PK–12 private school in a mid-sized midwestern city. While specific demographic data for the school are not publicly available, the school website indicates that 16% of students are students of color and that a variety of religious, ethic, and racial backgrounds are represented within the student body. Morrison offers financial assistance to increase accessibility regardless of socioeconomic status, but it is reasonable to estimate that the percentage of students who would qualify for free or reduced lunch is smaller than that of public schools in the same community. The school focuses on college preparation and has a 100% undergraduate matriculation rate. Admission is competitive.

In August 2011, the upper school, comprised of grades 6–12, issued iPads to all students for use at school and at home. In the first year of use, teachers were free to choose how to incorporate the new technology in to their classrooms and received only a technical orientation that focused on basic iPad features, not specific to any content area. Most students brought their iPads to class on a regular basis and teacher use of the iPads varied. Because this study took place in the second year of iPad use, students and teachers had prior experience with the technology, thereby diminishing the novelty of the iPad. Wireless Internet was available throughout the school and was viewed as reliable and fast by students and teachers. Network security features prevented access to most social networking sites and inappropriate content, although students could access blocked content on out-of-school networks or at home.

With regards to available content on the iPads, students had no access to the App Store or iTunes and were not able to individually request particular apps. All mathematics students in grades 6–12 had access to a calculator app, a graphing calculator app, and the Numbers spreadsheet app. Additionally, students frequently used the Internet. Teachers could requisition administrators and the school Information Technology Specialist to download apps onto students' iPads for their class, although this did not occur frequently.

Although the school did not adopt digital mathematics textbooks for the iPads during the first year, the school was considering digital textbooks for the future and viewed this study as a mutually beneficial opportunity to explore this option for mathematics classes.

Algebra 1 Textbooks

Both participating classrooms in this study received new textbooks to use during the study and throughout the school year. The first class received *Algebra 1 Common Core Edition* print textbooks (Burger et al., 2012a), published by Houghton Mifflin Harcourt Publishing. I purchased digital versions of the Algebra 1 textbooks for the teacher and all students in the second Algebra 1 class. The digital version of the Houghton Mifflin Harcourt textbook was enabled through the HMH Fuse app for iPad (Burger et al., 2012b). The textbook was not evaluated or selected for quality, but rather because the school preferred the textbook series. This particular textbook was chosen because the school used Prealgebra textbooks in the same series the previous year and because the publisher offered both print and digital versions of the same book. Furthermore, in addition to electronically rendering the content of the print textbook, the HMH Fuse digital textbook takes advantage of interactivity by including some communication, assessment, and mathematical tools.

In general, the examples, exercises, and mathematical content are identical in both the print and digital versions of the textbook. However, the presentation and manner in which material is accessed differs. Figure 3.1 illustrates how a portion of Lesson 4-1 appears in both the print and digital formats of the textbook. In both textbook formats, lessons are organized by numbered chapters and numbered lessons within each chapter. For example, Lesson 4-1 refers to the first lesson in Chapter 4 (arrows indicate the order in which screenshots appear in the digital textbook).

In both formats, each lesson begins with between two and six pages of worked out examples, text, and explanations, termed the 'Lesson and Examples' portion of the lesson. In this portion, each worked out example is followed by 'Check it Out' questions and exercises for students. Presumably, these exercises are intended for use during instruction to check for student understanding. The second section of each lesson is 'Guided Practice', usually consisting of less than twenty student exercises spanning the content of the lesson. The third and final section of each lesson is 'Practice and Problem Solving', which includes a number of student practice exercises and word problems.

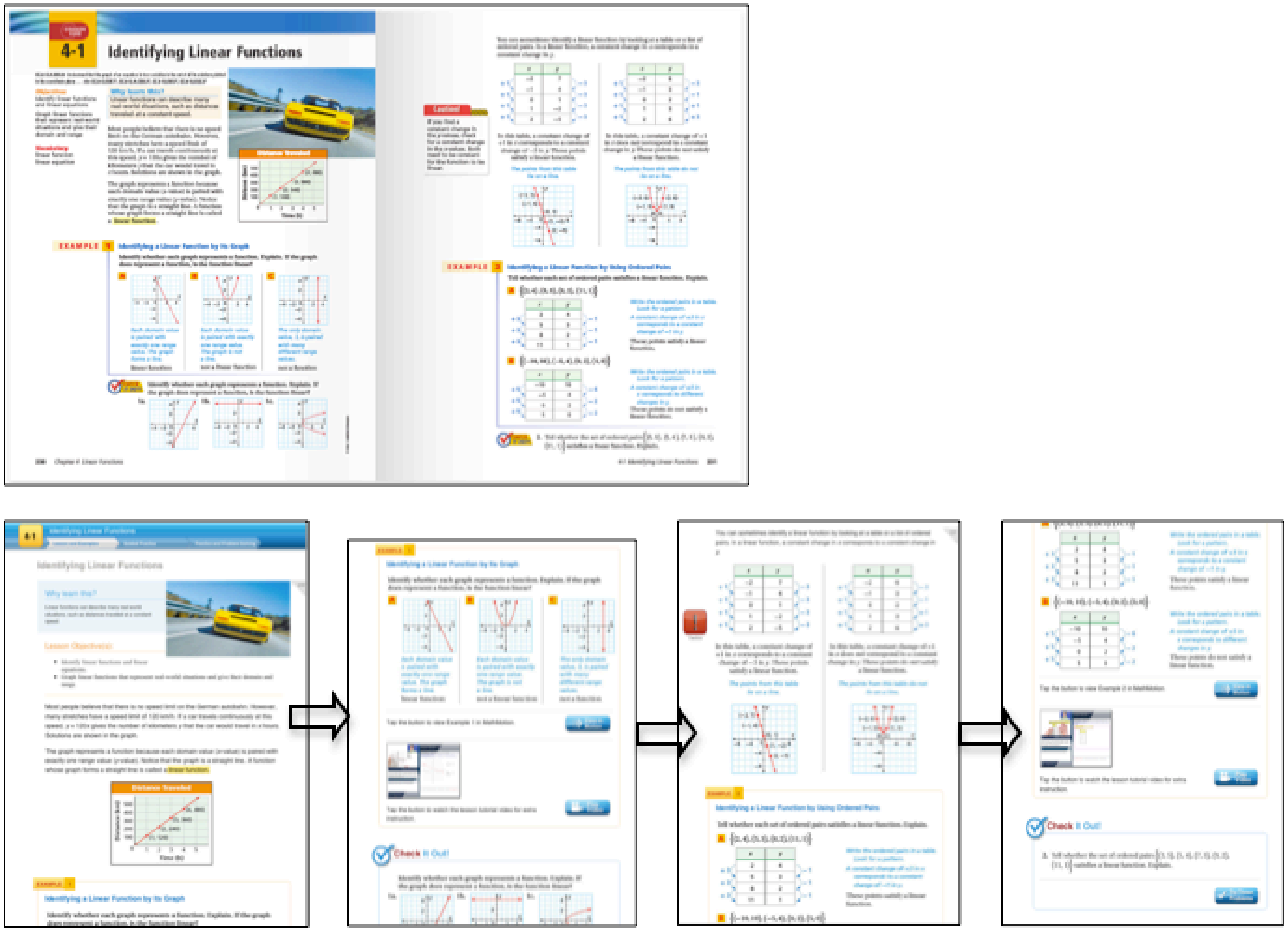


Figure 3.1. Lesson 4-1 in print textbook (top) and in digital textbook (bottom). (Burger et al., 2012a; Burger et al., 2012b)

Table 3.1

Chapter 4 Contents, Objectives, and Sequencing Differences (Burger et al., 2012a,b)

Table of Contents	Brief Description/Objectives	Difference between Print and Digital format
Contents	Table of Contents for Chapter 4 identical to that of the printed book	No sequencing difference
Are You Ready?	26 question quiz includes the following sections: Vocabulary, Ordered Pairs, Solve for a Variable, Evaluate Expressions, Connect Words and Algebra, Rates and Unit Rates	No sequencing difference
Study Guide: Preview	Where You've Been, In This Chapter, Where You're Going, Key Vocabulary/Vocabularie, Vocabulary Connections	Print: p. 228; Digital: Button embedded in Chapter 4: Contents
Reading and Writing Math	Study Strategy: Use Multiple Representations	Print: p. 229 Digital: Button embedded in Chapter 4: Contents
Skills Review	Video, Practice Questions, and Post Test covering the same sections as the Are You Ready quiz	Comparable review feature not available in print format
Lesson 1	Identify linear functions and linear equations. Graph linear functions that represent real-world situations and give their domain and range.	No sequencing difference
Lesson 2	Find x- and y- intercepts and interpret their meanings in real-world situations. Use x- and y-intercepts to graph lines.	No sequencing difference
Connecting Algebra to Geometry	Area in the Coordinate Plane	Print: p. 243 Digital: Button embedded in Lesson 4-3
Lesson 3	Find rates of change and slopes. Relate a constant rate of change to the slope of a line.	No sequencing difference
Lab	Explore Constant Changes	Print: p. 252-253 Digital: Button embedded in Lesson 4-3
Lesson 4	Find slope by using the slope formula.	No sequencing difference
Lesson 5	Identify, write, and graph direct variation.	No sequencing difference
Ready To Go On?	11 question quiz with questions corresponding to sections 4-1 through 4-5	No sequencing difference
Lesson 6	Write a linear equation in slope-intercept form. Graph a line using slope-intercept form.	No sequencing difference
Lesson 7	Graph a line and write a linear equation using point-slope form. Write a linear equation given two points.	No sequencing difference
Technology Lab	Graph Linear Functions	Print: p. Digital: Button embedded in Lesson 4-
Connecting Algebra to Data Analysis	Interpreting Trend Lines	Print: p. Digital: Button embedded in Lesson 4-
Lesson 8	Determine a line of best fit for a set of linear data. Determine and interpret the correlation coefficient.	No sequencing difference
Lesson 9	Identify and graph parallel and perpendicular lines. Write equations to describe lines parallel or perpendicular to a given line.	No sequencing difference
Technology Lab	The Family of Linear Functions	Print: p. Digital: Button embedded in Lesson 4-
Lesson 10	Describe how changing slope and y-intercept affect the graph of a linear function.	No sequencing difference
Ready To Go On?	17 question quiz with questions corresponding to sections 4-6 through 4-10	No sequencing difference
Lesson EXT	Graph absolute-value functions. Identify characteristics of absolute-value functions and their graphs.	No sequencing difference
Study Guide: Review	Vocabulary and section-by-section review questions for the entire chapter	No sequencing difference
Chapter Test	18 question sample test	No sequencing difference
College Entrance Exam Practice	5 multiple choice SAT practice questions	No sequencing difference
Test Tackler	Standardized test strategies for recognizing distracters in multiple choice questions	No sequencing difference
Standardized Test Prep	20 question cumulative standardized test practice including multiple choice, gridded response, short response, and extended response items	No sequencing difference

Chapter 4, the focus of this study, includes ten lessons and an extension lesson as well as a number of assessment features. The table of contents for the two formats of the textbook is summarized in Table 3.1. As the table indicates, there exist few differences between how the print and digital formats of the textbook are arranged. Both formats include the same lessons with the same objectives. Supplementary labs and connection activities are sequenced differently in the print and digital textbook formats. In the digital format, these activities are accessible via buttons embedded at the beginning of lessons. The digital format also includes an interactive 'Skills Review' at the beginning of the chapter. In this section, students can respond to multiple choice questions focused on prerequisite skills for Chapter 4, and receive immediate feedback on their responses. No corresponding skills review feature is available in the print format of the textbook. Since the print and digital textbook formats include the same content and are arranged similarly, I now focus on enhancements offered in the digital format.

Some of the digital textbook features that span all chapters in the book are found on the toolbar that appears at the top of the screen when one taps the screen. Figure 3.2 shows a screen capture, highlighting the top of screen toolbar. From this toolbar, one can access the full table of contents for the textbook (This Book), an abbreviated table of contents anchored on the page currently displayed on screen (Contents), a glossary and index (Index), a frame that appears at the bottom of the screen where students can type or audio record notes (Notes), mathematical and communication tools (Tools), a gridded frame where students can free-write (Scratchpad), and a set-up menu (Settings). Additionally, the top of the page always includes prompts to maneuver left and right to different sections of the textbook. The three sections of each lesson, 'Lessons and Examples', 'Guided Practice', and 'Practice and Problem Solving', are accessible via tabs at the top of the iPad screen. Within each section, one can swipe the iPad screen vertically to scroll through the content in each tab, and swipe horizontally to maneuver between tabs.

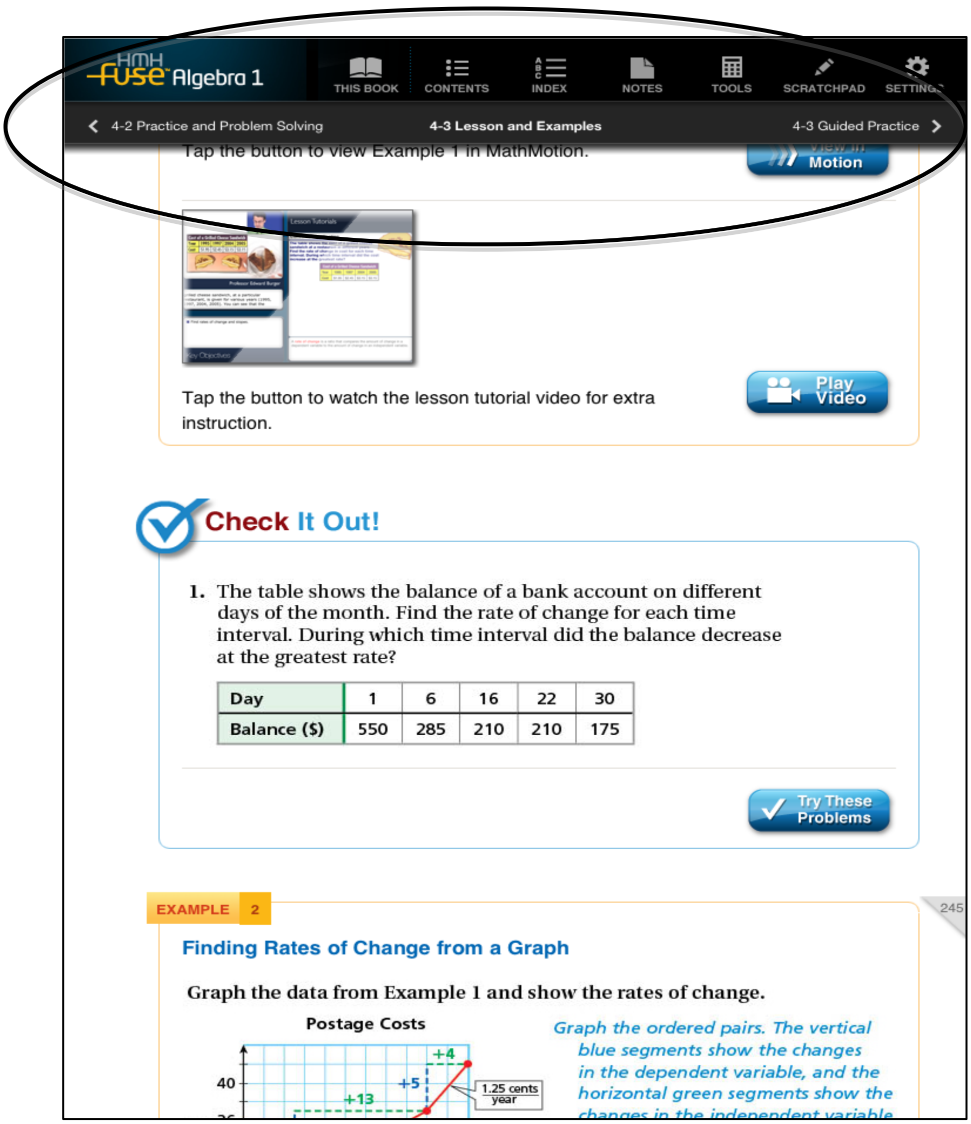


Figure 3.2. Digital Textbook Screen Image with Tool Bar (Burger et al., 2012b)

Across sections and chapters within each book, textbook features were similar. For example, at the beginning of each section in the printed textbook, a list of corresponding vocabulary words and *Common Core State Standards* are printed. However, the digital textbook does not identify these features. Throughout Chapter 4, this was the only instance where information in the printed textbook did not appear in the digital textbook. More often, the digital textbook altered the way in which one could access information present in both the print and digital versions. For example, vocabulary words that appear within in each lesson of the digital textbook are hyperlinked to the glossary and index. As shown in Figure 3.3, when one presses on highlighted vocabulary words (represented by the arrow in the figure), a frame appears at the bottom of the screen. This frame includes the definition of the word in English and Spanish, buttons to press for audio pronunciations of the word in English and Spanish, and all index entries for that particular vocabulary word. In the print textbook, the glossary and index are located at the back of the book and audio pronunciation is not possible.

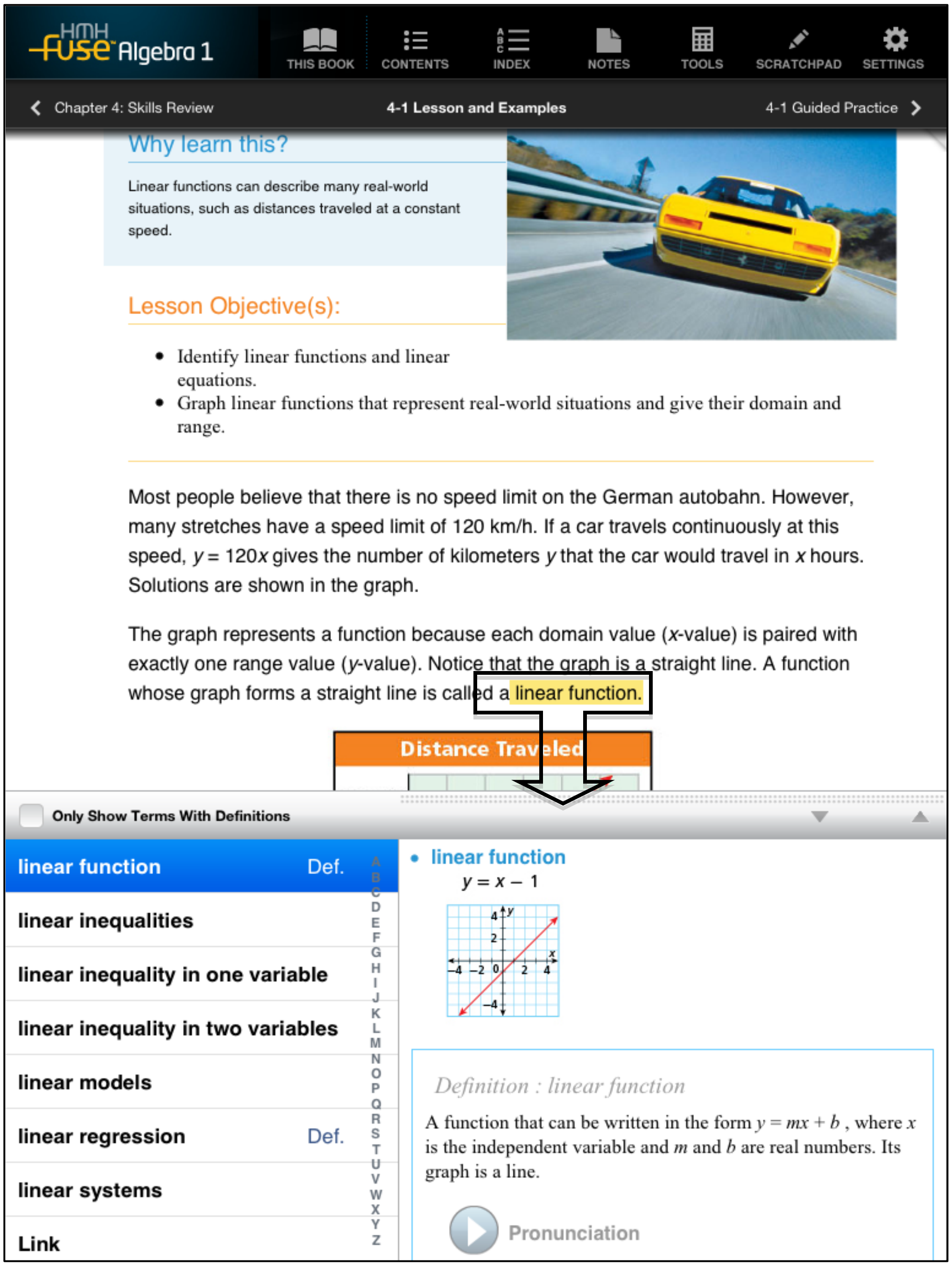


Figure 3.3. On-screen Glossary (Burger et al., 2012b)

Under the 'Lessons and Examples' tab of the digital textbook appears the same content as found in the print format. In the digital textbook, each example is followed by a 'View in Motion' feature that, when pressed, allows the user to reveal solutions to examples, step-by-step, by swiping the screen in a downward motion. A still image of this feature is shown in Figure 3.4, with the arrow indicating the screen that appears when the View in Motion button is pressed. A link to a video clip also follows each example. In these videos, Dr. Edward Burger, one of the book's authors, provides an explanation of the concept or procedure in the preceding example as whiteboard images and animated representations also appear in different frames on the same screen. Figure 3.5 presents a screen shot from one of these embedded videos. It is important to note that all examples in sections 4-1 through 4-10 included both the View in Motion and Video features. However, the examples in the Extension section at the end of Chapter 4 did not include video with the examples.

In both the print and digital textbook formats, each example in the text is followed by brief student exercises denoted with the phrase 'Check it Out'. However, the digital textbook takes advantage of interactivity by altering these questions to be multiple choice so that students can enter a response directly in to their book and check their answers for immediate feedback. Figure 3.6 shows how a 'Check it Out' question becomes interactive in the digital textbook. The 'Are You Ready' and 'Ready to Go On' assessments are also altered in the digital textbook so that students can enter multiple-choice responses and obtain immediate feedback on their performance.

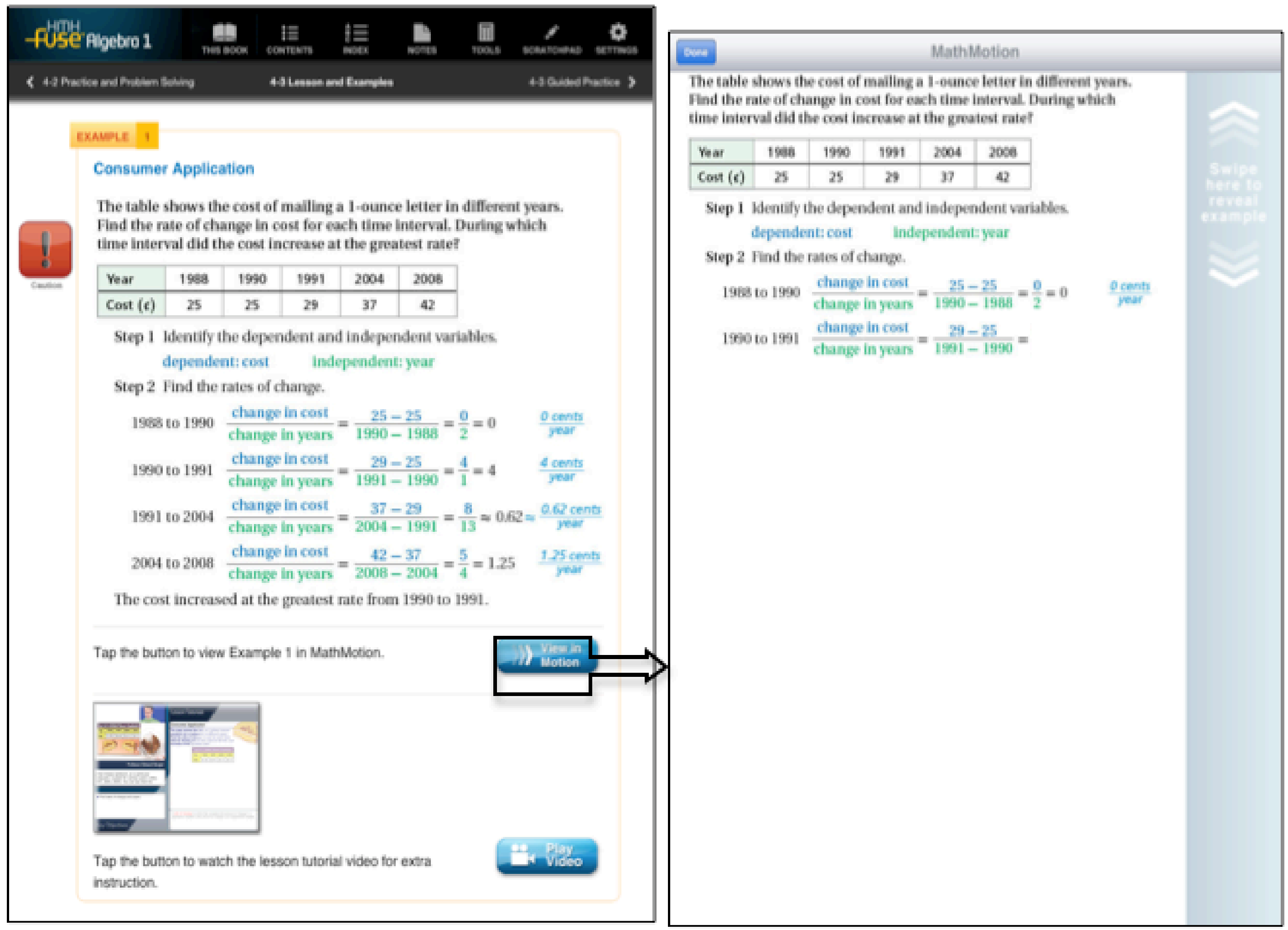


Figure 3.4. View in Motion feature accompanying Lesson 4-3, Example 1 (Burger et al., 2012b)

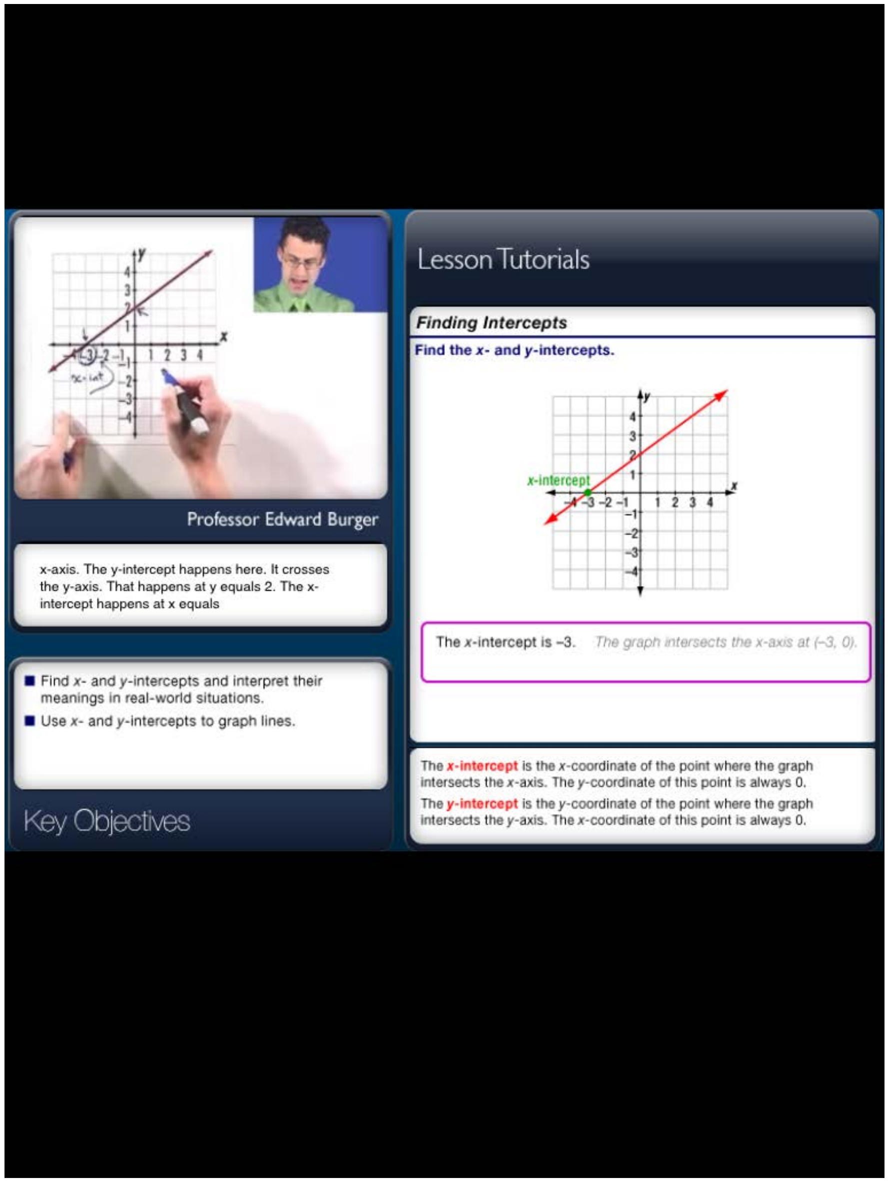


Figure 3.5. Screen shot of video accompanying Lesson 4-2, Example 1 (Burger et al., 2012b)

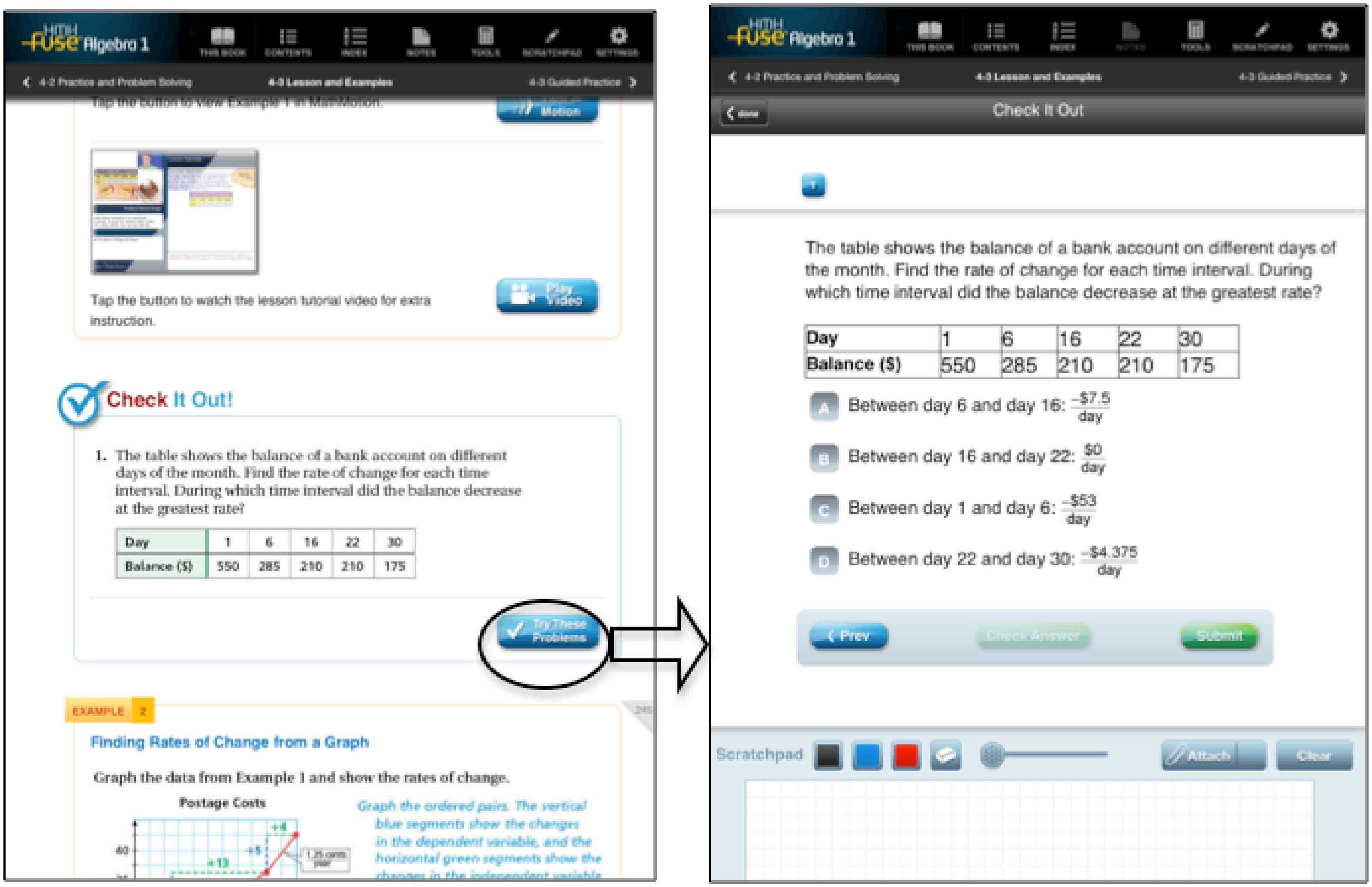


Figure 3.6. Check it Out feature accompanying Lesson 4-3, Example 1 (Burger et al., 2012b).

‘Guided Practice’ and ‘Independent Practice’ digital textbook tabs take advantage of the medium. The ‘Guided Practice’ tab includes problems with embedded example buttons. When pressed, the corresponding example from the lesson appears in a frame at the bottom of the screen. Figure 3.7 illustrates how corresponding examples and answers to odd-numbered exercises can appear in the digital textbook. The arrows in the figure point to what appears on the screen when buttons are pressed.

While answers to odd-numbered student exercises are available in the back of the print textbook, the digital textbook embeds buttons in each section to access this information, as shown in Figure 3.8. Additionally, the digital textbook includes buttons to display hints and step-by-step instructions for solving selected problems. The print textbook refers students to homework helps that are available online.

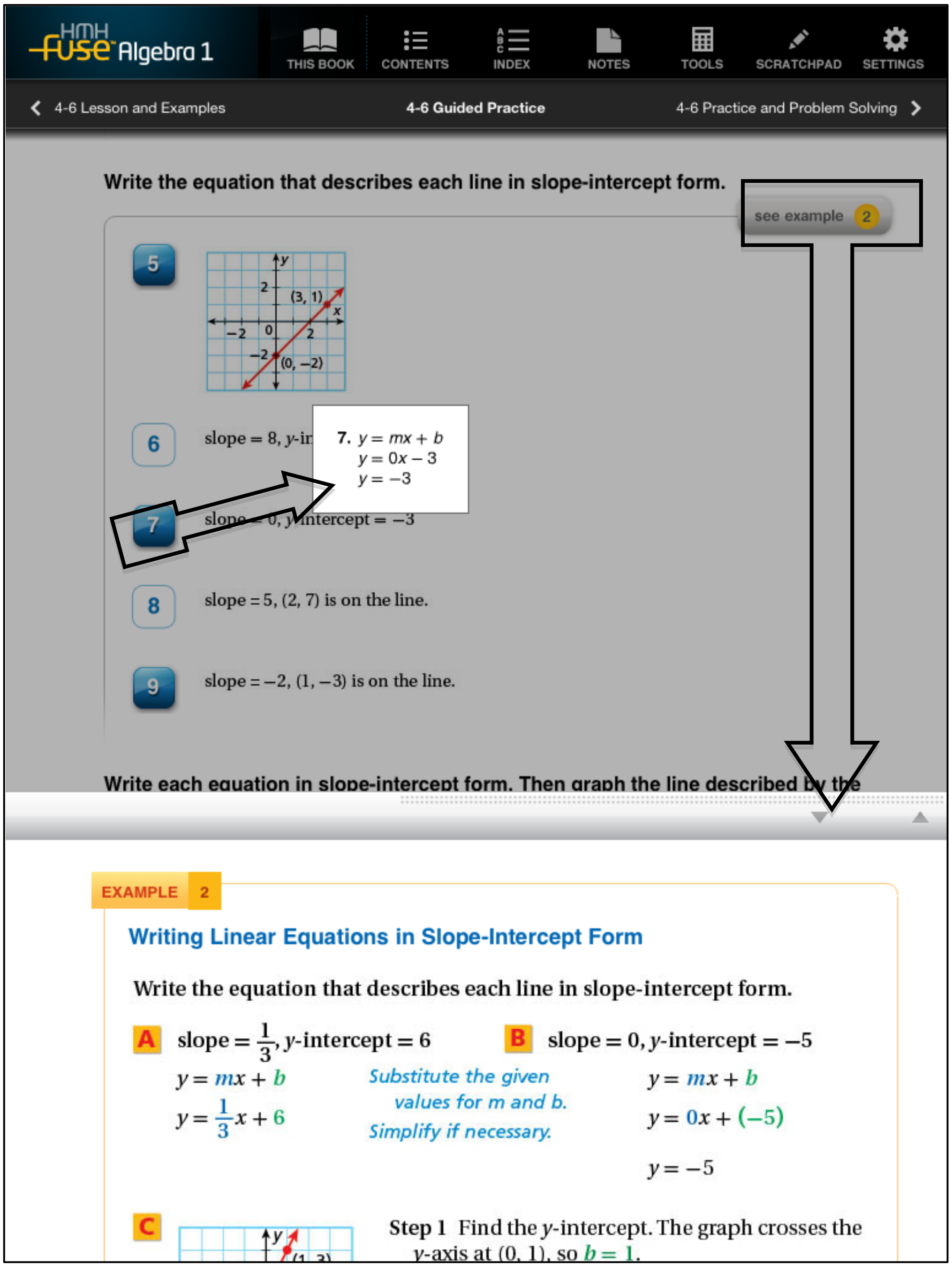


Figure 3.7. Guided Practice example and odd-numbered answer from Lesson 4-6 (Burger et al., 2012b)

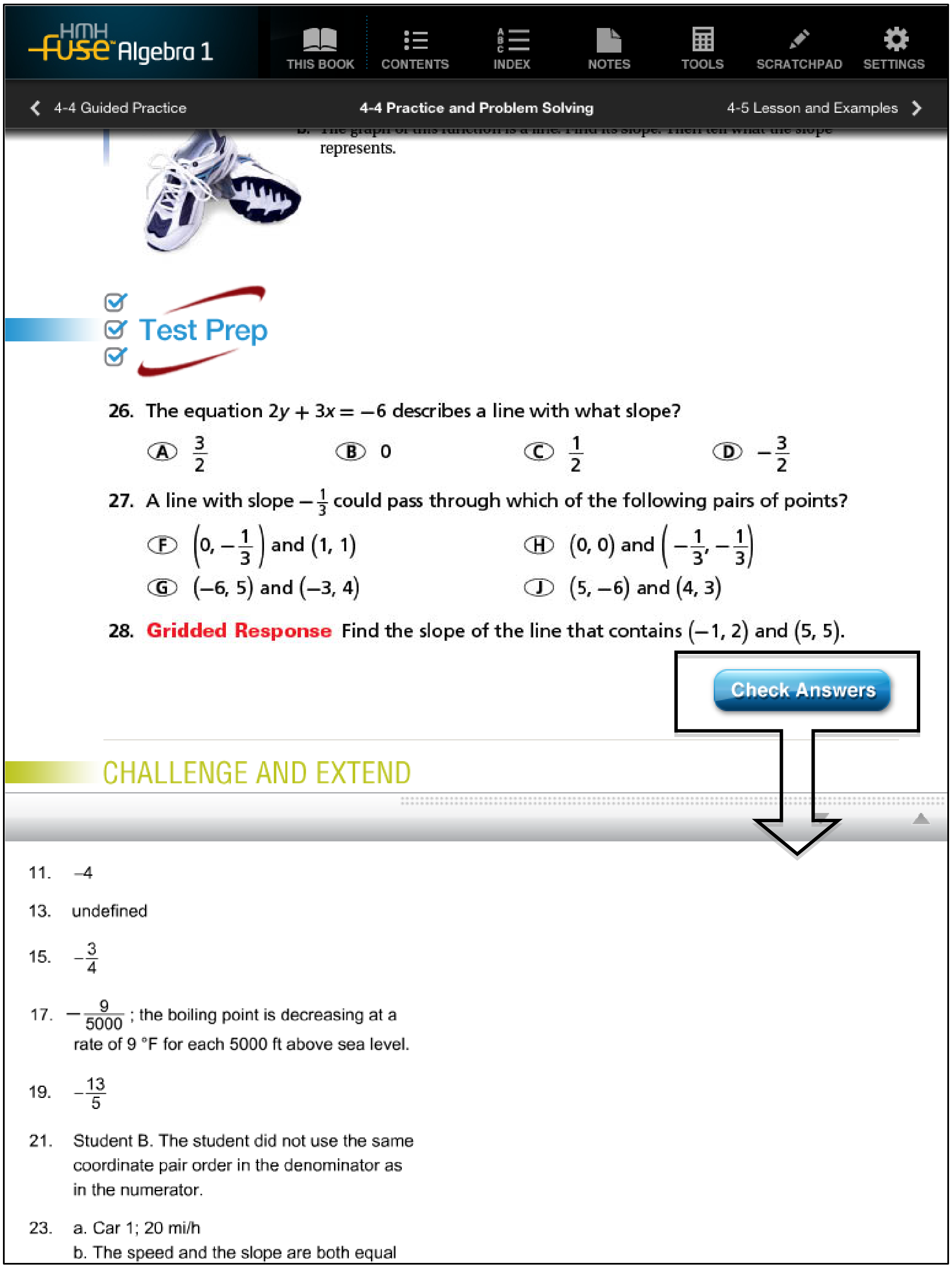


Figure 3.8. Check Answers feature within Lesson 4-4 Practice and Problem Solving (Burger et al., 2012b)

The presentation of marginal notes differs between the digital and print textbooks. The print textbook includes marginal notes of the following types: Know-it Note, Remember, Caution!, Helpful Hint, Link, Reading Math, and Writing Math. In the digital textbook, these notes are not visible but, instead, can be viewed when one presses marginal buttons. Chapter 4 includes sixteen 'Know-It Notes' to identify particularly important topics in the lesson. In the digital textbook, pressing these buttons causes a notes frame to appear at the bottom of the screen. There are a total of 21 other marginal notes/buttons in Chapter 4 that include only text.

Distinct features of the digital textbook are the 'Graph It' buttons, a type of marginal button that does not correspond to any feature of the print textbook. There are seven 'Graph It' buttons in Chapter 4, each of which brings up the function grapher tool in which students can enter up to four equations and view either graphs on a Cartesian plane or tables of x and y values. In Chapter 4, 'Graph It' buttons appear in sections 4-1, 4-2, 4-6, and 4-7. Figure 3.9 shows one of these examples and the corresponding 'Graph It' tool that appears. Notice that the equation from the example is pre-populated in the 'Graph It' tool and that this function can be viewed either graphically or as a table of values, as shown. Each section with a 'Graph It' button includes an objective that expects students to graph lines and the 'Graph It' buttons correspond with graphing examples. However, the converse is not true; not all graphing objectives or examples in the chapter include corresponding 'Graph It' buttons.

Graphing tools are also accessible via the Tools tab on the top of screen tool bar. This is also where one can find an embedded clicker system. The clicker system, when networked, allows the teacher to pose a multiple-choice problem of her own choosing. Students can then enter responses via their digital textbooks, and the teacher's digital textbook would collect and summarize student responses to guide further instruction. The clicker feature does not include actual questions and responses, thus giving the teacher the freedom to use questions from a variety of sources. Rather, this is a networked communication feature that allows the teacher formatively assess student learning in real-time in order to adjust instruction to meet student needs. Students cannot use the clicker feature independently; they would only be able to use this feature if the teacher configured the clicker system.

For some textbook features, there is little difference between the print and digital textbook. The assessment features at the end of the chapter, including Chapter Test, College Entrance Exam Practice, Test Tackler, and Standardized Test Practice, are essentially the same for both media. For these features, the digital textbook renders only screen images of the printed pages.

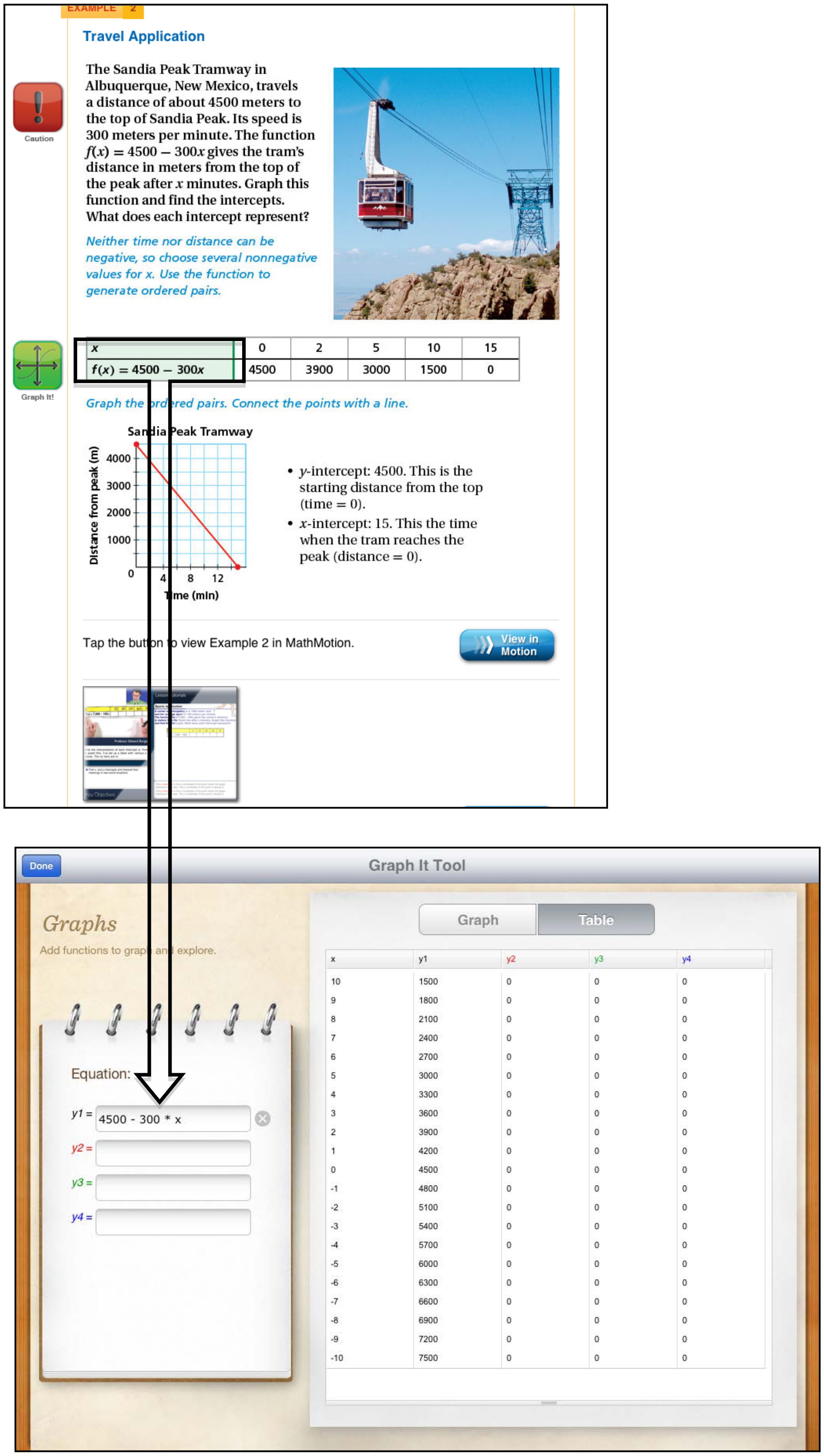


Figure 3.9. Graph it tool accompanying Lesson 4-2, Example 2 (Burger et al., 2012b).

Research Methods

Sample

Teacher. The two Algebra 1 classes that participated in this study were taught by the same teacher, Mrs. Rogers. At the time of the study, she was in her fourth year of teaching, all at the same school. She is certified to teach grades 5–12 mathematics and earned a Master's degree in Curriculum and Instruction specializing in mathematics education. She also serves as the head of the mathematics department, comprised of herself, one full-time middle school mathematics teacher, and a part-time secondary teacher. In this capacity, Mrs. Rogers also provides guidance to elementary teachers regarding mathematics instruction. Because the school is small, the teacher is responsible for a variety of middle and high school mathematics classes. Her teaching load during the study included AP Statistics, Precalculus, and two sections of Algebra 1.

It was evident from the previously described pilot study that Mrs. Rogers and her students used their mathematics textbooks in class on a regular basis. This was a particularly important feature of her practice as it relates to this study, since it provided opportunities to observe student textbook use within the classroom. For the academic year in which this study took place, Mrs. Rogers selected the hardbound teachers' edition and the student version of the digital textbook for her professional use.

This study included both of Mrs. Rogers' Algebra 1 classes. The first class, Class A, was the first class of the day and used print textbooks. The second class, Class B, met immediately after Class A and used digital textbooks. The decision about which textbook medium each class would use was made in coordination with Mrs. Rogers. She preferred to use the new, digital textbook medium in Class B because of smaller class size. Thus, for each lesson Mrs. Rogers first taught Class A using print textbooks, followed by Class B using the digital textbook format.

Class A: printed textbooks. Class A included nineteen middle school students, seven males and twelve females. All but two students were in Grade 7, which is the typical age at which students in this school enroll in Algebra 1. Two of the students were identified as advanced and enrolled in the class during Grade 6. No students were identified as special needs students or English Language Learners. As part of this study, all students received new hardbound Algebra 1 textbooks (Burger et al., 2012a) to replace their previous Algebra textbooks (Holt McDougall, 1998). The class began using these books approximately one month after the beginning of the school year. All students also had a school-owned iPad, but they were not provided access to the digital versions of the print textbooks.

The students in Class A were seated at ten tables, each with two chairs. Eighteen students sat with a peer, called a 'table partner'. One student preferred to sit alone. Mrs. Rogers assigned seating to all students and, during independent work, she permitted students to speak quietly with their table partners or students at neighboring tables. See Appendix A for a seating chart for Class A.

Of the nineteen students in the class, fifteen (twelve female and three male) consented to participate in this study. Ten of these students participated in one stimulated recall interview during Chapter 4. Additionally, four of the fifteen consenting students were randomly selected and invited to participate in initial task-based interviews and follow up interviews at the conclusion of the study. Of these four, three accepted the invitation for an initial interview and two participated in follow up interviews.

Class B: digital textbooks. Eight students comprised class B, five males and three females. This class included only students in Grade 8, none of whom were identified with special needs or as English Language Learners. At the same time class A was issued new printed textbooks, class B students received new digital Algebra 1 textbooks through the HMH Fuse app on their school-issued iPads (Burger et al., 2012b). I funded the purchase of these digital textbooks. Students in this class did not have personal access to the print version of the Algebra 1 textbook.

Because Class B included fewer students than there were tables in the classroom, students did not all have table partners. Four students chose to sit with a peer, while the other four students sat at their own tables. Mrs. Rogers did not explicitly assign seating in Class B, but students sat in the same locations throughout the study. Like Class A, Mrs. Rogers permitted students to speak quietly with their table partners or students at neighboring tables. See Appendix B for a seating chart for Class B.

Five students (three male and two female) consented to participate in this study. All of these students participated in one stimulated recall interview during Chapter 4, four completed a task-based interview prior to beginning the chapter, and the same four participated in a debriefing interview at the conclusion of the study.

Description of typical lesson in Mrs. Rogers' classrooms

Throughout the study it was observed that Mrs. Rogers followed a predictable routine for most class periods. At the beginning of every class period, she wrote Warm Up problems on the whiteboard for students to solve upon entering the classroom. Warm Up problems were short exercises based on content from the previous lesson. In interviews, she revealed that she selected these problems from a variety of resources including the primary textbook, supplementary textbooks and worksheets in her personal collection, and the Internet. Mrs. Rogers said that she also sometimes created the problems herself. After taking attendance and allowing students no more than five minutes to work on warm-up problems, Mrs. Rogers led a review of the previous day's materials, often by discussing the Warm Up problems or checking homework from the night before. Mrs. Rogers spent the majority of this time at the whiteboard in front of the class, with students asking questions and volunteering responses to her questions.

Observations indicated that the majority of time during each lesson was spent with Mrs. Rogers at the whiteboard engaging in what students described as "giving notes." For most class periods, Mrs. Rogers prepared notes pages for student use. These notes pages included examples, vocabulary words and space for definitions, and fill-in-the-blank statements. Often, examples for the notes were selected from the textbook but Mrs. Rogers also incorporated examples from outside sources such as supplementary texts and the Internet. During this period of direct instruction, Mrs. Rogers lectured and frequently posed brief, directive questions to students. After "giving notes," Mrs. Rogers typically assigned homework from the textbook and allowed students the rest of the period to work on these exercises as she circulated the classroom, assisting students individually.

As noted earlier, all students and teachers in Morrison Day School Upper School were equipped with iPads. In addition, Mrs. Rogers had a MacBook laptop computer and a projector, which she could use to display her laptop or iPad screen to the class. The classroom was not equipped with a Smartboard or ELMO projector. The school also operated on a modified block schedule, meaning that each class met for three 45-minute periods and one 90-minute block period per week.

Mrs. Rogers acknowledged that her teaching in Algebra 1 emphasized procedures and processes over concepts. It was her belief that students should gain fluency with algebraic manipulation and terminology in order that they could better access concepts in future, more advanced mathematics classes. In the final teacher interview, she articulated her thoughts on the matter:

I: A lot of times people talk about doing mathematical procedures and processes and learning mathematical concepts. Tell me your thoughts on that and how it plays out in your class.

T: Yeah, so I do believe Algebra is a time to learn processes. Um, our 6th grade program and our 7th grade program, 7th grade program is Algebra 1 I suppose, is big about that. And I struggled with that at the beginning of teaching because I wanted them to know what they're talking about rather than have them just memorize processes or something like that. But I've turned in my thinking and I think that it is-there's a reason for why we do this. And all advanced mathematicians use processes to do things, you know, and so I was like why do we do that that? Why is that important besides if you are going to be an advanced mathematician that's what we do. But frankly, the more we learn, the more we have important things to spend our thoughts on, I suppose. When it comes to the processes, learn how to, I mean, there's a shortcut given to you, that kind of thing, so you can spend your time thinking about something more important.

While this study does not directly focus on Mrs. Rogers or her teaching, descriptions of the typical classroom learning environment helps to establish the context in which this study took place.

Data Collection

Nardi (1996) summarized four characteristics critical to data collection from the perspective of activity theory (and arguably, qualitative research, in general).

1. A research time frame long enough to understand user's objects;
2. Attention to broad patterns of activity rather than narrow episodic fragments that fail to reveal the overall direction and import of an activity;
3. The use of varied data collection techniques;
4. A commitment to understanding things from the user's point of view.

This study attempted to address these characteristics with the duration and frequency of observations, variety of data sources, and methodologies aimed at capturing students' views on textbook use.

On-site data collection for this study spanned a four-week period. I observed in both classes daily throughout the duration of Chapter 4, beginning on October 29, 2012, and concluding on November 16, 2012. I also observed in both classrooms the week prior to beginning the chapter of focus, to gather general data regarding the relevant routines and norms in the two classrooms. This was intended to provide a broad view of the students' experiences with their textbooks relating to a well-defined collection of instructional objectives for the unit of instruction. The plan also sought to minimize what Nardi (1996) described as, "narrow episodic fragments that fail to reveal the overall direction and import of an activity" (p. 95), by observing daily classroom instruction throughout an entire textbook chapter.

Data sources included video recordings from student-worn head mounted cameras, initial task-based interviews with a total of seven students (three from Class A and four from Class B), stimulated recall interviews with a total of fifteen student in the two classrooms, follow-up interviews with the same subset of seven students who completed initial interviews (due to attrition, only six of the students participated in follow up interviews), student work from those wearing head-mounted cameras, whole class audio-video recordings, classroom observation notes, and four weekly interviews with the teacher. These data sources were intended to characterize the use aspect of classroom activity including subject, tool, object, and object (Stevenson, 2008), as well as the cultural-historic context involving the rules, community, and management of the classrooms. Each of these data sources is subsequently described in greater detail.

Data sources.

Student audio-video recordings. On each day of data collection, three students in each class wore head-mounted digital video recorders to capture images of textbook pages or screens that individual student attended to during instruction, group and/or independent work. The three cameras rotated among all consenting students in each class on a daily basis.

Ideally, video screen recording software would have been utilized to capture the digital textbooks but this technology is not yet commercially available. Thus, hat-mounted cameras focused on what students viewed on the page or screen and recorded students' interactions with their textbooks during class. These cameras served a similar purpose to eye-tracking software used in previous studies guided by activity theory (Nardi, 1996). Clips from these videos were used during student interviews to give students opportunities to elaborate on their actions and processes as they used their textbooks.

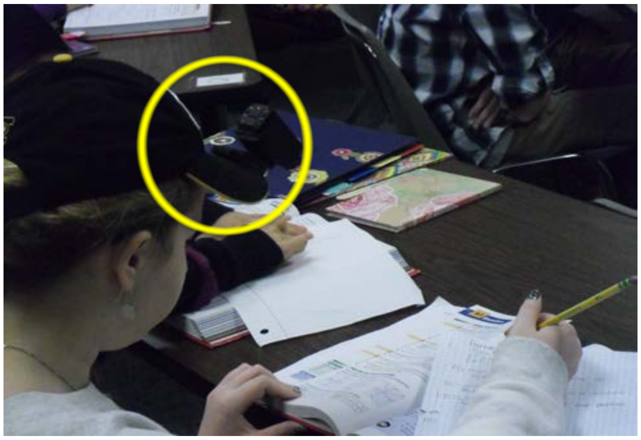


Figure 3.10. Student hat-mounted camera.

The digital video recorders were clipped to hats or visors, worn by the students, as shown in Figure 3.10. These cameras allowed the researcher to adjust the angle of the camera to focus on the images that the student viewed. The cameras were lightweight and comparable in size to a pack of gum, yet they captured two or more hours of high definition video and audio in downloadable, digital format. Figures 3.11 and 3.12 are static images of a print textbook and a digital textbook for iPad, taken from video captured by students. Student-recorded video served as a primary data source and also as a resource to prompt further reflection and explanation during student interviews.

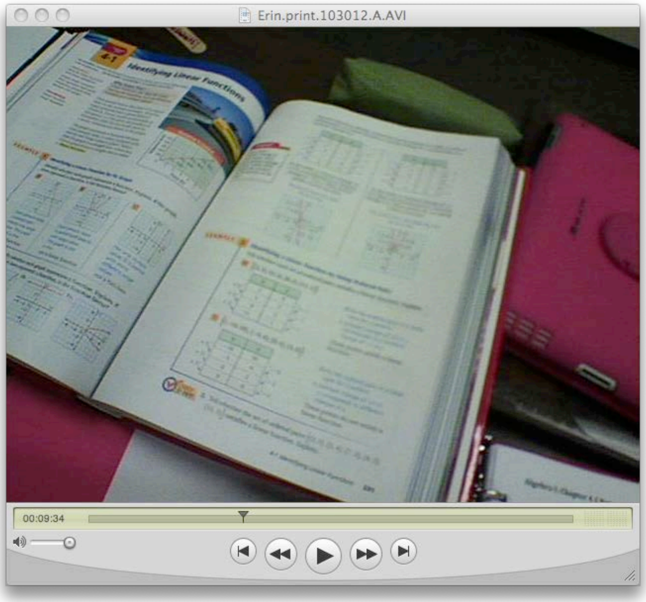


Figure 3.11. Screen capture of student using printed textbook.

Figure 3.12. Screen capture of student using digital textbook.

I am familiar with the use of student head-mounted video cameras through data collection and analysis work under Dr. Chval. She introduced this methodology for mathematics education in a pilot study and in her current NSF CAREER grant study of facilitating the participation of English Language Learners in elementary classrooms (Chval, 2012; Chval & Chávez, 2007). Chval employed this methodology to capture the elementary mathematics classroom experience from the perspectives of ELL students. While all student camera data were stored for eventual full analysis, clips from each student's head camera were selected each week for use during debriefing meetings with classroom teachers. Teachers viewed selected clips and were asked to react, reflect, and describe what they noticed when observing the classroom through the eyes of their students. My involvement in Dr. Chval's study provided me with opportunities to collect student head-mounted camera data, select and prepare clips from these video files, conduct debriefing meetings with teachers, and also to analyze video data.

In this study, I used student head-mounted cameras to capture students' interactions with their print and digital textbooks during their Algebra 1 classes. These cameras provided a unique perspective, capturing textbook use from students' points of view in a manner not afforded by more traditional video camera options.

Task-based student interviews. The task-based individual student interviews were scheduled immediately prior to Chapter 4 and involved three randomly selected students from class A and four consenting students from class B. The purpose of the task-based student interviews was to elicit students' perspectives on how and why they tended to use their mathematics textbooks both in class and at home. These interviews spanned approximately 20 to 30 minutes and were audio-recorded, transcribed, and analyzed.

Appendix C provides an overview of the interview questions that guided the initial student interview. At the beginning of the interview the students responded to questions about their mathematics textbook use during class and at home. Some of these questions included:

1. To what extent do you typically use your Algebra 1 textbook outside of the classroom (e.g., at home, during study halls)?
2. For what purposes do you usually use your Algebra 1 textbook outside of class? Can you give me an example?
3. How do you think you could use your Algebra 1 textbook more effectively outside of class?
4. Consider the last time you used your Algebra 1 textbook outside of class.
    a. What was your goal or purpose for using your textbook?
    b. To what extent do you think that goal was achieved?
    c. How do you know?

The interview was intended to provide data regarding how students tended to use their mathematics textbooks outside of the classroom. The second portion of the interview was task-based, asking the student to solve two problems from their textbooks while thinking aloud. They were encouraged to use their textbook as a resource to solve the problems if they so desired. This was intended to mimic how students might use their textbooks as resources for solving problems outside of class.

The exercises selected for the task-based portion of the interviews were available in both the print and digital versions of the textbook, as supplementary word problems. The two exercises included content from Chapters 1 and 2; at the time of the interviews, students were finishing Chapter 3. These supplemental problems identified the chapter and section in the textbook to which they corresponded, in order that students could readily refer to the textbook as a resource for solving the problems. The exercises, taken directly from the textbook, are identified below.

1. A cheetah can reach speeds of up to 103 feet per second. Use dimensional analysis to convert the cheetah's speed to miles per hour. Round to the nearest tenth. (*Lesson 1-8,* Burger et al., 2012a,b)
2. For maximum safety, it is recommended that food be stored at a temperature between 34° F and 40° F inclusive. Write a compound inequality to show the temperatures that are within the recommended range. Graph the solutions. (*Lesson 2-6*, Burger et al., 2012a,b*)*

Stimulated recall student interviews. The second series of student interviews began on the second day of instruction for Chapter 4. Every consenting student in each classroom was eligible to participate in one brief (approximately 20 minutes) stimulated recall interview (Lyle, 2003; Fox-Turnbull, 2011) during Chapter 4. Each day I reviewed that day's head-mounted video files, identified clips that showed students engaged with their textbooks, and invited two students to interview the following day. Each one to two minute clip focused on a student's specific actions and processes with the textbook in class. In her description of using activity theory to analyze video data Bødker (1996) describes a similar manner for choosing video clips for further analysis. Students were selected for interviews based on the richness of textbook interactions depicted in the video clips while ensuring that each consenting student is interviewed once. Each interview was audio-recorded, transcribed, and analyzed.

As students watched these clips, they were asked to describe and explain what they viewed in order to provide further insight as to what the student was doing with his or her textbook, why they were doing so, and the outcomes of those student-textbook interactions. As interviewer, I asked students to expand on the choices they made and their motivations for doing so. The data yielded from these interviews illuminated aspects of textbook use that might otherwise have been misunderstood or unclear.

Follow-up student interviews. A final set of follow up interviews was conducted one week after concluding in-class data collection. These included interviews with six of the seven students who participated in the initial task-based interviews. These brief, semi-structured interviews were audio-recorded, transcribed, and analyzed. Follow up interviews debriefed students on their use of the textbook, to gain information about how use might have changed since the first interview and as a result of being more conscious of their textbook use after participating in this research project. During this interview I also asked students to give me a tour of their textbook. This allowed me to see what features of their textbook students knew about and invited follow-up questions regarding the extent to which students used those features in and out of class.

This series of interviews was similar to the first, in that I asked students about their use of mathematics textbooks in class and also outside of school (see Appendix D for the interview protocol). However, since students had also participated in two interviews focusing on their textbook use, this interview elicited data about how students' textbook use, or conscious attention to textbook use, may have changed throughout this study. The following questions helped to elicit this information from students.

0. Explain how your use of the textbook during Algebra has changed since our first interview.
1. Explain how your use of the textbook outside of Algebra class has changed since our first interview.

Student work. Throughout observations, I photographed student work in order to provide data regarding the objects and outcomes of students' activity. In particular, I collected work from students wearing head-mounted cameras in order to complement data captured on the video recordings. Student work was an important data source for indicating the outcomes of students' interactions with the textbook, to the extent that those actions were for the purpose of solving mathematics problems from the textbook.

Whole class audio-video recording. A single, tripod-mounted video camera recorded the full duration of each classroom observation, with the exception of one observation during which the camera malfunctioned. This served as a record of whole-class activity, the classroom context, and the extent to which student textbook use is teacher or student initiated. This data source also yielded information about interactions between and among students and the teacher as it relates to the community in which activity occurs.

Observational field notes. Researcher notes for each classroom observation supported the whole class video files and provided administrative data, such as which student wore which camera, for each observation. The observation protocol is included in Appendices E and F and is an abbreviated version of the Inside the Classroom: Observation and Analytic Protocol used by Horizon Research, Inc. in

2000. Observations for each class period focused primarily on the three students wearing head cameras, noting interactions, circumstances, and gestures that might not be observable from head-mounted video files. However, because I simultaneously operated the whole class camera, managed student head cameras, and took field notes, written observations were sometimes limited by the need to tend to multiple tasks.

Teacher interviews. Prior to each week of data collection, and at the conclusion of in-class data collection, I conducted a total of four brief, semi-structured interviews with the teacher to obtain background data and discuss her instructional planning and goals for both of her Algebra 1 classes. Although the study focused on students' use of textbooks, interviews with the teacher provided data to better understand the classroom context, the object, rules, and management, of the activity structure. The interview protocol is adapted from the Inside the Classroom Teacher Interview Protocol (Horizon, 2000) and the *Middle School Mathematics Study* Teacher Interview Protocol (Reys, 2006). The protocol, found in Appendix G, also includes additional questions to be asked in the final interview. Interview questions include the following.

1. How do you think the lessons will differ between the two sections of Algebra 1?
2. To what extent will the textbooks for each class influence what or how you plan to teach next week's lessons? Will you use all of the activities/problem sets in the textbooks? If no, how will you decide what to use and what to skip?
3. What parts or features of the textbooks will you use most often this week? What parts or features of the textbooks do you think your students will use most often this week?

In general, questions focused on the teacher's planning, perceptions of textbook use in the two classes and student outcomes during the observed chapter. Additionally, Mrs. Rogers often volunteered her thoughts and perceptions of both the print and digital textbooks. Interviews were audio-recorded, transcribed, and analyzed; each interview was approximately 30 minutes in duration.

This study collected data from a variety of sources and perspectives. Each of the data sources served an important role, providing information about various aspects of student textbook use and, together, provided data to characterize the complex activity system in which student textbook use occurs. Table 3.2 summarizes the data sources for each student and each class period, with shaded columns indicating class periods during which no textbook use was observed. All names are pseudonyms.

Table 3.2

Summary of data sources (shaded columns indicate no in-class textbook use)

	Initial Interview	10/29	10/30	10/31*	11/2	11/5	11/6	11/7*	11/9	11/12	11/13	11/14*	Stimulated Recall Interview	Follow up Interview
Print Class		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		
Field notes		x	x	x	x	x	x	x	x	x	x	x		
Sabrina	x					x			x		x	x	11/14	
Ariel						x				x				
Farrah						x				x		x		
Chelsea		x					x						11/7	
Maggie	x	x					x						11/13	x
June		x					x						11/7	
Lindsay			x										10/31	
Holly			x					x		x		x	11/15	
Ellen			x										10/31	
Evalyn				x									11/5	
Mason					x									
Sydney				x							x		11/5	
Chase					x				x		x			
Miles	x			x									11/6	x
Lin					x			x						
Digital class		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		
Field notes		x	x	x		x	x	x	x	x	x	x		
Blake	x	x	x	x			x	x		x			11/12	x
Wesley	x	x		x	x						x		11/14	x
Piper			x	x		x			x		x	x	11/14	
Robyn	x	x			x			x	x			x	11/9	x
Drake	x	x	x		x	x	x		x	x		x	11/13	x
Mrs. Rogers	x				x				x					x

Data Analysis

In general, data analysis was guided by the components of activity theory. Activity theory is particularly suited for analyzing complex, context-rich data. In a critical review of Nardi (1996), Roschelle (1998) writes, "Because the theory is oriented to stable structures, it naturally lends itself to organizing rich data in concise tables and diagrams that neatly summarize findings" (p. 253). While activity theory (AT) provided a tool for helping to organize and analyze the data in this study, it was not necessarily prescriptive. Bødker (1996) wrote:

> AT allows us to be instrumental without being reductionist…It helps structure analysis without totally prescribing what to look for. It also means that we are constantly reminded in our analysis of the context and history of the actions and operations that we are looking at, thus preventing us from viewing the interaction in isolation. (p. 172).

Because the research questions focus on student use of textbooks, defined as how individuals or groups employ artifacts in practice (Stevenson, 2008), data analysis primarily focused on sources that provided data on student textbook use. In particular, all student interviews were transcribed and analyzed, as well as selected video clips of textbook use captured by head-mounted cameras. Video data were selected and summarized using Transana qualitative analysis software. This study yielded approximately 24 hours of interview audio data and 120 hours of raw video data from which clips of textbook use were identified and analyzed.

Analyses of stimulated recall interviews, head-mounted video clips, and field notes allowed me to build descriptions of activity structures for each student in each lesson of recorded textbook use. These sources provided data on the subject, tool, object, and outcomes aspects of each activity. Additionally, whole class video and transcripts from teacher interviews were consulted for evidence of the rules, community, and management aspects that compose the context in which student textbook use occurs. This allowed for a more complete description of the activity structures for individual students in these two classrooms. While activity profiles summarized each student's textbook-related activity during a lesson, interview excerpts supported these profiles, providing more in-depth description of each student's activity.

Student task-based and follow-up interviews primarily examined students' textbook use outside of the classroom environment. Therefore, analysis of these interviews supplemented activity profiles by focusing on the relationships between subjects, tools, objects, and outcomes, not particular to the context of the classroom during a lesson.

Coding procedures. All interviews were transcribed from audio files for coding. Throughout data collection, I viewed student head-mounted video files daily to identify clips in which students use their textbooks. Using Transana qualitative software, I created written summaries of video clips showing student textbook use, which students later explained during stimulated recall interviews. That is, only video clips from class periods related to stimulated recall interviews were fully analyzed. Interview transcripts and video clip summaries were then open coded within Microsoft Word. Subsequently, the open codes were categorized according to the six aspects of the activity theory pentagon: subject, tool, object, community, rules, and management, as well as outcomes. Coding for activity theory aspects was accomplished via highlighting with seven colors to correspond with the components of activity theory.

Portions of whole class video relevant to textbook use, transcriptions of teacher interviews, observational field notes, and student work were consulted to supplement or provide additional contextual data relating to each student's stimulated recall interview. Activity theory codes were summarized in activity profiles for each student who participated in a stimulated recall interview, based on the class period on which they reflected in the interview. For Class A, ten students took part in one stimulated recall interview regarding textbook use in one of three classes. In Class B, five students participated in one stimulated recall interview regarding textbook use in one of three classes. One student in Class B, Derek, did not yield rich data for this study and his activity profile is not reported.

For each lesson, an activity profile table was created with columns representing the activity of individual students within the lesson. Activity theory codes relating to rules, management, object, and outcomes were, for the most part, consistent across students within each lesson. Tables also represented individual differences among students, particularly with regards to student interactions with the community and textbook features that individual students utilized during the lesson. This coding scheme and the resulting activity profile tables allowed me to systematically summarize the complexity of student textbook use during class. These descriptive overviews were then supported with more detailed excerpts from student interviews to build rich descriptions of how individual students used their Algebra 1 textbooks and for what purposes.

Initial and follow-up interviews were openly coded and sorted according to the aspects of activity theory, but because these interviews yielded minimal rich data to support the research questions, results from these data sources were used to supplement what was found from video data and stimulated recall interviews.

Summary

In this case study of student use of textbooks in two Algebra 1 classes, a variety of data sources including two types of video, three types of student interviews, teacher interviews, observational field notes, and student work artifacts helped to characterize student use of print and digital textbooks. From these data, activity profiles were created for fourteen students in six class sessions. Comparison of activity profiles among students within each of the two classes and between the two classes addressed the three research questions related to student use of print textbooks, student use of digital textbooks, and comparative use of digital and print textbooks. Results are presented in the following chapter.

IV. Results and Analysis

This chapter presents the study results and is organized by the three research questions. The first and second sections describe student textbook use in Class A (printed textbooks) and Class B (digital textbooks), focusing on classroom use during a subset of lessons that were recorded using students' head cameras. These video recordings served as the focus of stimulated recall interviews with students. The third section presents comparative analysis of the data presented in the first two sections, describing how student textbook use differed between the class of students who used printed textbooks and the class that used digital textbooks. Relevant information from task-based and follow-up student interviews and weekly teacher interviews is woven throughout this chapter.

Student Use of Printed Algebra Textbooks

Throughout the period of the study, fifteen students in Class A recorded their textbook use via head-mounted cameras during one or more of the eleven class periods that comprised instruction for Chapter 4. One or more students captured textbook use in five of the eleven class periods. Table 3.2 summarizes these data sources. This section focuses on student textbook use during four of these lessons. I focus on these four lessons because the ten Class A students who participated in stimulated recall interviews elaborated on video clips they recorded during one of these four class periods. Results include analysis of these video clips and transcripts of corresponding stimulated recall interviews, with supporting data from whole class video, teacher interviews, student work, and observer field notes.

For each of the four class periods, I provide a general description of that day's lesson, instructional objectives, tasks, assignments, and how Mrs. Rogers used the textbook during instruction. This information is reflected in the table of student activity profiles for each lesson. Structured according to the seven elements of activity theory, these profiles characterize how individual students used their Algebra textbooks during the lesson. Activity profiles are followed by more in-depth description of how individual students used their textbooks, including details from stimulated recall interviews and other supporting data sources.

Print textbook use during a lesson about identifying linear functions

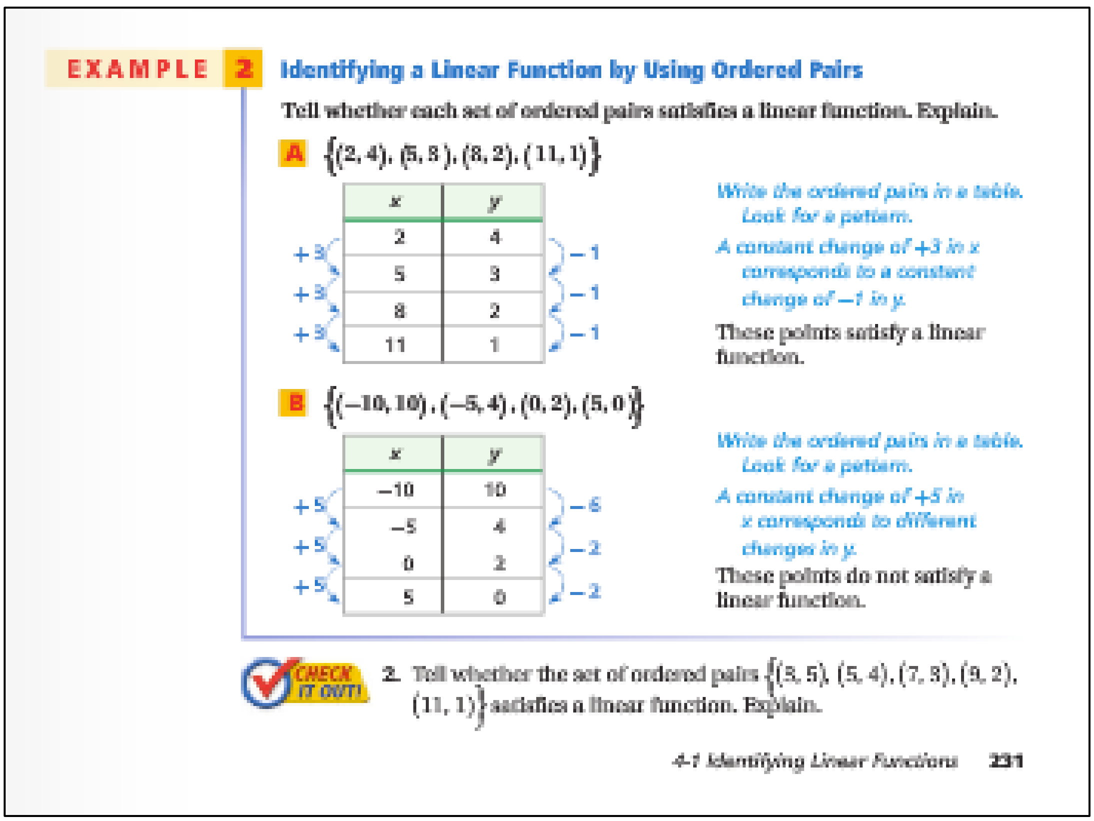
This forty-five minute lesson took place on the second day of instruction of the unit on Linear Functions and was the first day the textbook was used during this unit. The previous day, students engaged in an activity that involved collecting and plotting authentic data points with linear relationships. In the second lesson, Mrs. Rogers used the previous day's activity to launch instruction based on Chapter 4, lesson 1 (4-1).

Following her typical classroom routine, class began with students independently solving daily warm up problems Mrs. Rogers selected from a variety of sources and posted on the whiteboard. Then, Mrs. Rogers briefly discussed the previous day's class and proceeded with teacher-led instruction. During this time, students took notes on pages that Mrs. Rogers prepared for them. During the note-taking portion of class, Mrs. Rogers explicitly told students to open their textbooks to view specific examples on a particular page. After the teacher-led instruction, homework problems from the textbook were assigned and students were given approximately ten minutes to work on these exercises independently in class.

The objectives of lesson 4-1 (Identifying Linear Functions) appeared in the textbook as follows:

- Identify linear functions and linear equations.
- Graph linear functions that represent real-world situations and give their domain and range.

Mrs. Rogers emphasized the first objective, omitting examples and exercises from the textbook relating to domain and range.



EXAMPLE 2 Identifying a Linear Function by Using Ordered Pairs

Tell whether each set of ordered pairs satisfies a linear function. Explain.

A $\{(2, 4), (5, 3), (8, 2), (11, 1)\}$

	x	y	
	2	4	
+3	5	3	−1
+3	8	2	−1
+3	11	1	−1

Write the ordered pairs in a table. Look for a pattern.

A constant change of +3 in x corresponds to a constant change of −1 in y.

These points satisfy a linear function.

B $\{(-10, 10), (-5, 4), (0, 2), (5, 0)\}$

	x	y	
	−10	10	
+5	−5	4	−6
+5	0	2	−2
+5	5	0	−2

Write the ordered pairs in a table. Look for a pattern.

A constant change of +5 in x corresponds to different changes in y.

These points do not satisfy a linear function.

CHECK IT OUT! 2. Tell whether the set of ordered pairs $\{(3, 5), (5, 4), (7, 3), (9, 2), (11, 1)\}$ satisfies a linear function. Explain.

4-1 Identifying Linear Functions 231

Figure 4.1. Lesson 4-1, Example 2, Explicitly Referenced during Lesson (Burger et al., 2012a)

The written notes and enactment of the lesson concentrated on identifying linear relationships from tables of values, sets of points, graphs, and symbolic equations. See Appendix H for the notes template for lesson 4-1. Mrs. Rogers selected some of the examples directly from the textbook, but other examples were chosen from the previous year's textbooks and the Internet. In particular, Mrs. Rogers asked students to refer to Example 2, as shown in Figure 4.1. Students' homework exercises included only textbook questions that aligned with this focus of classroom instruction.

Two female students, Ellen and Lindsay, wore head-mounted cameras to record the lesson and participated in stimulated recall interviews about episodes they recorded of their own textbook use during class. The profiles of their classroom activity related to textbook use during this class are summarized in Table 4.1.

Table 4.1

Student activity profiles for Ellen and Lindsay.

	Ellen	Lindsay
Subject	Ellen, Grade 7	Lindsay, Grade 7
Rules	Mrs. Rogers explicitly asks students to refer to specific examples in their textbooks during instruction. Homework exercises are also assigned from the textbook.	
Community	Mrs. Rogers and students in Class A.	
	Ellen volunteers responses aloud during whole class instruction. During independent work, Ellen interacts with Mrs. Rogers and one other student.	Lindsay shares her textbook with her table partner. During independent work, Ellen interacts with Mrs. Rogers, her table partner, and two peers at neighboring tables.
Division of labor/management	Classroom instruction is teacher-centered and textbook use is teacher directed. During homework, students work independently or with neighboring classmates.	
Tool/artifact	Print textbook: Examples in Lesson 4-1, Guided Practice, Practice & Problem Solving.	
Object	Textbook use during the lesson is directed at learning through viewing and discussing textbook examples.	
	Textbook use during independent practice is directed at student exercises that require recognition and categorization.	
Outcome	Identify linear functions and linear equations.	

Ellen. Ellen, Grade 7, wore a head mounted camera once during the study. She elaborated in a stimulated recall interview the following day. Ellen's table partner was a male student who did not consent to participate in the study.

In general, Ellen actively participated during whole class instruction, frequently volunteering responses aloud. During class, she attended to textbook examples, as directed by Mrs. Rogers. Although Ellen looked at the textbook examples, she became distracted at one point in the lesson and began to fidget with an object on her notebook. In her interview, Ellen viewed the video clip of this action and acknowledged her distraction. She characterized the textbook example to which Mrs. Rogers referred during instruction as "cluttered" and "confusing":

> I**:** Ok, she specifically had referred you to Example 2 in the book and it looks like there in the beginning you looked at those examples for a little bit. Do you remember the extent to which you found those examples helpful?
>
> E: I didn't find them very helpful.
>
> I: Why not?
>
> E: Usually with like examples they um I find it a little helpful but like it looks like there's a lot going on there with all like the lines and stuff. I know that sounds silly but it seems a little bit cluttered and it's not very clear. I think it would be a lot more helpful if it just said example 1, 2, 3 whatever and then it had the examples instead of showing like what the examples are because I never read the margins.
>
> I: Why not? Why do you think that is?
>
> E: I don't know the margins they just don't seem that helpful, or whenever I do look at them they just kind of confuse me more I think. Or at least in my opinion it just confuses me more with the margins because it seems like its over-, it's over-explaining them and I'm someone who's just kind of clear. You just have to explain it once and then I have it and just like a simple definition and, um, so sometimes the margins are confusing. (Ellen, Stimulated Recall Interview, 10/31/12)

In spite of Ellen's criticism of the textbook examples in lesson 4-1, she did identify the examples as the most helpful thing about her book. She expressed skepticism about the extent to which the textbook examples would have been helpful without assistance from the teacher. Ellen's explanation indicates that she relied on Mrs. Rogers to explain the content of the textbook.

> I: Um in that situation what would you say was the most helpful thing about what was in your book?
>
> E: Um the examples were helpful it's just that I guess if I was doing it by myself then I probably wouldn't have gotten it but doing it with the class it's a lot helpful, a lot more helpful yes.
>
> I: Why do you think you wouldn't have gotten it if you were doing it by yourself? Can you elaborate on that a little bit?
>
> E: Just because we had help from Mrs. Rogers and she explained kind of what's going on there which sometimes isn't as clear kind of. Um, yeah I don't think I would have been able to get that from the book if it was just me.
>
> I: If it was just you?
>
> E: Yeah because she can interpret better, I guess interpret, than I think a student could.

During the stimulated response interviews, I often selected video clips that showed students encountering difficulty and using resources within the classroom to move past these difficulties. Questions surrounding clips such as these focused on which resources students consulted for assistance and the extent to which students considered the textbook a useful resource. For example, I showed Ellen a clip of her working with her table partner as they struggled to understand the distinction between linearity and function in the context of the assignment. In class, she discussed her question with her table partner and then asked Mrs. Rogers for clarification. Ellen did not use her book as a resource for overcoming her difficulty in class and, when asked how she would figure it out if working alone, she identified Google as a resource, adding at the end that she might also consult the back of the book.

> I: So see you're kind of discussing back and forth with your table partner. Do you remember what you were trying to figure out here?
>
> E: We were trying to figure out if it was linear and if it was a function. But then I found out later today that we weren't supposed to find out if it was a function because they're all functions, we were supposed to figure out if they were linear or nonlinear.
>
> I: I see.
>
> E: Which I did get right though.
>
> I: Good, good. Well if you had been at home working on that and there hadn't been Mrs. Rogers and your table partner, what would you have done to try to figure that out?
>
> E: Um I'd probably look up the definition of a function or a linear function.
>
> I: Where would you look at?
>
> E: Google. [laughs]
>
> I: That's fine. That's what I want to know. Where would you really look it up?
>
> E: Probably either Google or the back of the book.

The textbook did provide a description for both function and linear function in section 4-1. However, Ellen did not look for this definition within the textbook. She described having used the glossary in the back of the textbook, although she misidentified it as the index.

> I: So what features of this book do you use the most?
>
> E: Um…like the homework questions.
>
> I: Anything else that you refer to very often?
>
> E: The index I guess. Like where it tells you what certain terms mean in each chapter and stuff. Because the math ones aren't clear on what that means or you didn't catch it or whatever.

Overall, Ellen's use of the textbook during this class period was limited to viewing examples for her notes and homework exercises from the 'Guided Practice' and 'Practice and Problem Solving' sections at the end of lesson 4-1. Both of these uses during class were teacher-directed and Ellen demonstrated no evidence of independently using the textbook as a resource to answer her questions about the assigned exercises. Nonetheless, Ellen successfully completed the homework exercises. Her correct responses suggest that she met the intended outcomes for this lesson; that is, she was able to identify linear functions and linear equations as presented in the assignment.

Lindsay. Lindsay, Grade 7, wore a head mounted camera once during the study. She participated in a stimulated recall interview the following day to elaborate on how she used her Algebra 1 textbook. Lindsay's table partner during most of the study was Lin, a seventh grade female student who consented to the study but did not participate in an interview.

Review of video recorded from Lindsay's perspective indicated that she intermittently followed along with Mrs. Rogers' instruction during class and while she opened her book to the pages she was supposed to, Lindsay appeared to shift her gaze frequently, exhibiting a pattern of getting a couple of questions behind and then 'catching up' as she took notes during class. I selected a video clip of this phenomenon to elicit Lindsay's interpretation and explanation. She did not acknowledge any distractions, instead identifying both Mrs. Rogers' direct instruction and the textbook as helpful elements during this portion of the class period.

I: As you wrote the answers down I noticed sometimes you were looking at the paper and sometimes you were looking at the book. Mrs. Rogers was also saying some of the answers for that out loud. What do you think was most helpful for you there?

L: It helped me that Mrs. Rogers was telling what the answers were but it also helped me when I could look in my book so I could see for myself so I could work it out myself and see what I was doing then, at that same time.

I: So did you find the examples in the book helpful?

L: Yeah I found them helpful. Because then she's telling them to me but I like having a visual aid so I can see, while listening too.

It warrants mention that all students were aware I was investigating student textbook use, which may help to explain the contradiction between Lindsay's video data and interview response.

A notable aspect of Lindsay's in-class textbook use was her engagement with other classmates while using the textbook. Throughout the lesson, Lindsay shared a textbook with her table partner, Lin, although both girls had their Algebra textbooks with them at the time. In addition to sharing a textbook, Lindsay frequently engaged in discussion with Lin and two peers at a table behind her, Holly and June.

I: Ok so the reason I show this clip is because it seems like there's a little more discussion. Can you tell me what you were talking about in this clip?

L: We were working on some homework problems and I was discussing with Lin some of the answers here because I didn't understand some of them and then we had talked about it and then I realized she got some wrong and she realized I got some wrong so we kind of helped each other out to look at the book and realize what we were doing like properly.

I: So do you prefer to work alone from your textbook or with a partner?

L: I prefer to work with a partner so then if I don't understand something I can say to them, look I don't see what's going on here so they can help me and tell me you're doing this.

Lindsay's description of peer discussion aligned with the video data. Both data sources indicated that Lindsay collaborated with peers while working on textbook exercises, asking questions about what she didn't understand, answering peers' questions, and confirming her responses with other students. From the perspective of activity theory, the aspect of community was particularly important in Lindsay's textbook use.

To probe in to how Lindsay would use the textbook (or other resources) if disconnected from this community of peers, I asked Lindsay what resources she would consult if she was working on homework exercises alone. The resources she identified were textbook examples and talking to the teacher or others. Lindsay also mentioned that her mother tended to refer to textbook examples when attempting to assist her with homework questions.

> I: And so I wonder, when we looked on here you were talking to your table partner and that discussion seemed to be helpful for you. What if you were at home doing the homework and you didn't have anybody there at your table to talk to. What kind of resources would you use then?
>
> L: If I didn't have anybody to talk to and I didn't understand the question I would look through the book to find some examples I can see. And I know sometimes when I really can't understand it I ask my mom and she's always looking back at the examples and then she'll mark the page and then I'll look off that page and go back and see what I'm doing and what examples and what things to do, so that helps.
>
> I: Are there any other resources that you ever use to help you out if you're stuck in Algebra?
>
> L: I just look at the examples or ask the teacher to see what I'm supposed to do but if I've got the book I look at the examples.

This particular class period required that students consult examples during instruction and homework exercises at the end of class. Not surprisingly, Lindsay reported these textbook features as the ones she used most often, adding that she tends to disregard many of the textbook images.

> I: So within your book what features do you think you use the most?

> L: Like features? Just examples and questions and that but, hm, I don't when there are pictures and stuff I don't, I don't know why, I don't look at them. But examples and questions those are my main, I look at them a lot.

Lindsay's activity profile for the October 30 class period revealed that her textbook use was teacher-directed and incorporated collaboration among her community of peers. In this instance, her responses to homework exercises indicated success in identifying linear functions and linear equations, as represented in the assignment.

Comparison of Ellen and Lindsay's print textbook use. Comparing Ellen's textbook use with Lindsay's textbook use during this lesson, one finds that both students used the textbook as directed by Mrs. Rogers, with neither student referring to features of the book not required during class that day. That is, neither Ellen nor Lindsay independently used their textbooks as resources to clarify their own questions or overcome difficulties within the lesson. A noticeable difference between the two girl's classroom textbook use involved the peer community, with Ellen working mostly independently and Lindsay engaged with peers as she used her textbook. However, both Ellen and Lindsay effectively used their textbooks for the objects of this class period, as evidenced by correctly completing their assignments.

Interview responses suggest that both Ellen and Lindsay did not attend to many of the textbook features, focusing instead on examples and student exercises, as well as the glossary, which Ellen misidentified as the index. Not only did both students report that their textbook use was limited to a few features, but also that they disregarded or disliked some of the textbook features. In spite of limited use and some negative perceptions, Ellen and Lindsay claimed to find the textbook and examples helpful to some extent. Both girls stated that textbook examples were helpful but preferred either teacher explanation or peer interaction to supplement or 'interpret' the textbook material.

Print textbook use during a lesson about using intercepts

The class period on October 31 was a 90-minute block period comprised of review, instruction over new material, and independent practice. At the beginning of class, Mrs. Rogers provided students with time to independently finish and refine responses to the previous night's homework exercises drawn from the textbook. She then led the class in checking and reviewing homework responses together, focusing on exercises that students identified as troublesome.

New material during the October 31 class period focused on textbook Lesson 4-2: Using Intercepts. Mrs. Rogers provided students with printed notes pages and then led direct instruction as students completed the notes. During the last twenty-five minutes of class, students worked independently or with table partners to complete a homework assignment from the 'Guided Practice' and 'Practice and Problem Solving' portions of Lesson 4-2. The lesson objectives, appeared in the textbook as follows:

- Find *x*- and *y*-intercepts and interpret their meanings in real-world situations.
- Use *x*- and *y*-intercepts to graph lines (Burger et al., 2012a,b).

The examples Mrs. Rogers selected for classroom instruction and students' notes included contextual problems, graphing a line using intercepts, identifying intercepts from linear graphs, and finding intercepts given linear equations. Homework exercises for this section also included a variety of problems. See Appendix I for the notes template Mrs. Rogers provided students for this lesson.

Three students recorded and participated in stimulated recall interviews regarding this block class period. Activity profiles in Table 4.2 summarize how each student used his or her textbook during instruction on October 31, 2012.

Table 4.2

Student Activity Profiles for Evalyn, Miles, and Sydney

	Evalyn	Miles	Sydney
Subject	Evalyn, Grade 7	Miles, Grade 7	Sydney, Grade 6
Rules	Mrs. Rogers leads the whole class in checking the previous night's assignment from the textbook. The textbook is not explicitly referenced during direct instruction. Homework exercises are assigned from the textbook and students are given time in class to work on these exercises.		
Community	Mrs. Rogers and students in Class A		
	Works independently	Works independently	Works independently
	Mrs. Rogers-asks questions about assignment but not mathematical content	Mrs. Rogers-asks questions about mathematics	
Division of labor/management	Classroom instruction is teacher-centered and textbook use is teacher directed. At the beginning of class and during homework time at the end, students could work independently or with neighboring classmates.		
Tool/artifact	Print textbook: 4-1 and 4-2 Guided Practice, Practice and Problem Solving		
Object	Textbook use during independent practice is directed at student exercises that require graphing and interpreting features of linear functions from multiple representations.		
Outcome	Find *x*- and *y*-intercepts and interpret their meanings in real-world situations. Use *x*- and *y*-intercepts to graph lines.		

Evalyn. Evalyn, Grade 7, recorded her classroom experiences on a head-mounted camera twice during the study; textbooks were used during only one of these lessons. She participated in a stimulated recall interview two class periods after capturing textbook use via the camera. Evalyn was seated next to a male student who did not consent to participate in this study.

Throughout this block class period, Evalyn remained on task, attentive during teacher-led instruction, and focused on exercises in her textbook, when appropriate, at the beginning and end of the class period. In fact, Evalyn's textbook use during class was limited to looking at student exercises in lessons 4-1 and 4-2. When shown clips of herself using the textbook as a source for homework exercises, Evalyn revealed that although she was aware of textbook features other than student exercises, she was not familiar with the sequencing of textbook lessons.[1] Evalyn's response and lack of familiarity with the general structure of textbook lessons suggested that she did not often refer to the body of the textbook or she might have exclusively relied on locating content by page number. She also conveyed a somewhat negative perception of the textbook's utility in helping her to understand new material, preferring the type of explanation provided by Mrs. Rogers, instead.

I: So in this particular clip, tell me what I was watching.

E: Um, I was doing the homework that we were given for that day so writing down the equation and then finding the *x* and *y* intercepts.

[1] Each lesson in the book was comprised of three sections: narrative and examples, guided practice, and practice and problem solving, with homework exercises usually assigned from the last two sections.

I: So with those exercises there at first, because it looks like you had just started that assignment, did you find the exercises clear?

E: Yes because I had, we had talked about it during class and I had seen a few examples, though if I did just look at the book and was trying to learn about it just by looking at the book I think it would be a little bit difficult just because how the book was made. It just doesn't explain it very much as it would in a classroom.

I: That raises an interesting idea. I notice here, as I watch you, you stay on these two pages, which is just the exercises, asking you questions, those are the problems. Where else would you look in the book if you didn't remember what Mrs. Rogers had said about it? Or would you?

E: Um, I think there's multiple pages in the book talking about this concept, but I wouldn't know for sure because I haven't flipped through every page in the book. But, if I looked in the glossary or in the index or wherever, there would be like page numbers for certain exercises that would probably be a place where I could find different problems on this subject.

When asked what resources she used to assist with solving textbook exercises, Evalyn did not mention the textbook. Instead, she said she would refer to her completed homework problems and notes at home or, in class, ask Mrs. Rogers. This suggested that Evalyn looked to her textbook primarily as a source for assigned work, a notion that she later acknowledged explicitly.

I: Ok, so you mentioned you look at your homework and you look at your notes. Are there any other resources you use if you're not sure?

E: If I can't quite figure it out or if I'm not sure if I'm doing the right thing if I'm doing a problem, I would ask Mrs. Rogers. That's the only other…

I: Are there any other resources you would use if you were at home and you got stuck?

E: My notes I think is all I would use because my parents don't know how to do it.

I: Ok. So in general, how useful do you find your textbook?

E: Um I usually only use it whenever I'm doing homework, though sometimes if I'm looking at something and I can't quite-and I'm looking at my homework problem that I was given I might flip a few pages back or forward to see if there are any other examples that I might have done for homework before to see if I can help myself remember what I'm supposed to do or something.

Another notable aspect of Evalyn's activity during class was her lack of interaction with peers during class. Throughout the lesson on October 31 Evalyn worked alone, rarely interacting with peers as she checked and completed homework exercises from the textbook. When asked about peer interactions, she indicated that she did sometimes consult her table partner for confirmation if she was not confident about her own response.

I: So while you're doing homework do you consult with your table partner very often?

E: Sometimes. It I guess it depends on if um if I did something and I'm like uh, I'm not quite sure if that's right then I'll ask my partner to compare and see what I might have done right or wrong.

Evalyn's personal interactions with Mrs. Rogers were also infrequent, focusing on clarification of the assignment and directions rather than mathematical content. During the stimulated recall interview, Evalyn commented on a video clip in which she asked Mrs. Rogers for clarification about the directions as printed in the textbook. Her responses to questions about that video clip further reiterated her previous assertion that the textbook included limited explanation.

I: Ok, so do you think that the book directions are clear?

E: I think they do say like what they want you to do, but sometimes the teacher would need to explain how to do it or if they want you to do something in addition to what the book says. Usually I think the book directions are very broad, just kind of saying solve these equations or find x or something, instead of like explaining what they want you to do in full, like a teacher would do if they were explaining something.

Observation and interview data indicated that Evalyn tended to use her textbook as Mrs. Rogers directed, most often for homework on which she worked alone. Although Evalyn tended to work independently on exercises from the book, she did not perceive the book as a useful resource for independent learning, preferring instead to consult her notes and Mrs. Rogers' explanations of textbook content. Evalyn's limited use of the textbook did not appear to impede her success in this lesson. She correctly responded to all assigned exercises.

Miles. Miles, Grade 7, participated in an initial task-based interview, a follow-up interview, and a stimulated recall interview that focused on his textbook use during the one class period in which he wore a head mounted camera. Miles preferred to work alone with no table partner. Mrs. Rogers indicated that Miles' advanced vocabulary and difficulties in social situations might indicate an undiagnosed exceptionality, and that his parents communicated with the school and teachers regularly to ensure that his needs were met to their satisfaction.

During this lesson, Miles referred only to the student exercises for Lessons 4-1 and 4-2. He worked alone as he used his textbook, which was typical for Miles who elected to sit alone at a table in the back of the classroom. In this lesson, two male classmates chose to sit at the opposite end of this table and socialize, sometimes loudly, as Miles worked. In spite of this potential distraction, Miles remained on task and claimed not to mind.

> I: And I'm curious, that day [two other students] were working at the back table with you and you heard some of the noise from that. Do you like having other people back at the table working with you or do you think you work better independently when it's quiet?

M: I work better independently, but I don't mind company. It's fun to have company because you get to have someone to talk with when you're done, if you want to talk, but if they want to talk and you want to talk, but I also like working solo because you don't have the distraction.

I: Ok, did you find that to be a distraction that day?

M: No. You sort of get used to it.

Unlike Evalyn, Miles did identify the textbook as a useful resource for this lesson. Miles also seemed to demonstrate an awareness of how the chapters are arranged, pointing out the front matter of each chapter. This was corroborated by his descriptions of the textbook during the initial task-based interview and the follow up interview. While Miles perceived his textbook as a useful resource and seemed aware of many textbook features, he preferred to consult Mrs. Rogers for questions and confirmation of his responses.

I: Now she [Mrs. Rogers] serves as a very helpful resource in this situation. Are there any other resources that you might consult to check to see if your work was right? To help to see if you're on the right track if you're not 100% confident?

M: I guess my book. My book has a lot of useful information. Something in front, there's like a little thing in front that basically explains what you're doing, sort of a chapter review, and that might have been a very good something to turn to, so I think if I had plugged it back in and it hadn't worked I tried to solve it again and I wasn't able to, either Mrs. Rogers or if Mrs. Rogers wasn't available, my book. So those are two very good resources.

I: So one of the things your book has, and I know many books do, are some of the answers in the back of the book to check. Do you ever use that feature?

M: I do yes. If I'm stuck on something, I ask for help, or actually if I was just stuck on something, I'd ask for help and I'd solve it and afterwards I'd check the answer to see how I could have done it and if I got the answer right. So it's yeah, a very helpful resource.

Sydney. Sydney, Grade 6, wore a head-mounted camera twice during the study, and the class used their textbooks in one of these lessons. She participated in a stimulated recall interview two class periods later. Sydney was seated next to a male student who did not consent to participate in this study.

Sydney was considered to be a gifted student and, in order to enroll in Algebra 1 in sixth grade, she independently studied Prealgebra content during her fifth grade elementary class. Sydney and another advanced student, June, worked together in fifth grade, independently learning content from the Prealgebra textbook while their teacher led the rest of the students in fifth grade mathematics lessons. Thus, Sydney had considerable experience in using a mathematics textbook as a resource for independent learning. Furthermore, the adopted Prealgebra textbook was from the same publisher and series as the Algebra 1 textbook used in this class, so Sydney was familiar with the general arrangements and features similar across the books in the textbook series.

During class, Sydney focused only on the student exercises in lessons 4-1 and 4-2, never turning to different pages in the book. She also said that she felt very confident about the content of the lesson and did not encounter any difficulties in the lessons, often determining *x*- and *y*-intercepts of linear equations in her head, without any algebraic manipulation or intermediate steps written on paper or with technology. Since this lesson only required Sydney to use her textbook to solve exercises, she did not have a need to refer to the textbook, other than to look at problems.

S: Um, I think I was listening to the answers that she was telling me and I was correcting them and stuff like that. And I was looking at problems in the book and why they were right and why some of them were wrong.

I: Ok. As you followed along, how useful did you find your book?

S: Oh, I found it pretty useful because I could go back and look at the problem and see um and see and work from there and see what step I had gotten wrong and stuff like that.

I observed Sydney engaged in limited textbook use, which she said was typical. She described occasionally using textbook examples and content as a resource for clarification when she encounters difficulties.

I: I notice that for all of the video for that day, which was a block class so it was quite a while, the only pages I ever see you on in the book are just the exercises, which isn't bad. But I did notice that those are the only pages that you're ever on in there. Do you ever turn away to different pages in your book?

S: Uh, no not really. I usually just stay on those ones unless there's, unless there's another exercise on another page that I need a little bit more clarification on then I'll turn to that page and then I'll just turn back and um draw on from where I was.

I: So when you say another exercise on another page are you meaning, like, an example or…

S: Yeah, usually an example not like any problems. Just the examples where they show you how to do it and stuff like that.

I: So do you look at those…

S: Yeah. Sometimes I look at those, not very frequently but just when I need them. Just to help me understand a little more.

She also identified the teacher-provided notes as a helpful resource but, unlike most students, did not mention seeking help from peers or the teacher. Sydney was one of the only students in the study who did not mention asking others for help if she was struggling with a question or problem, instead reporting that she would consult her textbook or written notes. One might conjecture that this is related to her previous independent study experience in which she learned from her textbook with minimal teacher guidance.

I: Now, in general, I wonder if you're having trouble with an exercise, and it sounds like you feel pretty confident about this chapter so far and that hasn't been the case, but if you were having trouble with an exercise what kind of resources would you consult?

S: I might go to the table of contents and try and find um try to find something that's similar to that problem so I can go and reference it and find out a little more about why it's happening or some things, why the steps in the equation are going wrong, something like that.

I: What about outside the book? Are there any other resources you would use other than the book?

S: Um, not, most of the time I will go through my notes and stuff and look at what's in my notes.

I: So in general I guess to what extent do you find your textbook helpful, for you?

S: It's pretty helpful because if I need a little more clarification I can go through it and find, and it has almost everything that we've learned in it so if I have any questions then I can go in to my book and look it up.

Comparison of Evalyn, Miles, and Sydney's print textbook use. As Table 4.2 indicates, textbook use among Evalyn, Miles, and Sydney, was similar. Throughout a ninety-minute class period, all three students' textbook use was limited to student exercises. Although each student described the textbook as helpful, they seemed to have little impetus to consult textbook features during the lesson other than the assigned student exercises.

Evalyn, Miles, and Sydney all worked independently throughout the lesson, barely interacting with other students. Evalyn and Miles asked Mrs. Rogers questions for clarification and confirmation but Sydney's in class textbook was completely independent. The lesson followed Mrs. Rogers' typical structure and whole class video revealed that many other students chose to work more collaboratively with table partners and peers. The lack of community interaction did not appear to be related to this particular lesson. Review of additional video data from other class periods indicated that these three students typically worked alone and it was by random chance that all three of these students were recorded and interviewed about the same lesson.

Print textbook use during a lesson about rates of change

Classroom instruction on Tuesday, November 6, was a continuation of lesson 4-3 in the textbook: Rates of Change. On the previous day, notes and instruction focused on variable rates of change and using tables of values to determine and compare rates of change on intervals. On November 6, the second of this two-day lesson, Mrs. Rogers focused on slope as a constant rate of change for linear functions. As stated in the textbook, the instructional objectives for this lesson were as follows:

- Find rates of change and slopes.
- Relate a constant rate of change to the slope of a line (Burger et al., 2012a,b).

Examples in the notes included determining slopes of lines from graphical representations, by counting rise and run on grids. See Appendix J for the notes template for this lesson. Student textbook use during this class period comprised the last fifteen minutes of class when students began working on homework exercises from lesson 4-3 in the book. These homework exercises included material from the current and previous day's classes.

The class period on November 6 was forty-five minutes in length and followed Mrs. Rogers' typical routine. When students entered the classroom, warm up exercises were posted on the whiteboard and students spent the first few minutes of class working independently on these exercises. Mrs. Rogers then proceeded to project on the whiteboard an image of the notes sheet she had prepared and distributed to students. At the board, she demonstrated how to determine slopes of linear functions from their graphs by counting rise and run on a grid. With approximately fifteen minutes of class remaining, Mrs. Rogers assigned homework from the textbook and students had the last portion of class to work on this assignment.

Three students, Chelsea, June, and Maggie, recorded their experiences during this class and elaborated on the resulting videos during stimulated recall interviews. Table 4.3 summarizes these three students' activity during the lesson on November 6.

Table 4.3

Student Activity Profiles for Chelsea, June, and Maggie

	Chelsea	June	Maggie
Subject	Chelsea, Grade 7	June, Grade 6	Maggie, Grade 7
Rules	The textbook is not explicitly referenced during instruction. Homework exercises are assigned from the textbook and students are given time in class to work on these exercises.		
Community	Mrs. Rogers and students in Class A		
	Mrs. Rogers-asks for guidance Table partner (Farrah)-questions about assignment 2 students at adjacent table-socialize	Mrs. Rogers-confirmation of responses Table partner (Holly)- questions and confirmation of responses Lin at adjacent table-questions and confirmation of responses	Works independently. Table partner (Sabrina)-share iPad
Division of labor/management	Classroom instruction is teacher-centered and textbook use is teacher-directed. During homework, students work independently or with neighboring classmates.		
Tool/artifact	Print textbook: 4-3 Guided Practice	Print textbook: 4-3 Lesson & Examples, Guided Practice, Practice and Problem Solving, Appendix (answers to odd-numbered exercises)	Print textbook: 4-3 Guided Practice, Practice and Problem Solving
Object	Textbook use during independent practice is directed at student exercises that require applying algorithms and interpreting graphical representations.		
Outcome	Find rates of change and slopes. Relate a constant rate of change to the slope of a line.		

Chelsea. Chelsea, Grade 7, recorded her classroom experiences twice during the study, capturing textbook use during one of these class periods. She participated in only one interview during the study, a stimulated recall interview focused on classroom textbook use on November 6. During most of Chapter 4 instruction, Chelsea's table partner was Farrah, a seventh grade student who consented to participate in the study but did not complete any interviews.

In this lesson, Chelsea was frequently off task, socializing with her table partner and neighboring students. In the fifteen minutes Mrs. Rogers allotted for students to work on the homework assignment, Chelsea attempted but did not complete the first exercise. As Chelsea began to work, she immediately asked Mrs. Rogers for assistance. Mrs. Rogers referred her to a corresponding example in the textbook, provided a brief explanation, and then assisted other students. Chelsea did not utilize the example Mrs. Rogers showed her. Instead, she began to write a response on her paper, struggled to continue, and engaged in off-task behavior until Mrs. Rogers returned to her table. After viewing the corresponding video clip during the stimulated recall interview, Chelsea explained that she would be unlikely to consult a textbook exercise, instead preferring a verbal explanation.

> I: So in this particular example [Mrs. Rogers] says well, example 1 and then she flips back to example 1, which seems to kind of jar your memory a little bit. I hear you say, "Ohh…"
>
> C: Yeah.
>
> I: I wonder what the likelihood would be of you referring to that example if she hadn't turned to it for you. What do you think?
>
> C: Umm, well she said it before I did the problems but I probably wouldn't.
>
> I: Why not?

C: Sometimes it's just easier to ask somebody instead of look at the book because sometimes it doesn't explain all the questions you ask.

I: I'd like to-can you say a little more about that, the book doesn't explain…

C: Yeah. I mean they get the basics but like you saw in the problems, you know you come home from school and you kind of forget what you did at the beginning of the day and then the book helps you but it doesn't explain like they give examples but they're not going to give you the exact problem you're working on but if you did the example and saw how to do it, but if you still have questions and they don't show it, then you're either going to ask a teacher or maybe a parent or something.

Although Mrs. Rogers directed Chelsea to an appropriate textbook example, Chelsea did not look at the example Mrs. Rogers identified. (Figure 4.2 shows the homework exercise Chelsea attempted and the corresponding example to which Mrs. Rogers directed her.) In this instance, Chelsea chose not to use the textbook to help her with a problem she found difficult. Likewise, in the interview she did not identify the textbook as a resource she would consult outside of class.

I: Would you in this problem or any other problem, if you were at home, you had a question, Mrs. Rogers's not there to answer the question, what kind of resources would you use to help you out?

C: Well maybe trial and error because that's what I do with some of my things, with the homework problems. And if I get it wrong then I see what I did wrong and then I correct it in class if we go over it and if I don't then I'll ask my mom because sometimes she knows what it is but sometimes she doesn't and she doesn't have time to answer.

I: Are there any other resources, internet, book, notes, friends…?

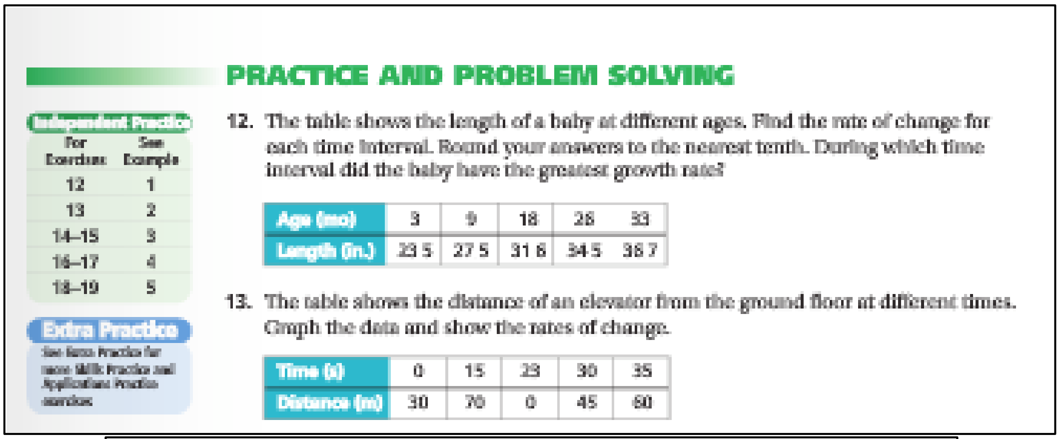
C: Yeah one time I was like um how do you find, how do you divide fractions and it said you multiply the reciprocal or something and so it worked and I got through it but they give us iPads so it's a lot easier.

I: Do you use that to help you out sometimes?

C: Yeah, sometimes it's uh sometimes it doesn't give you the right information. Sometimes there's not-websites are kind of stupid. But we have calculators on them and that's kind of useful.

I: Ok, so that's something you would use you think?

C: Yeah.



PRACTICE AND PROBLEM SOLVING

Independent Practice

For Exercises	See Example
12	1
13	2
14–15	3
16–17	4
18–19	5

Extra Practice

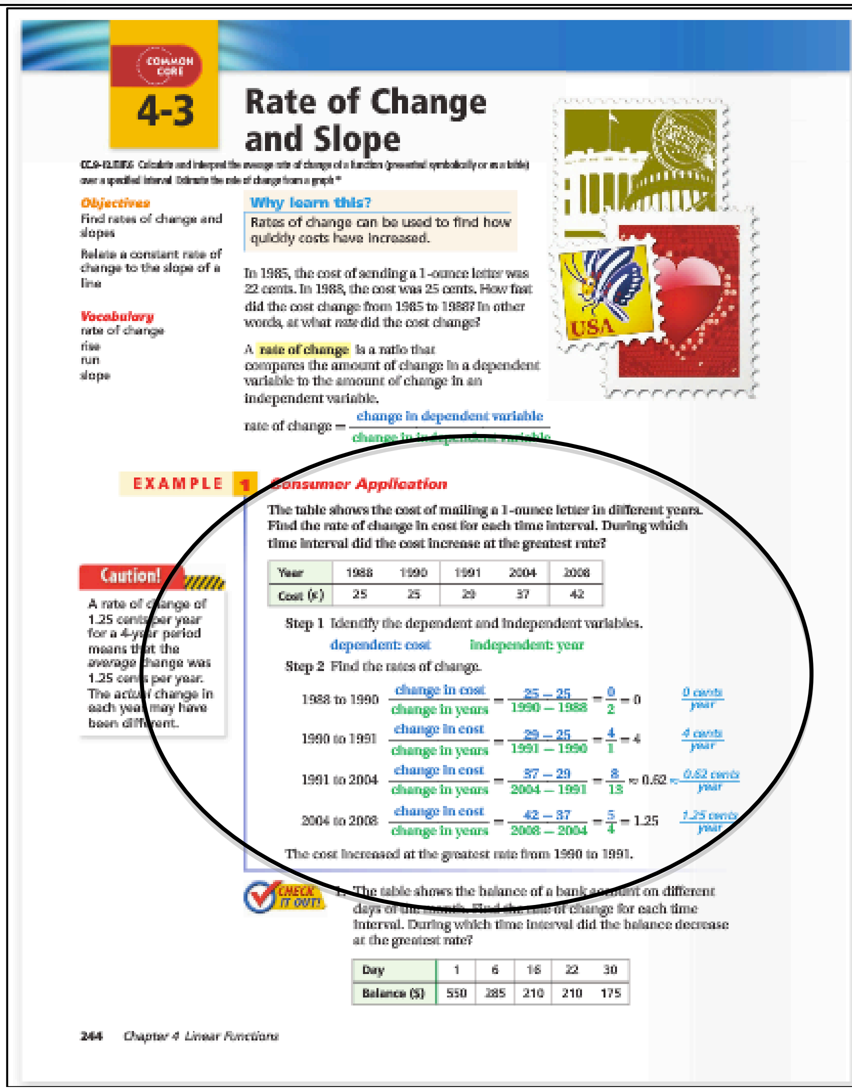
See Extra Practice for more Skills Practice and Applications Practice exercises.

12. The table shows the length of a baby at different ages. Find the rate of change for each time interval. Round your answers to the nearest tenth. During which time interval did the baby have the greatest growth rate?

Age (mo)	3	9	18	26	33
Length (in.)	23.5	27.5	31.6	34.5	36.7

13. The table shows the distance of an elevator from the ground floor at different times. Graph the data and show the rates of change.

Time (s)	0	15	23	30	35
Distance (m)	30	70	0	45	60



COMMON CORE

4-3 Rate of Change and Slope

CC.9-12.F.IF.6 Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.*

Objectives

Find rates of change and slopes

Relate a constant rate of change to the slope of a line

Vocabulary

rate of change

rise

run

slope

Why learn this?

Rates of change can be used to find how quickly costs have increased.

In 1985, the cost of sending a 1-ounce letter was 22 cents. In 1988, the cost was 25 cents. How fast did the cost change from 1985 to 1988? In other words, at what rate did the cost change?

A **rate of change** is a ratio that compares the amount of change in a dependent variable to the amount of change in an independent variable.

$$\text{rate of change} = \frac{\text{change in dependent variable}}{\text{change in independent variable}}$$

EXAMPLE 1 Consumer Application

The table shows the cost of mailing a 1-ounce letter in different years. Find the rate of change in cost for each time interval. During which time interval did the cost increase at the greatest rate?

Year	1988	1990	1991	2004	2008
Cost (¢)	25	25	29	37	42

Step 1 Identify the dependent and independent variables.

dependent: cost independent: year

Step 2 Find the rates of change.

1988 to 1990 $\frac{\text{change in cost}}{\text{change in years}} = \frac{25-25}{1990-1988} = \frac{0}{2} = 0$ $\frac{0 \text{ cents}}{\text{year}}$

1990 to 1991 $\frac{\text{change in cost}}{\text{change in years}} = \frac{29-25}{1991-1990} = \frac{4}{1} = 4$ $\frac{4 \text{ cents}}{\text{year}}$

1991 to 2004 $\frac{\text{change in cost}}{\text{change in years}} = \frac{37-29}{2004-1991} = \frac{8}{13} \approx 0.62$ $\approx \frac{0.62 \text{ cents}}{\text{year}}$

2004 to 2008 $\frac{\text{change in cost}}{\text{change in years}} = \frac{42-37}{2008-2004} = \frac{5}{4} = 1.25$ $\frac{1.25 \text{ cents}}{\text{year}}$

The cost increased at the greatest rate from 1990 to 1991.

Caution!

A rate of change of 1.25 cents per year for a 4-year period means that the average change was 1.25 cents per year. The actual change in each year may have been different.

CHECK IT OUT! 1. The table shows the balance of a bank account on different days of the month. Find the rate of change for each time interval. During which time interval did the balance decrease at the greatest rate?

Day	1	6	16	22	30
Balance ($)	550	285	210	210	175

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Figure 4.2. Lesson 4-3 Exercise 12 and corresponding Example 1 (Burger et al., 2012a)

The one aspect of the textbook that Chelsea identified as helpful was the availability of answers to odd numbered exercises in the back of the book. She also liked the appearance of the textbook, although it was unclear how this contributed to her use of the textbook.

> I: So I wonder if you can tell me a little bit more about how useful you find the book you have now.
>
> C: I think it's good because if you do um like 24-7 there's going to be some odd problems and just to see you can turn to the back of the book and see look I got this one wrong but this one and this one is right so I think I'm on track I just need to fix this one. But it's only the odd numbers so you can, if you're doing it right one way then you have to do it on all of them so it helps.
>
> I: Are there any other features of this book that you find yourself using?
>
> C: Um, I think it's all new and it's um you know like they use colors and it looks, it looks fun even though it's math!

Throughout the class, Chelsea interacted with peers, both socially and to ask questions about the homework. Although Chelsea asked her table partner, Farrah, for some assistance with the first problem, the two did not work collaboratively to solve the problem. Instead, Farrah proceeded with her homework exercises while Chelsea engaged in social conversations with peers at neighboring tables. When asked about working collaboratively, Chelsea expressed a preference for working with a partner and revealed that she sometimes uses the iPad Facetime video-calling app to work with others from home.

> I: But I wonder if discussing things with your table partner is helpful to you…
>
> C: Yeah.
>
> I: …and how often your discussion centers around math and what you're doing in class?
>
> C: Sometimes she's ahead of me and she can help me but sometimes I'm ahead of her so you know it's good to sit with somebody because if you're alone you're going to get in trouble for turning back and asking somebody,

even though teachers don't think that we're talking about the right subjects sometimes, I think it's helpful that we sit with somebody.

I: So would you rather, I mean when you're doing math, would you rather sit down and work on it alone, you and your book, or would you rather have a partner? Which do you think is more helpful and productive for you?

C: No, I think if I had a partner because you know, math is sometimes, you know, homework it's kind of boring but if you have a friend and you're on the same problem kind of working together it's a lot more fun I guess because if you're alone like I Facetime my friends on my iPad sometimes just to see you know hey what'd you get for this one, I can't figure it out. I've done that before and it helps sometimes.

I: Like from home?

C: Yeah.

Overall, Chelsea's textbook use was limited and she relied heavily on interaction within the classroom community as she attempted homework exercises from the textbook. Although Mrs. Rogers explicitly encouraged her to use the textbook as a resource during class, Chelsea did not and later required assistance from Mrs. Rogers. Many of Chelsea's social interactions were off task and distracted from her engagement in the mathematics lesson.

June. June is a sixth grade student in Class A. She recorded her classroom experience during two lessons, capturing textbook use in one lesson. June participated in a stimulated recall interview the following day. June and Holly were table partners during all but day 1 of Chapter 4.

In order to take Algebra 1 in sixth grade, June independently studied Prealgebra content in her fifth grade elementary math class. She described that she and her classmate Sydney worked together to learn Prealgebra from the textbook with minimal teacher explanation. This experience may partially explain the extent to which June independently used her Algebra 1 textbook as a resource during the rates of change lesson.

> J: Yeah, my friend Sydney and I we were actually in 5th grade but they were actually doing a different math. Last year was kind of difficult because Sydney and I would just come out to like the behind the door and then our teacher would have to teach both classes but since we're only a class of two she would just say try to understand this and read it but it was hard because we didn't have somebody to explain it to us.
>
> I: Ok.
>
> J: So we had only us, like Sydney and I to kind of like help each other but that was a little bit harder but now that I actually have a class, it's a lot easier.
>
> I: I see.
>
> J: But we still have the textbook and had the Prealgebra book though.

Throughout this study, June was the only student who regularly consulted her textbook to assist her when she encountered difficulties with student exercises during class. In this lesson, June used several features of her textbook to assist her with exercises. She also utilized in-text cues such as the lesson examples that are identified with 'Guided Practice' questions. Figure 4.3 shows an example of 'Guided Practice' for Lesson 4-2 and a corresponding example. These instances of textbook use were self-initiated, rather than explicitly suggested by Mrs. Rogers. During the stimulated recall interview, June explained how she used textbook content to assist her with a homework exercise:

> J: Well in this one we were doing like a problem with a graph and then I didn't really understand it and so the example, at the top it said like see example 2 or 3 or whatever, so then if you go a couple pages back it says example 2, so I like to like see if I was really confused I can go back to that example and see how they did it and find out how to do the problem.
>
> I: I see. And I think Mrs. Rogers pointed out those cues yesterday. Is that something that you had used before also?
>
> J: Yeah.

I: It is?

J: Sometimes if I'm stuck on a problem and usually those problems reappear in different question forms so I like to use those to help understand.

I: So do you, I'm curious a little more about that. Some of the problems tell you what example to look at. Is that where you always go right away?

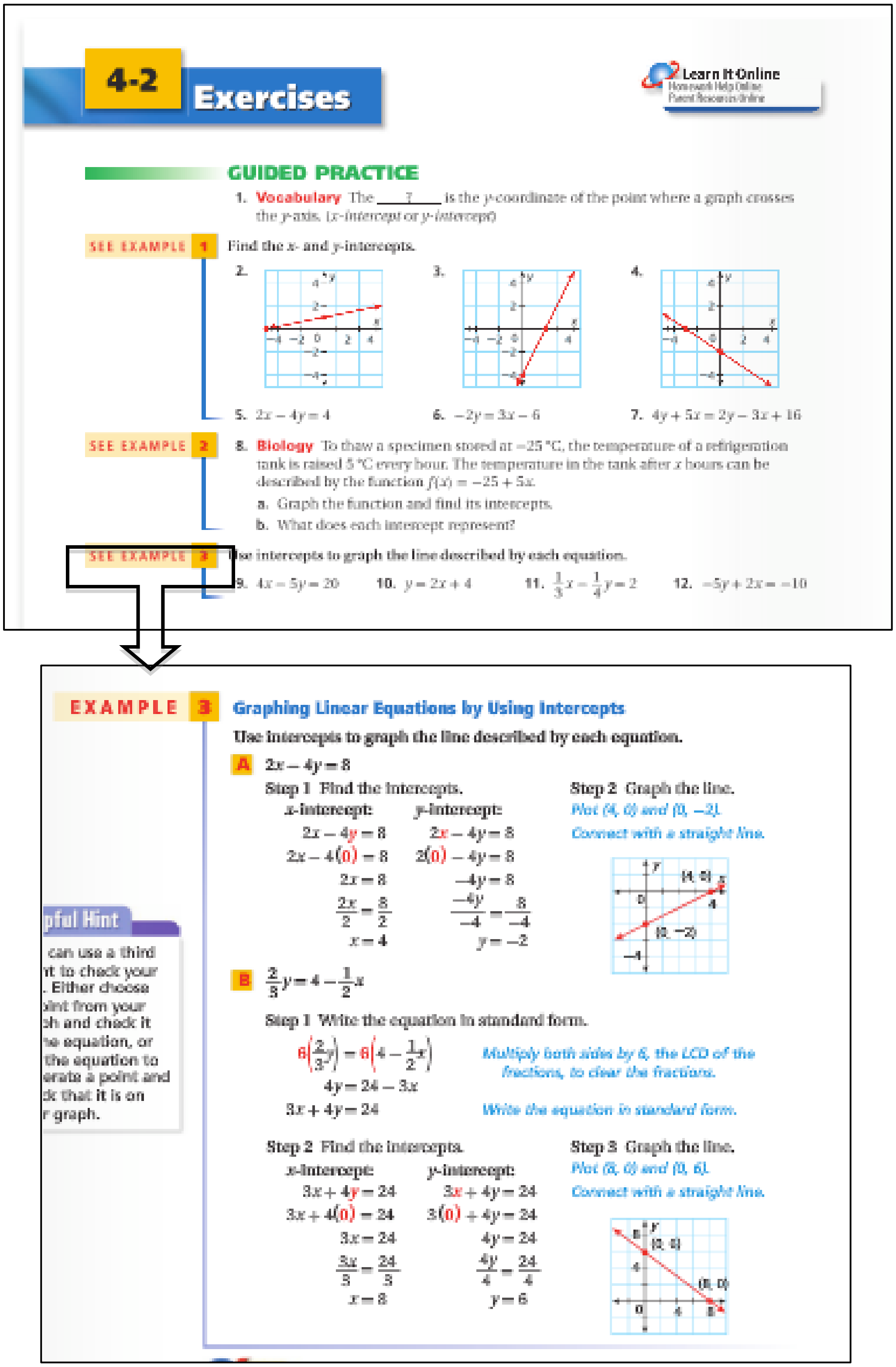
J: Usually I do but sometimes I'll like go to my notes if I don't understand something so I can like see what happened in the notes and like the work that I need and stuff.

I: I see. So when you go to the example they refer you to, do you read just that example or do you look at other stuff on the page? Because you flipped back and forth a few times.

J: Usually I like to look at the example and see how they're connected and see which like if they were the same question and which ones go with each other.

I: How do you know when an example is helpful for you?

J: Well I usually read the problem and if I'm kind of confused or don't really understand how I'm supposed to solve it then I usually go the examples but most of the times I usually can understand it by myself.



4-2 Exercises

Learn It Online
Homework Help Online
Parent Resources Online

GUIDED PRACTICE

1. **Vocabulary** The __?__ is the y-coordinate of the point where a graph crosses the y-axis. (x-intercept or y-intercept)

SEE EXAMPLE 1 Find the x- and y-intercepts.

2. 3. 4.

5. $2x - 4y = 4$ 6. $-2y = 3x - 6$ 7. $4y + 5x = 2y - 3x + 16$

SEE EXAMPLE 2 8. **Biology** To thaw a specimen stored at −25 °C, the temperature of a refrigeration tank is raised 5 °C every hour. The temperature in the tank after x hours can be described by the function $f(x) = -25 + 5x$.

a. Graph the function and find its intercepts.

b. What does each intercept represent?

SEE EXAMPLE 3 Use intercepts to graph the line described by each equation.

9. $4x - 5y = 20$ 10. $y = 2x + 4$ 11. $\frac{1}{3}x - \frac{1}{4}y = 2$ 12. $-5y + 2x = -10$

EXAMPLE 3 **Graphing Linear Equations by Using Intercepts**

Use intercepts to graph the line described by each equation.

A $2x - 4y = 8$

Step 1 Find the intercepts.

x-intercept: $2x - 4y = 8$; $2x - 4(0) = 8$; $2x = 8$; $\frac{2x}{2} = \frac{8}{2}$; $x = 4$

y-intercept: $2x - 4y = 8$; $2(0) - 4y = 8$; $-4y = 8$; $\frac{-4y}{-4} = \frac{8}{-4}$; $y = -2$

Step 2 Graph the line.

Plot (4, 0) and (0, −2).

Connect with a straight line.

B $\frac{2}{3}y = 4 - \frac{1}{2}x$

Step 1 Write the equation in standard form.

$6\left(\frac{2}{3}y\right) = 6\left(4 - \frac{1}{2}x\right)$ Multiply both sides by 6, the LCD of the fractions, to clear the fractions.

$4y = 24 - 3x$

$3x + 4y = 24$ Write the equation in standard form.

Step 2 Find the intercepts.

x-intercept: $3x + 4y = 24$; $3x + 4(0) = 24$; $3x = 24$; $\frac{3x}{3} = \frac{24}{3}$; $x = 8$

y-intercept: $3x + 4y = 24$; $3(0) + 4y = 24$; $4y = 24$; $\frac{4y}{4} = \frac{24}{4}$; $y = 6$

Step 3 Graph the line.

Plot (8, 0) and (0, 6).

Connect with a straight line.

Helpful Hint

You can use a third point to check your graph. Either choose a point from your graph and check it in the equation, or use the equation to generate a point and check that it is on your graph.

Figure 4.3. Guided Practice and corresponding Example (Burger et al., 2012a).

In addition to the lesson examples, June also used the answers to odd numbered exercises found in the appendix of the book to verify her work. In anticipation of this lesson, June had used adhesive tabs to bookmark the answer pages that corresponded with lesson 4-3. When she was struggling with one of the homework problems, she referred to the appendix. June explained that she sometimes used the appendix to not only check her answers, but to help her when she was struggling. She also reported using the glossary outside of class.

> I: You were using the back of the book again. Tell me a little more about what you were using it for there.
>
> J: For that one I um looked at what I did because it was like the one where you had to figure out what number it was, but then today in class we went over the answers and this was more toward the end of the class so I was kind of trying to get it done but then if you talk and then I didn't put like the front number. This one I was kind of confused on what I was supposed to do so I went to the back to check like to see my answers, because I don't like to do the answer and then go back and see that they're all wrong and then I got the complete wrong concept. So sometimes I like to do it so I know that I have the right concept.
>
> I: So you check as you go along?
>
> J: Yeah. Sometimes but usually I only do that if I'm really struggling with a problem, but I usually don't do it all the time.

In addition to using her textbook as a resource, June also reported and was observed asking peers and Mrs. Rogers for assistance and confirmation of her work when she encountered difficulty. More than any other student in this study, June demonstrated a purposeful coordination between referencing content in her textbook and content-focused interactions with her peers and the teacher as she struggled to solve problems from the textbook.

> I: So in some cases you look back at your book, in other cases you talk to the teacher or partner and in this case for this problem, it was kind of a long

problem, you did both. Do you have a preference in terms of what you do when you're kind of stuck?

J: Well sometimes like if I did the problem but I don't really get it I'll ask my friend to see what she got to see if we like got the same thing and if I'm actually doing the problem correctly or not?

I: Are there other resources you would you if you were doing this at home and let's say Mrs. Rogers wasn't there?

J: Usually, I'll just look in the book for more examples but there's not really been a problem where I didn't get anything in the book or anything didn't help me.

Maggie. Maggie, Grade 7, participated in an initial task-based interview and a follow up interview. She wore a head-mounted camera twice during the study, capturing textbook use during one of those class periods. She participated in a stimulated recall interview one day after recording her textbook use in class. Maggie's table partner throughout most of the study was Sabrina.

Throughout this lesson and other observed lessons, Maggie's observed textbook use was mostly limited to accessing assigned exercises. When interviewed, she stated, "I was looking for the homework page. That's really all we ever use out of our book." Maggie did notice a textbook feature in the 'Guided Practice' problems. This feature referenced textbook examples from the lesson to correspond with student exercises. Maggie misapplied this feature when the 'Guided Practice' referenced "Example 1" she referred to Example 1 from her teacher-generated notes rather than the textbook lesson. This suggested that Maggie possessed an incomplete understanding of the relationship between Mrs. Roger's notes and the textbook.

I: Ok. So when your notes didn't seem to help you, you mentioned the examples in the book, in that particular instance I didn't see you flip back in the book at all. Is that something that you do sometimes or…

M: I don't usually like flip back through the book but it said like example 1 on that page so I just looked at that first. And then…that didn't help.

I: Ok. Like in your notes?

M: Yeah.

I: So you used the example one here to refer to example one in your notes?

M: Yeah.

I: Ok, that's for explaining that because I didn't realize that's how you were doing that. Is that something Mrs. Rogers usually does, coordinates those examples?

M: I don't think so. I think she like looks in the book and makes the examples different to where they're not the exact same thing as our homework.

In the lesson, Maggie shared an iPad with her table partner, Sabrina, an arrangement that led to disagreement when both girls wanted to use the iPad calculator app at the same time. Maggie also interacted with Sabrina at the beginning of the lesson to ask questions about a textbook problem she did not understand. While she reported finding this interaction helpful, Maggie stated that she typically prefers to work alone from her textbook, particularly when it is material about which she feels confident.

I: Do you prefer to work independently from your book or would you rather work from your book with a partner?

M: I usually like to work by myself.

I: So we saw a clip where working with a partner kind of helped you a little bit. Do you think that's more helpful than what you can find on your own? How did having a partner there add to your experience?

M:I think that when you have a partner there with you when you get stuck it's like more helpful but if you like know the stuff really well then it'll be just as helpful as working on your own.

Maggie tended to use only the exercises in the textbook, rather than other textbook features that provided instructional support. Nonetheless, Maggie worked successfully toward the object and intended outcomes in this lesson, finding accurate solutions for the exercises she finished during class.

Comparison of Chelsea, June, and Maggie's print textbook use.

Textbook use varied widely among Chelsea, June, and Maggie, during this lesson. Chelsea struggled to use her textbook effectively and demonstrated multiple off task behaviors while attempting to work on exercises from the textbook. Although she preferred interaction with peers and the teacher, peer interactions sometimes proved distracting and Chelsea relied on Mrs. Rogers to guide her to solve the one problem she worked on for fifteen minutes. June, on the other hand, integrated various elements from the textbook with productive peer and teacher interactions, successfully completing the assignment in the time allotted. Maggie worked mostly independently and textbook use was restricted to accessing student exercises. This limited use of the textbook did not impede Maggie's success with the assignment for this class, although she was not able to completely finish the work during class.

Print textbook use during a test review task

The ninety-minute block period on November 14 was split in two portions. During the first half of class, students worked independently on a worksheet that Mrs. Rogers created (not drawn from the textbook). This assignment served as a review for the second half of the class, during which students took an examination over Chapter 4, covering content from lessons 4-1, 4-2, 4-3, 4-4, and 4-6. Video data from November 14 includes only the first half of class.

At the beginning of class on November 14, Mrs. Rogers distributed a review worksheet. The review worksheet included eight question of her own creation (see Appendix K). The task required students to use their textbooks to find examples of functions, non-functions, linear functions, non-linear functions, non-constant rate of change, linear functions with positive and negative slope, and horizontal and vertical lines. Some of the exercises specified the type of representation that students should seek. For instance, the first question asked students to find a table of values representing a function, and a table of values representing a non-function. Mrs. Rogers asked students to provide explanations for each of their choices and also to write equations for graphical representations of lines.

The purpose of this assignment, according to Mrs. Rogers, was to help students review for the exam, encourage students to use their textbooks as a study resource, and to reinforce instructional objectives such as:

- Identify linear functions and linear equations (Burger et al., 2012a,b, p. 230).
- Relate a constant rate of change to the slope of a line (Burger et al., 2012a,b, p. 244).
- Write a linear equation in slope-intercept form (Burger et al., 2012a,b, p. 268).

The nature of the assignment required that students use their textbooks during class. In this respect, textbook use during this class period was teacher-directed. However, because the assignment was open-ended, students were at liberty to attend to textbook features and pages of their own choosing. Although the assignment required selecting examples, no definition was provided with regards to what constituted an example.

Sabrina and Holly recorded this activity on head-mounted cameras and participated in stimulated recall interviews shortly thereafter. The integration of the textbook into this assignment provided opportunities to observe how these two students used their textbooks independently and to what portions of the textbook the students attended. Their activity is summarized in Table 4.4.

Table 4.4

Student Activity Profiles for Sabrina and Holly

	Sabrina	Holly
Subject	Sabrina, Grade 7	Holly, Grade 7
Rules	The teacher requires textbook use for this assignment. Students individually choose what to attend to in their textbooks. No definition of "example" is provided.	
		Holly does not complete the exercises in this assignment in numerical order.
Community	Algebra 1 classroom. Sabrina interacts with her tablemate, Maggie, and Mrs. Rogers.	Algebra 1 classroom. Holly interacts with her tablemate, June, two students at an adjacent table, and Mrs. Rogers.
Division of labor/management	Students work independently throughout the lesson. Mrs. Rogers circulates the classroom and answers individual students' questions.	
Tool/artifact	Printed textbook: Chapter 4 lessons, student exercises, and Study Guide Review	Print textbook: Student exercises and Study Guide Review for Chapter 4. Lesson 4-3 examples.
Object	Textbook use is focused completing a teacher-constructed worksheet that requires students to identify examples from the textbook, write linear equations, and explain why selected examples illustrate the characteristic in question.	
Outcome	Recognize functions and non-functions, linear and non-linear functions, increasing and decreasing linear functions, horizontal and vertical lines from graphs and tables of values. Write equations of lines from graphs.	

Sabrina. Sabrina, Grade 7, participated in an initial task-based interview and wore a head-mounted camera four times during the study. However, of the three days on which Sabrina wore a camera, she only used her textbook during one class. She participated in a stimulated recall interview on November 14, reflecting on her textbook use earlier that same day. While Sabrina was invited to participate in a follow up interview, she declined to do so because of numerous extracurricular obligations. During most of the study, Sabrina was seated at a table next to Maggie. Their interactions during the recorded lesson were minimal, limited to a couple of questions confirming one another's responses to items on the worksheet.

Review of video data indicated that Sabrina quickly identified appropriate textbook examples from the corresponding lessons for the types of functions or situations required of worksheet tasks. Sabrina explained that she used titles to help her select and identify textbook examples.

> I: How did you know which example to choose for that one. How did you choose which one was appropriate?
>
> S: In the book, very handy, above their examples they'll tell you let's find the linear equation, let's find a linear function, or just a function, or intercepts or whatever that we're on. And so that helped a lot.
>
> I: So like the titles? Is that what you're referring to?
>
> S: Mm hm. Yeah so that helped a lot. And then I also knew like what notes we were in. So that helped so I looked in that area, yeah.
>
> I: Did you consider any other examples before you chose that one or…
>
> S: Yes, I looked through all the examples trying to find the one that would best suit it, which I thought would suit pretty good. And I thought I had to pick two so I picked two of those, I think.

As Sabrina proceeded with the assignment, she began to identify student exercises as examples for some of the questions. Neither the worksheet nor the textbook provided a description of what would constitute an example; thus, students relied on their own interpretations, which varied from what the textbook labeled as examples. In the textbook, examples were part of the body of the lesson and were often accompanied by explanatory text, figures, or tables. Textbook examples included a question or problem, the solution, and some explanation or demonstration of how that solution was obtained. Sabrina explained what constituted an example from her perspective:

> I: How do you distinguish an example in your book? Tell me what constitutes an example for you.
>
> S: When it kind of has, it has um there's a graph or an equation or a table and it gives like an example or it gives some wording um down there and then um and then also it's, it like it really keeps you step by step and also it shows what the answer is and so you know, ok, you can mark out this part and then you can check your answer.
>
> I: Ok, do you feel like that was the case with these?
>
> S: Yes.
>
> I: I mean, did they give you enough worked out? Did you know what the answer was before you chose those?
>
> S: Yes, because of the, like, because of up there and you could tell like, they'll tell you like this is a negative slope and this isn't even like a linear function. It isn't even a function and you have like all that help up there and it even gives you like the next page, or like the last page you read, it gives you this whole bunch of examples and like you go to the page you're working on and it gives you, you don't have to flip back and forth, and it's a little cheat sheet right there.
>
> I: On this page, I wonder if you could point to me which part of it is the cheat sheet for you.
>
> S: Like up here, more.
>
> I: Ok. The Guided Practice part where it refers to the examples. Ok. Alright, let's look at the next one.

Although Sabrina described something similar to what the textbook identified as an example, she explained that student exercises from the 'Guided Practice' portion of a lesson were examples because they referred to in-text examples. She also mentioned that examples should be 'step-by-step,' a term she had used in the initial interview, as well, to indicate what she found helpful about the textbook. What she described in the stimulated recall interview suggests that Sabrina may have understood how to use the in-text examples as resources for solving 'Guided Practice' problems, but she did not clearly distinguish between exercises and examples.

Holly. Holly, Grade 7, wore a head camera during four different lessons throughout the study, recording at least some textbook use in three of the class sessions. Holly participated in a stimulated recall interview focused on her textbook use on the last lesson from Chapter 4. Holly's table partner was June.

Throughout the review activity, Holly repeatedly identified student exercises as examples for certain types of functions or relations. In fact, for nearly all of the questions, she looked only at student exercises and did not refer to the body of the lessons, which included solved examples and explanations. What constituted an example for Holly seemed to differ from what the textbook presented as examples.

> I: For you what is it that makes an example? How do you define an example that's appropriate?
>
> H: If I was to define an example it would be something that shows you how to do a certain thing in math, particularly for math.
>
> I: Ok. So in this case do you feel like those were the best examples for what you were looking for?
>
> H: Yes.

I: Did you look at others or did you just go with the first ones you came up with?

H: I did see some others but those seemed like the best ones I could find.

Although Holly did not distinguish between textbook examples and textbook exercises during this lesson, she did imply a distinction when discussing how she used the textbook to prepare for tests.

I: Do you use your book quite a bit to review for the test?

H: Yes.

I: Tell me a little bit about how you use your book when you're reviewing- what you do.

H: Um in this I just do the review problems and then I'll go back and look at the examples.

Holly's out-of-class textbook use influenced how she used the textbook during this assignment in class. For one question, Holly spent over a minute flipping pages in what appeared to be a disorganized fashion. Upon further investigation during the interview, Holly revealed that she was actually using section numbers in the review section of Chapter 4 to help her locate a specific example she recalled from the night before. This instance was the only time during this assignment that she identified a textbook example rather than a student exercise.

I: That's ok, I wouldn't expect you to remember that off the top of your head, certainly! So you were doing a lot of flipping through and as you were looking at the review pages you spent a lot of time there. What was it you were looking for there?

H: I was looking for the unit number so I could go back in to the right section of the book.

I: I see. Ok so you weren't really looking at the problems in the review, you were just looking for where you could go?

H: Yes.

I: I see. See I couldn't tell that just by watching so that's why I interview, that's good to know. And you said throughout all of that you had one particular example in mind that you remembered.

H: Yeah.

I: Did you remember that example from class or from when you had used the book before?

H: I remember it from when I had used the book before.

I: Was it when you had used it like to do homework or tell me a little more about that.

H: The night before we were doing a review assignment and I was looking for um a certain graph like that and I remember finding that one so I was trying to go back and find it.

Holly demonstrated and reported familiarity with some features of her textbook and apparently used her textbook, independently, as a resource to prepare for Algebra tests. In the stimulated recall interview, she revealed that her use of the textbook limited to reviewing content from the lessons and exercises within the chapter, and that she disregards the supplemental material in the back of the textbook, including the answers to odd-numbered exercises and the glossary.

I: Are there things in your book now that you feel like you don't use and you don't need?

H: I don't use much in the back of the book.

I: Do you use the answers in the back, the odd answers? Do you ever check with them?

H: Um not usually. Definitely not like the glossary or anything.

While working on the review assignment in class, two peers who sat at an adjacent table asked Holly for assistance with writing equations of the lines for some of the examples they had identified. Holly's interactions with other students were in response to others as she guided them through interpreting information from the textbook in order to write equations of lines. However, Holly also revealed a misconception that went unchallenged throughout the lesson. She mistook slope for the equation of a line, explaining to her classmates how to use the slope formula but stopping short of actually writing an equation for the lines in question. Holly used her textbook effectively to meet the object of the given worksheet, but this did not help her to better meet one of the intended outcomes, to write equations of linear functions from graphs. Had Holly selected completed textbook examples which provided this information rather than student exercises, she may have correctly recorded the equations of given linear functions. Copying that information may or may not have challenged the misconception she demonstrated between finding slope and writing linear equations.

At the end of the observed portion of this class, Holly used the textbook as a source of student exercises as she worked with neighboring peers to solve problems at the whiteboard. In preparation for the test that took place during the second half of class, Holly selected and read aloud textbook problems as three or four other students solved these problems on the whiteboard. This in-class use of the textbook was spontaneous and student-initiated.

Comparison of Sabrina and Holly's print textbook use.

This lesson provided unique opportunities to better observe and understand how students used their textbooks. One of the key findings during this lesson was the ambiguity both Sabrina and Holly expressed in distinguishing between textbook examples and student exercises. Although both of their descriptions corresponded with what would be called 'examples' in the textbook, their responses to the assigned task made no distinction between the exercises and examples.

Sabrina and Holly differed in terms of their engagement with the classroom community as they used their textbooks. Sabrina worked independently throughout most of the activity, occasionally asking Mrs. Rogers and Maggie questions to confirm her answers. Holly also completed much of the assignment independently but assisted neighboring classmates to find slopes of lines, although she mistook this for finding the equations of those lines. Holly's interactions with peers were more frequent and she engaged with peers at the end of class in student-initiated review using the textbook as a source of problems to prepare for the test. In terms of outcomes, Sabrina correctly responded to all questions on the assignment, whereas Holly's erroneously wrote slopes of lines instead of equations.

Print textbook use among students in Class A

Data from eleven class periods, three initial interviews, 28 student head-camera recordings, ten stimulated recall interviews, two follow up interviews, and student work provided an overall image of printed textbook use among students in this class. Across students and lessons, students tended to use only a small subset of what was available in the textbook, almost always using the textbook as directed by Mrs. Rogers, and often working collaboratively while using the textbook as a source for homework exercises.

Printed textbook use outside of class. Initial task-based interviews were intended to reveal insights about how students use their mathematics textbooks outside of class. However, these interviews revealed little rich data, instead indicating that students engaged in very limited textbook use out of the classroom. All three students from Class A who participated in initial interviews stated that they only used their textbooks outside of class for doing homework. Maggie stated, "I've never used it [the printed textbook] for anything other than homework." When asked whether they felt they used their textbooks to their full potential outside of class, two of the three students stated that they did, with Sabrina admitting that she could use her printed mathematics textbook more for reading content to study and prepare for class. Rather than textbooks, students claimed to consult their notes struggling with mathematics exercises outside of class.

Use of print textbook features. Students tended to use or attend to a small number of the available features within their textbooks. During the five observed lessons in which the textbooks were used during class, only two features were used by all students in all lessons: 'Guided Practice' (see Figure 4.3) and 'Practice and Problem Solving'. These two sections of each lesson included student exercises and all of the homework assignments in this chapter were taken from these two sections of the book. The second most used feature of the textbook was the 'Lesson and Examples' section which comprised the body of each lesson. In two lessons, all, or nearly all, students referred to the 'Lesson and Examples' portion of the text. In one class, Mrs. Rogers directed all students to look at specific examples in the body of Lesson 4-1 (see Figure 4.1). In the final observed lesson, the teacher-generated worksheet required students to use their textbooks to find examples, but some students did not distinguish between exercises and examples, attending mostly to student exercises. Other textbook features that students used were the included the 'Study Guide Review' from which Mrs. Rogers assigned homework and the Appendix that included answers to odd numbered exercises. Only two students were observed using the Appendix to check homework answers, although it is possible that other students could have done so during class.

When asked about the textbook features they used most often (both in and outside of class), students overwhelmingly referred to the homework problems and examples. Three students also indicated that they used the glossary and index in the back of the textbook and one student mentioned 'Skills Practice' in the back of the textbook.

All the interviewed students indicated positive perceptions of their textbook but there were three features that students specifically identified as not helpful. One student claimed to ignore all marginal notes, calling them 'confusing'. Another student said that she tends to ignore the pictures in the textbook. A third student claimed to never use features in the 'back of the book' such as the glossary.

Some of the textbook features were never observed or mentioned during observations or interviews. For example, no student used or mentioned the assessment tools that were interspersed throughout the book, including a pre-chapter skills quiz, a mid-chapter test, 'are you ready' questions, and test preparation sections at the end of the chapter. Other features not mentioned were activities and labs that Mrs. Rogers did not discuss in class. Mrs. Rogers skipped Lesson 4-4: Direct Variation, and three activities/labs that were located in between textbook lessons. Accordingly, students did not mention the skipped lesson and features within Chapter 4.

Teacher-directed print textbook use. As all students' activity profiles indicate, observed textbook use across all lessons was overwhelmingly teacher-directed. That is, when students used their textbooks it was generally because Mrs. Rogers had instructed them to do so either explicitly or by assigning student exercises from their textbook to be solved during class. Throughout the study, there was no observed instance in which students decided to open or refer to their textbooks on their own accord. In fact, although many students were observed to refer to the Lesson and Examples sections within Chapter 4, only one student, June, independently chose to refer to a textbook example to help her understand how to solve a problem from the homework assignment in the textbook.

Observed and self-reported student textbook use corresponded with the features of the textbook that Mrs. Rogers directed students to use. For the most part, students did not explore what was in their textbook beyond what they had learned to access from Mrs. Rogers. One exception was June who was observed and reported using various features of her textbook. It is important to note that June's history of textbook use was also exceptional in that she had completed Prealgebra in fifth grade via independent study with a textbook as the primary tool. Although, Sydney had the same experience the previous year, she did not use or report using many textbook features in the current year.

Student perceptions of printed textbooks. In interviews, students in Class A indicated mostly positive perceptions of their printed textbooks. For the first month of the school year, the class reviewed content from the previous year using the school's prior Algebra 1 textbooks, published in 1998. When students commented about their new Houghton Mifflin Harcourt Algebra 1 textbooks (Burger et al., 2012a), they were pleased to have new textbooks, with three students noting that the old books were in poor repair. Words and phrases that students used to characterize the printed textbook included: “convenient,” “a good resource,” and “very helpful.” Negative opinions of the textbook included its size and weight, cluttered pages, and vague instructions to student exercises. However, the students who voiced these criticisms also conveyed favorable perceptions of the printed textbook. As students’ in- and out-of-class printed textbook use was limited, most students viewed the textbook primarily as a source for homework exercises.

Print textbook use and the classroom community. The extent to which students engaged with the classroom community while using their textbooks varied greatly among students. The physical arrangement of the classroom and typical classroom routines provided ample opportunities for students to interact with a table partner and students at adjacent tables. In addition, Mrs. Rogers routinely circulated throughout the classroom to monitor students’ work and respond to student questions as they worked from the textbook. As the student activity profiles and descriptions indicate, all but one student interacted with Mrs. Rogers during episodes of textbook use. While a majority of students interacted with peers during textbook use, the nature and extent of these interactions varied from off-task social conversations to discussions among small groups of students to arrive at consensus about responses to questions.

Observed in-class textbook use and interview data regarding textbook use outside of class indicated that students tend to use the portions of the textbook that Mrs. Rogers models in class or requires for homework. Although there was some variation among the textbook features students tended to use, all students perceived the textbook primarily as a source for homework exercises and used student exercises most often. The extent to which print textbook use involved peer interaction was the aspect of use that varied the most among students.

Student Use of Digital Algebra Textbooks

As noted in table 3.2, five students in Class B recorded their textbook use on head-mounted cameras during four or more of the eleven class periods that comprised instruction for Chapter 4. One or more students captured textbook use in seven of the eleven class periods, although two of the class periods included less than 10 minutes of student textbook use at the conclusion of class. This section focuses on student textbook use during two of these lessons. I focus on these two lessons because four of the Class B students who participated in stimulated recall interviews, elaborated on video clips they recorded during one of these two class periods. Results include analysis of these video clips and transcripts of corresponding stimulated recall interviews, with supporting data from whole class video, teacher interviews, student work, and field notes.

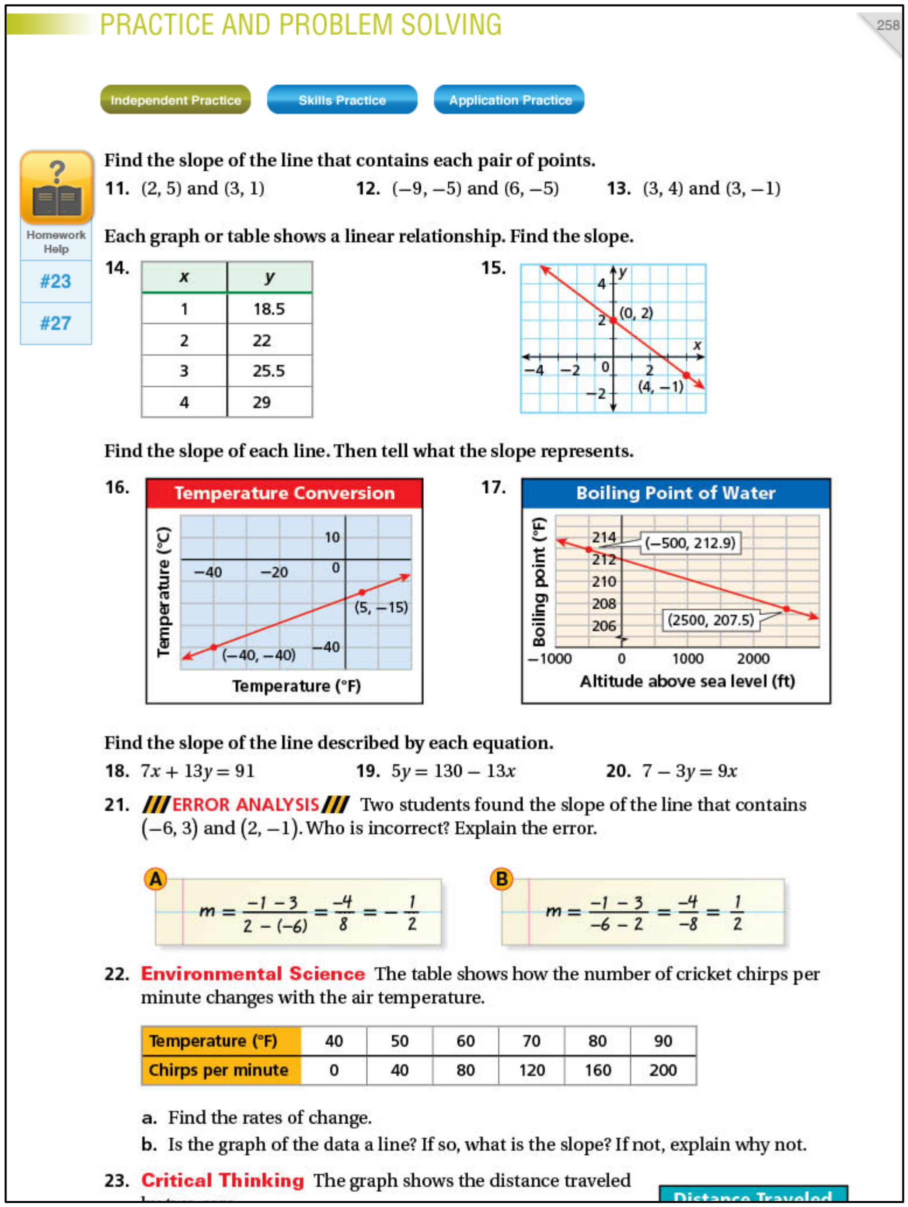
For each class period, I provide a general description of that day's lesson, instructional objectives, tasks, assignments, and how Mrs. Rogers used the digital textbook during instruction. This information is reflected in the table of student activity profiles for each lesson. Structured according to the seven elements of activity theory, these profiles characterize how individual students used their digital Algebra textbooks during the lesson. Activity profiles are followed by more in depth description of how individual students used their digital textbooks, including details from stimulated recall interviews and other supporting data sources.

Digital textbook use during a lesson focused on the slope formula

The lesson about slope formula took place during a 90-minute block period comprised of review, instruction over new material, and independent practice. At the beginning of class, Mrs. Rogers led the class in checking and reviewing homework responses from the previous night's assignment over Lesson 4-3. She focused on exercises that students identified as troublesome, re-teaching as needed. Textbook use was restricted to accessing the exercises; Mrs. Rogers explained solutions verbally or demonstrated solutions on the whiteboard.

New material during this class period focused on textbook Lesson 4-4: The Slope Formula. Although Mrs. Rogers typically provided students with printed notes pages, for this lesson she asked that students take notes on their own paper as she delivered direct instruction. She did not explicitly refer to the textbook during this segment of the lesson. During the last twenty minutes of class, students worked independently or with table partners to complete a homework assignment from the 'Practice and Problem Solving' tab of Lesson 4-4. Figure 4.4 shows a portion of the 'Practice and Problem Solving' tab for Lesson 4-4 in the digital textbook. The lesson objective, appeared in the textbook as follows:

- Find slope by using the slope formula.



PRACTICE AND PROBLEM SOLVING 258

Independent Practice | Skills Practice | Application Practice

Homework Help #23 #27

Find the slope of the line that contains each pair of points.

11. (2, 5) and (3, 1) **12.** (−9, −5) and (6, −5) **13.** (3, 4) and (3, −1)

Each graph or table shows a linear relationship. Find the slope.

14.

x	y
1	18.5
2	22
3	25.5
4	29

15.

Find the slope of each line. Then tell what the slope represents.

16.

17.

Find the slope of the line described by each equation.

18. $7x + 13y = 91$ **19.** $5y = 130 - 13x$ **20.** $7 - 3y = 9x$

21. ERROR ANALYSIS Two students found the slope of the line that contains (−6, 3) and (2, −1). Who is incorrect? Explain the error.

A $m = \frac{-1-3}{2-(-6)} = \frac{-4}{8} = -\frac{1}{2}$

B $m = \frac{-1-3}{-6-2} = \frac{-4}{-8} = \frac{1}{2}$

22. **Environmental Science** The table shows how the number of cricket chirps per minute changes with the air temperature.

Temperature (°F)	40	50	60	70	80	90
Chirps per minute	0	40	80	120	160	200

a. Find the rates of change.

b. Is the graph of the data a line? If so, what is the slope? If not, explain why not.

23. **Critical Thinking** The graph shows the distance traveled

Figure 4.4. Practice and Problem Solving tab for Lesson 4-4 (Burger et al., 2012b)

As students worked on the assignment from the digital textbook, Mrs. Rogers circulated throughout the classroom and showed individual students the ‘Check Answers’ button in the digital textbook (see Figure 3.8). With this feature, they can access answers to odd numbered exercises in the ‘Practice and Problem Solving’ tabs of each lesson. Mrs. Rogers asked that students use this feature to check their responses to the day’s homework exercises.

Two students participated in stimulated recall interviews regarding this block class period. Activity profiles in Table 4.5 summarize how each of these three students used their textbooks during the lesson focused on the slope formula.

Table 4.5

Student Activity Profiles for Blake and Robyn

	Blake	Robyn
Subject	Blake, Grade 8	Robyn, Grade 8
Rules	Mrs. Rogers leads the whole class in checking the previous night's assignment from the textbook. The textbook is not explicitly referenced during direct instruction. Homework exercises are assigned from the textbook and students are given time in class to work on these exercises.	
Community	Algebra 1 class	
	Works alone. Mrs. Rogers shows him how to use the Check Answers button.	Volunteers responses during whole class instruction. Shares digital textbook with peer at adjacent table during instruction. Works alone. Mrs. Rogers shows her how to use Check Answers button and answers a question.
Division of labor/management	Classroom instruction is teacher-centered and textbook use is teacher directed during independent practice. At the beginning of class and during homework time at the end, students could work independently or with neighboring classmates.	
Tool/artifact	Digital textbook on iPad: 4-4 Practice and Problem Solving, Check Answers button in 4-4, Graphing calculator app	Digital textbook on iPad: Emailed screen image of 4-3 Practice and Problem Solving, 4-4 Practice and Problem Solving, Check Answers button in 4-4, Calculator app
Object	Textbook use is directed at checking and solving student exercises. Student exercises require applying algorithms and interpreting graphical representations.	
Outcome	Find slope by using the slope formula.	

Blake. Blake, Grade 8, recorded six class periods during the unit on a head-mounted camera. During four of those lessons, Blake captured his textbook. He participated in a stimulated recall interview focused on one of these lessons. Blake also participated in both an initial task-based interview and a follow-up interview. Throughout this study, Bill sat alone at a table, although he occasionally partnered with Wesley who sat alone at an adjacent table.

Video data and interview responses indicated that Bill looked to his digital Algebra textbook primarily as a source for accessing homework problems. Throughout the study, he rarely captured video of himself using any features other than the 'Practice and Problem Solving' student exercise tab at the end of each section. In one instance, Blake scrolled through multiple pages as if he was looking for something specific, but in the stimulated recall interview, he revealed that he accesses page numbers in the digital textbook not by typing in the number, but rather by scrolling through pages until he finds what he sought.

I: Ok, in that clip, you can't hear it very well, but usually the sound isn't that big of a deal. Tell me what you saw.

B: Well I was look at um, I was doing math problems and some people were talking so I looked at them. And that's pretty much it. I was just shuffling through the Algebra CC app.

I: Ok and when you were shuffling through, what specifically were you looking for at that point?

B: I was looking for a different problems because I had moved past one stage of the assignment and I was going to the next page.

I: Now when you look for the problems that you're working on do you look by page number, do you look by section, how do you find what you're looking for in your book?

B: I usually just flip. I don't go to like the index and type in a number.

I: Ok. Do you pay attention to the page number or is it like the section number or the topic or which one of those things lets you know that you're where you need to be?

B: Usually it's just the page number because Mrs. Rogers she puts the page numbers of the assignment on the board.

In interviews, Mrs. Rogers indicated that she particularly liked the tab layout of the digital textbook, which seemed to better highlight the different features of each textbook lesson. Yet, in the case of Blake, these tabs did not help him to access textbook content any more efficiently than a traditional print book.

The other digital textbook feature that Blake used during this lesson was the 'Check Answers' button embedded within 'Practice and Problem Solving.' When pressed, this button brought up a frame on the screen, which showed the answers to odd numbered exercises (see Figure 3.8). This feature is similar to the Appendix in the printed textbook but accessible on the same screen instead of turning to the back of the book. During this particular class period, Mrs. Rogers circulated throughout the classroom to individually demonstrate the Check Answers button and encourage students to use this textbook feature to check their own homework responses.

Prior to this, Blake reported that he did not know the 'Check Answers' feature existed in the digital textbook and that, although he had known about the feature in previous printed mathematics books, he had rarely used it. In this class period, Blake finished his homework assignment and began to turn it in when he remembered to check his odd answers. Blake was confident he would continue to use the feature in the future.

> I: So it looks like that feature came back up again, that she had shown you earlier in the lesson. Is that something she asked you to do or did you decide to check them or how did that work?
>
> B: Well she told us that we could check our answers for the odd problems when we finished our homework. And I was about to turn them in after I checked them and that's why it was kind of why I was zooming out the camera.
>
> I: So it looks like you did check them and everything was…
>
> B: Yeah I had checked them and was about ready to turn them in.
>
> I: Ok, do you see yourself using that feature more in the future to check your answer. Is that something that…
>
> B: Yeah, definitely. For homework assignments just because I don't want to get a bad grade or anything.
>
> I: Sure, so to what extent do you think it's a convenient way to use it?
>
> B: Yeah, it's convenient. It's easy to find.

Throughout this instance of textbook use, Blake worked alone, interacting with Mrs. Rogers only when she explained the 'Check Answers' feature to him. Blake typically worked independently from the book, although he did often volunteer responses during whole class discussion and socialize with other students when appropriate. The community aspect was minimal in Blake's classroom textbook use.

Blake's in-class textbook use was limited to accessing and checking homework exercises. During the stimulated recall interview, he described other textbook features he tended to use, mainly examples and the table of contents. When asked whether he had ever accessed any of the video or interactive features in the digital textbook, Blake was unaware of some of the features and reported having never watched the instructional videos that accompany each example in the digital textbook. Notably, he indicated that he had consulted videos for other classes but that he did not feel a need to access the Algebra digital textbook videos because of he understood the content.

> B: Um, I don’t really watch the videos to be honest.
>
> I: Why do you think that is?
>
> B: Probably because I already understand the problems pretty well. And I don’t really struggle greatly in class.
>
> I: Let’s say you did come to something that you didn’t quite understand as well as you do with the material right now, is that something you think would be helpful for you in that situation?
>
> B: Yeah definitely because whenever I don’t understand something I’ll always look to examples and sometimes print examples aren’t enough so I go to videos.
>
> I: Have you gone to videos before, not necessarily in this book, but just in general to help you understand things?
>
> B: Yeah, I have gone to videos.

Robyn. Robyn, Grade 8, participated in an initial and follow up interview. During the study, she wore a head mounted camera during five class periods, capturing her textbook use in three of these lessons. Robyn participated in a stimulated recall interview focused on her recorded textbook use one day prior. Throughout this study, Robyn’s table partner was Derek.

Like her classmates, Robyn primarily used her digital textbook to access homework exercises in class. At the beginning of class, Robyn’s iPad screen showed pages from her textbook as she checked the previous night’s homework but the screen appeared different from the textbook. Robyn explained that she had a technical difficulty with the digital textbook and worked with a friend to overcome the difficulty using the iPad camera and email.

> R: Ok, that was when we were going over our homework and I was just looking at the graph to figure out what we did for the homework, to kind of check it.
>
> I: Ok. So I want to ask a couple things about that. One, your screen is different on your iPad. You've got like your email over to the side and then the page. Tell me a little bit about that.
>
> R: Oh! Ok, I didn't have my homework downloaded so I asked my friend to take a screenshot and so she emailed me the screenshot of the homework page on the textbook, so that was really nice because if we had actual textbooks that's really hard to do that. So she just took a screen shot and emailed it to me and so I was using that, I was on my email, using that picture to look up our homework.
>
> I: Did that work effectively for you in that situation?
>
> R: Yeah, it worked perfect.

As Robyn used her textbook to access homework problems, she also used the digital format on the iPad as an assistive device. The capability to enlarge text and images in the digital textbook allowed Robyn to compensate for her visual difficulty. Robyn noted that she did not wear glasses but sometimes had trouble seeing, especially on screens.

> I: Very good, and I also noticed that as you were working on that problem you enlarged it. Why did you do that? How is that helpful?
>
> R: Mm hm. Um we had to count the squares and find the rise and the run and it's kind of hard to do on something that's electronic because it's a screen and I kind of have trouble seeing, counting, because on my homework I miscounted and so I make it bigger so I could see fully without it getting kind of blurry.

Robyn also used the iPad calculator application while working on homework exercises from her digital textbook. Although the calculator and digital textbook were both contained on the same device, the digital textbook did not contain an embedded calculator. Thus, students had to exit their textbook page to access the calculator in a separate application. Robyn felt it might be easier to use the calculator in conjunction with a print textbook rather than toggle between apps.

> R: Sometimes I need to quickly look up a problem. Yeah, it would be cool if there was a calculator on the online textbook already there for you.
>
> I: So do you find it helpful since your book is on your ipad and your calculator is on your iPad, that you can navigate between those or do you think it's any different than if you had a print book and a calculator separately? What do you think?
>
> R: I think it might almost be easier to have a textbook and the calculator because you can have the calculator put up the whole time and use a textbook and that I have to click through to back from the textbook to the calculator, but also it's easier because I have everything on one thing. But it would probably be easier to use the calculator with a textbook.

It was during this lesson that Mrs. Rogers showed students how to access answers to odd numbered exercises using the 'Check Answers' button in the 'Practice and Problem Solving' tab. During the stimulated recall interview, Robyn recalled this and said that she found it useful to have the button embedded with the exercises. She reported using the corresponding feature in printed textbooks but prior to this class, Robyn did not know the 'Check Answers' feature was available in the digital textbook.

Robyn was the first student to describe using a digital textbook feature that Mrs. Rogers had not explicitly shown to students. In the stimulated recall interview, she reported some independent exploration of the digital textbook and had discovered the on-screen examples that could be accessed to accompany student exercises in the 'Guided Practice' tab (see Figure 3.7). While she knew these 'popup' examples existed, she did not associate them with only 'Guided Practice' problems and tried, unsuccessfully, to find this feature while working a on 'Practice and Problem Solving' exercise during class.

> R: Oh, in this video I was trying to find one of the examples I was telling you about and I was looking to see if the answers for the odd, it showed you how to do the problem but it didn't and since I couldn't find an example I think I ended up looking at my notes or I just figured it out.
>
> I: Ok, that's what I was curious about because I saw you scrolling back and forth and you pulled up the exercises and I just, I can see what you're doing but I can't always tell why you're doing it so that's a great explanation and that's very helpful to me. When you say the examples, I'm curious, that's what you were looking for where it shows you how to do them, are they, were they something that you linked to within the homework?
>
> R: They were, you kind of clicked on it, like it's above the problem where the numbers are, you kind of like, what section it is and it's a little button and it says examples and you click on it and it kind of pops up an example and you can close it and go back to the problem.

Comparison of Blake and Robyn's digital textbook use. Both Blake and Robyn reported positive perceptions of their digital textbooks and used them as Mrs. Rogers directed during this class. In addition, Robyn demonstrated self-initiated use of the digital textbook and iPad features, as well as awareness of features that she had discovered on her own. Neither Blake nor Robyn interacted with peers as they used their textbooks during class, and their individual interactions with Mrs. Rogers were limited to demonstrations about the 'Check Answers' feature of the digital textbook. In this lesson, both students used the digital textbook to successfully complete the assignment.

Digital textbook use during a review lesson

On the class period before the Chapter 4 exam, Mrs. Rogers led the class in checking the homework from the day before, focusing on 4-6: Slope Intercept Form.

No new content was covered during this class. Rather, students were given sufficient time in class to complete a review assignment from the end of Chapter 4. Mrs. Rogers selected exercises from the 'Study Guide: Review' and students used their digital textbooks to access these problems.

The instructional objectives that were addressed in these exercises included:

- Identify linear functions and linear equations.
- Find *x*- and *y*-intercepts and interpret their meanings in real-world situations.
- Use *x*- and *y*-intercepts to graph lines.
- Find rates of change and slopes.
- Relate a constant rate of change to the slope of a line.
- Find slope by using the slope formula.
- Write a linear equation in slope-intercept form.
- Graph a line using slope-intercept form (Burger et al., 2012a,b).

Table 4.6

Student activity profiles for Piper and Wesley

	Piper	Wesley
Subject	Piper, Grade 8	Wesley, Grade 8
Rules	Mrs. Rogers leads the whole class in checking the previous night’s assignment from the textbook. Review exercises are assigned from the textbook and students are expected to work on these exercises during class.	
Community	Algebra 1 class	
	Works with alone and with table partner Asks Mrs. Rogers a question	Works alone Asks Mrs. Rogers a question Briefly speaks with peer
Division of labor/management	Classroom instruction is teacher-centered and textbook use is teacher directed. Students write solutions on the board, but Mrs. Rogers explains these solutions. In the last portion of class, students could work independently or with neighboring classmates.	
Tool/artifact	Digital textbook: 4-6 Practice and Problem Solving; CH 4 Study Guide: Review; iPad calculator app	Digital textbook: CH 4 Study Guide: Review
Object	Textbook use is directed at student review exercises that require applying algorithms and interpreting graphical representations.	
Outcome	Objectives from textbook Lessons 4-1, 4-2, 4-3, 4-4, and 4-6	

Piper. Piper, Grade 8, was the only consenting student in Class B who did not participate in an initial or follow up interview, only because she consented to participate after the study had begun. Piper wore a head mounted camera six times, capturing her classroom textbook use in three classes. She participated in a stimulated recall interview on the last day of the study. Throughout the entire study, Piper sat at a table with a female student who did not consent to participate in this study.

During this class, students were expected to use their digital textbooks to access homework exercises. Accordingly, Piper's head-mounted video recording indicated that her use of the textbook was limited to accessing the 'Practice and Problem Solving' tab. The stimulated recall interview revealed that, although Piper demonstrated limited textbook use during class, she was aware of some of the other features the digital textbook offered.

> I: Do you remember how you used your book in class yesterday?
>
> P: Um, we just like read the questions on there and did the answers on the paper.
>
> I: Is that pretty typical of how you use your book in that class do you think?
>
> P: Mm hm. Usually. Sometimes if I need help I'll use like the examples. I don't think I did that yesterday though.

One of the digital textbook features Piper described was the 'Guided Practice' tab and linked examples. Mrs. Rogers did not tell students about this textbook feature, but Piper was aware that some digital textbook problems allowed the student to press an embedded button to reveal a corresponding example on the same screen (see Figure 3.7). Piper also knew that this feature was available in the 'Guided Practice' tab, demonstrating her understanding of how the digital textbook lessons were organized.

> P: I don't remember but I don't think that one, that one didn't have the things where we could like pull it up and like let it show you how to do it and um yeah I think those were like the ones at the very end of the chapter that were supposed to be like practice problems but so I don't think that I had

any other way. I didn't really think about going back and trying to figure it out.

I: I'm curious when you said it didn't have the thing where you can pull up how to do it. Tell me a little bit more about what you're talking about there.

P: Well like for each question they'd have like a little button and it'd say see example and it'd have a little button and you could pull it up and then it could show you an example of like the question but maybe with different numbers or something else to like jog your memory because I know with like this and with that question I learn so much and so sometimes I just need her to like, oh yeah, and show me like how to do it again because I usually forget.

I: So when you are able to pull up those examples, do you find that helpful? Is that something that you've used some?

P: Oh yeah. Definitely I like that a lot.

I: Ok. Do you remember what part of your book that's in?

P: I think it's in like there's three things at the top and it's in guided practice, I think guided practice has it and I think in the one before but I don't know what the one before was called.

I: Ok. Have you used all three of those parts for each of the sections?

P: I think we've used, in homework, we've used different ones.

Many of the students in this study expressed a preference for examples that provided step-by-step procedures and explanations for problems similar to what they were expected to do in homework. The digital textbook included a feature that allowed students to swipe the screen to show examples in a step-by-step manner, revealing steps at a pace determined by the student (see Figure 3.4). Of the five students who had access to this feature, Piper was the only student who expressed awareness of this feature. Piper's familiarity with digital textbook features not mentioned in class suggested that she had explored her digital textbook independently, outside of the classroom.

P: I like the iPad textbook and I would want it to have a calculator in it. That would be really nice. It'd be really cool-I do like the videos. I didn't ever get a chance to use the videos but the videos would be really cool. Like a teacher talking to you like in a video that would be really nice. Um what else would be cool? Um I like how um the examples it's step-by-step and you can control it. I really like that.

I: What do you mean you can control it?

P: Well like it shows you one step and then you can scroll and it shows you another step.

I: Oh, within the digital book?

P: Yeah. I like that.

I: Is that something you've used at home? I haven't seen you use it in class.

P: Yeah I've used it.

I: Have you? Maybe I just didn't capture it.

P: Yeah but I do use the slide down. I don't remember-I don't remember ever using it in class but I do use it at home.

In addition to the digital textbook features Piper described or used during class, she employed some features of the iPad to support her textbook use during class. Piper used the iPad calculator app, saying that she liked having the calculator and textbook on one device but that she would prefer if the digital textbook had an embedded calculator tool to avoid toggling between apps. Piper also used the assistive capability of the iPad to enlarge text and images on her iPad screen.

I: Are there other features on the iPad besides the book, that you find yourself switching around from the book, like are there other apps you go to besides the calculator.

P: Um, I don't think so. Not in math. Not with the book.

I: I notice in this clip that you zoomed in on some of the exercises. How helpful is that feature for you?

P: I like it a lot because technically I'm supposed to wear glasses but I always forget them and I never wear them. It's I can see like the lines better and stuff by zooming in.

In this particular lesson, students worked on homework exercises from the 'Study Guide: Review' section for Chapter 4. For each lesson in Chapter 4, this section presents one or two examples on the left side of the page and a sampling of student exercises to the right. This feature (included in both print and digital format), shown in Figure 4.5, provides an overview of the chapter and practice exercises for students. While Piper indicated familiarity with many of the features in the digital textbook, she was less familiar with this feature. She did not refer to the examples during class and revealed in the interview that she did not even notice the examples to the right of the problems on which she was working.

I: Ok. I wonder in here next to the exercises there were examples.

P: Oh.

I: Did you use those at all or did you notice them?

P: I don't know. I probably didn't even know they were there.

During the class, Piper's iPad battery died and she had to share an iPad with her table partner for the remainder of the class. Piper frequently interacted with her table partner during class but in this instance, sharing an iPad required her to use the digital textbook in association with a peer. She described that while she liked working together with a partner, she preferred to have her own textbook rather than sharing an iPad.

I: So do you prefer-when you're working from your book in this class-do you prefer to work independently out of your book or would you rather work with a partner out of your books? I mean not necessarily sharing a book but…

P: Yeah, um, I like working with partners, like talking to partners but I kind of wish I would have my own book.

I: You mean like here where you were sharing the book?

P: Yeah. Like have my own book because it's kind of hard but yeah, I do like working with partners.

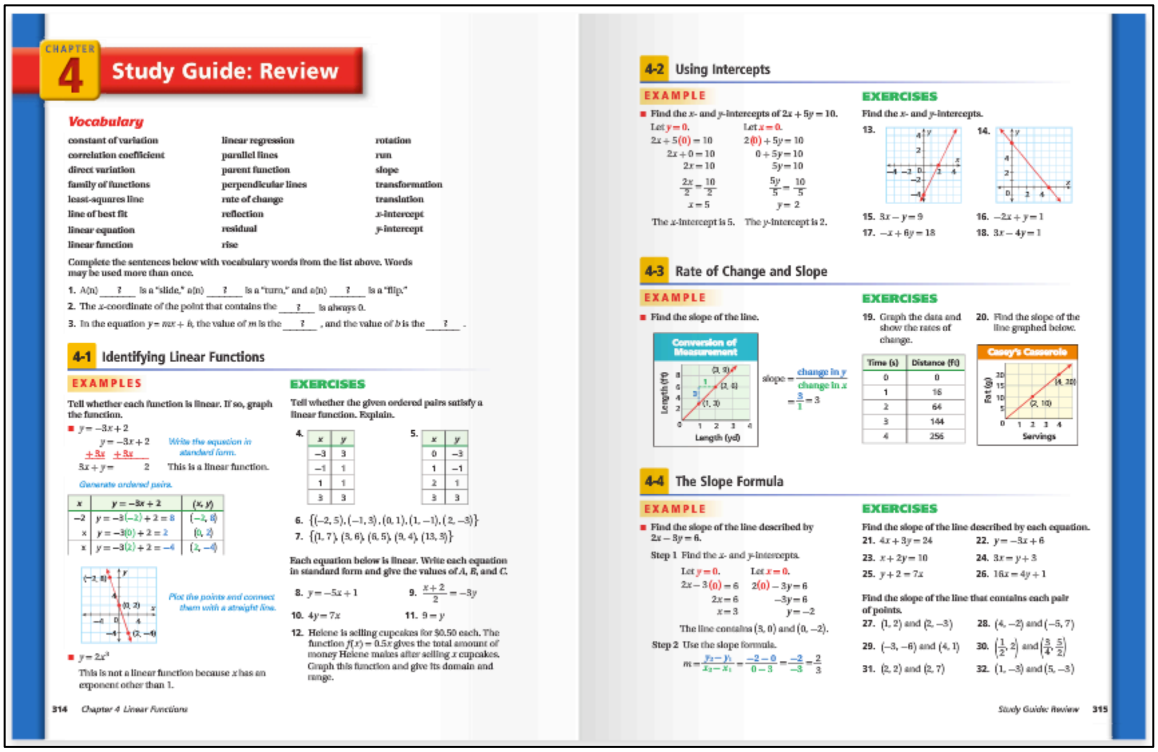


Figure 4.5. Study Guide: Review as presented in the print and digital textbooks (Burger et al., 2012a,b).

Wesley. Wesley, Grade 8, participated in an initial task-based interview and a follow up interview. During the study, he wore a head mounted camera four times, capturing textbook use in three of these lessons. Wesley participated in a stimulated recall interview on the last day of this study, focusing on his textbook use in class the previous day. Wesley sat alone at a table and occasionally partnered with Blake who sat at an adjacent table.

Wesley's classroom textbook use was limited to accessing homework problems from the digital textbook. While working on student exercises from the Study Guide: Review section toward the end of Chapter 4, Wesley disregarded the corresponding examples that were located to the right of the exercises.

I: Do you know specifically what you were looking at on that page? Does anything…

W: A problem.

I: Just the problem itself?

W: Yeah, whenever I pause I just like think about the problem in my head first and then I do it.

I: So I wonder with what you were working on yesterday there were examples to the side and then the exercises. How helpful were those examples?

W: I didn't look at them.

I: Did you know they were there?

W: No.

Throughout the stimulated recall interview, Wesley mentioned looking at problems in his textbook and doing them 'in his head'. Although he was aware of the 'Check Answers' feature in the digital textbook, he chose not to use the feature, instead reportedly checking his answers by "redoing the question[s] in [his] head to see if [he] got the same answer."

I: I'll pause there. It looks like you have the iPad down in your lap so we can't see the screen at all. Why did Mrs. Rogers bring your paper back to you?

W: To check your answers.

I: All right. And how do you check your answers in the book?

W: I just look at the answer and just like redo the question in my head.

I: Ok, so do you look up answers within the book itself?

W: No.

I: Do you know how to?

W: No.

I: Ok.

W: Wait, isn't there like you scroll down and there's like an answer section or something?

I: There is.

W: I think she showed me that one time but I forgot where.

I: So were you using that as you were doing this?

W: No.

I: Were you checking your answers or doing other stuff?

W: No I was checking my answers.

I: Ok, but you weren't really using your book to check your answers, is that right?

W: No. I was looking at the question and then I was redoing the question in my head and to see if I got the same answer.

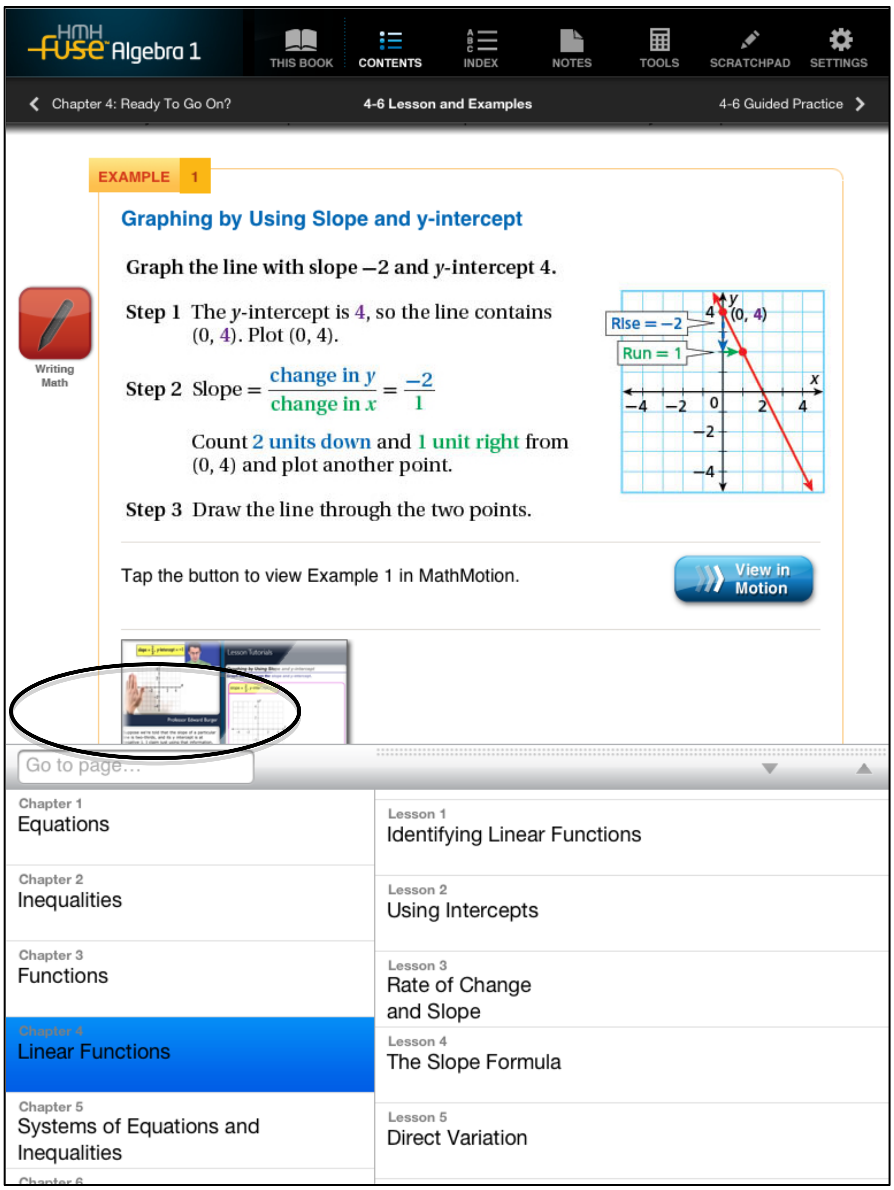


Figure 4.6. On-screen Contents menu (Burger et al., 2012b)

The stimulated recall interview revealed that Wesley was unaware of many of the features in his textbook. When navigating within his digital textbook, Wesley relied on scrolling through pages to find the correct page number. He claimed that he knew no other way to locate material in the digital textbook. However, the digital textbook did offer other options, allowing users to type in a page number or choose lessons from the table of contents at the touch of a button (see Figure 4.6). It appears that Wesley had not independently explored the digital textbook. While he liked the idea of some of the interactive features in the textbook, he did not know those features were available in his digital textbook.

> I: What about things like videos, or animations, or where you can put in an answer directly in to the book and it checks it, things like that you can do with digital books. Any of those appeal to you? Do you think you'd use anything?
>
> W: That would be cool, yeah.
>
> I: So you think you'd use those if they were there?
>
> W: Mm hm.
>
> I: Do you know if your book now has any of those?
>
> W: No, I don't know.
>
> I: You don't know, or it doesn't?
>
> W: I don't know if it does or not.
>
> I: Ok. So have you messed around with your book very much or just looking at the problems?
>
> W: Just looking at the problems.

Comparison of Piper and Wesley's digital textbook use. Piper and Wesley's textbook use during class was similar but stimulated recall interviews indicated major differences in their awareness of what their digital textbook offered. Whereas Piper searched for and claimed to use a number of digital textbook features, Wesley was unaware of many features and even chose not to use one of the features Mrs. Rogers had demonstrated to students.

Both Piper and Wesley chose to work independently throughout much of the independent practice, with each asking Mrs. Rogers one question. At the beginning of class, both Wesley and Piper volunteered to write their responses to previous textbook homework questions on the board. In general, Piper tended to interact frequently with her tablemate, a female who did not participate in the study. However, Wesley did not tend to engage with peers most of the time.

Digital textbook use among students in Class B

The multiple data sources summarized in Table 3.2 helped form a picture of how digital textbook use compared across students and lessons in Class B. The digital textbook use described in the two previous lessons was fairly typical of most class periods. While all students used only a small portion of their digital textbooks features during class, awareness of the digital textbook's features varied among students. Most of the in-class use was teacher-directed, but students varied in terms of their exploration of the digital textbooks outside of class. There was little variation among students in the community aspect of digital textbooks, with students working independently from their textbooks most of the time.

Digital textbook use outside of class. The four students from Class B who participated in initial task-based interviews indicated that their out-of-class textbook use was limited to accessing assigned homework exercises. When asked what resources they would use if struggling with a textbook problem, two students said that they could use their book but generally do not. Students reported using the following resources to assist with mathematics outside of the classroom:

- Notes (*n = 3)*
- Email or ask the teacher or a peer (*n = 3*)
- Textbook (*n=2*)
- Internet resources (*n = 1*)
- Parent (*n = 1*)

All four students indicated that they could use their digital textbooks more effectively, noting that the digital mathematics textbook was still fairly new and unfamiliar.

Use of digital textbook features. Only two textbook features were used across four or more lessons and by all students: Guided Practice and Practice and Problem Solving. In classes where digital textbook use was observed, students used their books to access homework exercises and all but two assignments were from these two tabs in the digital book. In the print textbook, 'Guided Practice' and 'Practice and Problem Solving' were continuously numbered exercises and students did not seem to distinguish between these two sections. However, in the digital textbook, students could not simply scroll down the page through all student exercises because 'Guided Practice' was on a separate tab from 'Practice and Problem Solving,' and each tab included different digital supports, as shown in Figure 4.7.

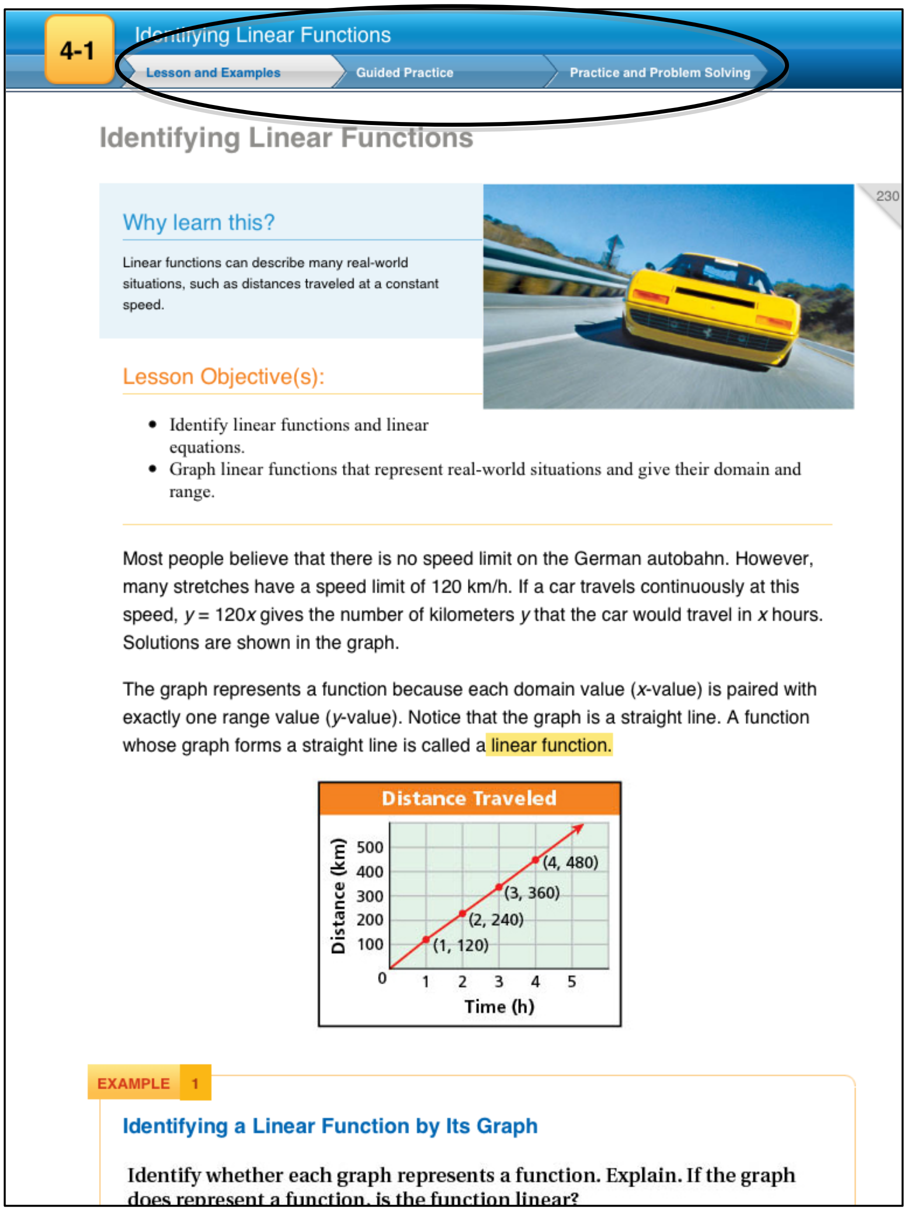


Figure 4.7. Layout of digital textbook page with tabs circled (Burger et al., 2012b).

Within the ‘Guided Practice’ tab in the digital textbook, students could access corresponding examples for reference while solving problems (see Figure 3.7). Of the five students interviewed, only two students were aware of this feature and the feature was observed in class only one time. The digital textbook provided links to additional practice, homework hints, and answers to odd numbered exercises under the ‘Practice and Problem Solving’ tab. Because Mrs., Rogers explicitly showed students the feature, all students knew about the 'Check Answers' button at the end of these exercises (see Figure 3.8). Only three of five students actually used this feature during class. Links to 'Skills Practice,' 'Applications Practice', and 'Homework Help' remained unnoticed to all students throughout the study.

In the digital textbook, the body of each lesson was contained under the 'Lesson and Examples' tab. Here, students could find explanatory text and examples, videos to accompany examples (see Figure 3.5), a 'View in Motion' feature that revealed steps of problems as students swiped their finger down the screen (see Figure 3.4), 'Check it Out' exercises which provided instant feedback for multiple choice responses (see Figure 3.6), marginal notes buttons, and graphing tool buttons (see Figure 3.9). Student use of most of these features was not observed during Chapter 4. Other than an assignment that required students to locate examples within the textbook, none of the students recorded themselves using any features under the 'Lesson and Examples' tab of Chapter 4.

Initial, stimulated recall, and follow up interviews indicated that use outside of class was also minimal. Four of the five students knew the digital textbook included videos but no student reported ever viewing one of these videos. Only one student discovered the 'View in Motion' feature. When asked to 'give me a tour' of their digital textbooks at the conclusion of the study, not a single student was familiar with embedded graphing tools, marginal buttons, or self-assessment tools.

Students demonstrated varying degrees of proficiency with navigating in the textbook. Two of the five students relied on scrolling from page to page in order to locate page numbers for assignments. The other three students regularly accessed the 'Contents' feature, which allowed them to type in page numbers or navigate the book by pressing on the lesson number (see Figure 4.6). In follow up interviews, three of the five students were able to easily access the glossary and index but did not report using it. All students were unaware of the mathematical tools accessible from the Tools tab on the onscreen toolbar.

Overall, students did not use or report using many of the features in the digital textbook. One student, Wesley, reported that he had attempted to type notes using the digital textbook 'Notes' tab, but that he found the printed notes easier to use. What might be considered the most 'interactive' features were among the least utilized. These included graphing tools, videos, 'View in Motion', and embedded multiple choice assessment items. Some students exhibited more curiosity about their digital textbook than others and were at least aware that such features existed. There was little variation among students in terms of the digital textbook features they used during class, but out-of-class use seemed to differ more.

Teacher-directed digital textbook use. Mrs. Rogers was aware of most of the digital textbook features but choose to direct students toward using only a few of these features. Just as she did in the print classroom, Mrs. Rogers assigned homework from the student exercises at the end of each textbook lesson; thus, directing students to attend to these portions of the digital textbook. In addition to viewing student exercises, Mrs. Rogers also introduced students to the 'Check Answers' button at the end of lessons. Early in Chapter 4 she also showed students how to efficiently find page numbers by typing in the number rather than scrolling. It is not surprising that nearly all observed digital textbook use involved the features that Mrs. Rogers had directed students to use. She did not make use of the embedded clicker system during the study.

Student perceptions of digital textbooks. Throughout the initial, stimulated recall, and follow up interviews, students in Class B voiced positive perceptions about their digital mathematics textbooks. Two students indicated that the digital textbooks could potentially distract some students, but noted that the book did not distract them, personally. In spite of some early technical difficulties with downloading chapters and occasional dead iPad batteries, all students indicated that they liked the digital textbook for its convenience. Although all four students reported frequently taking their previous printed textbook home, they indicated that they rarely forgot their iPad and could access their digital textbook at anytime, even when they had additional time in other classes. Students also liked that the digital textbooks were lightweight, as opposed to large, heavy printed textbooks. Students did not voice strong opinions about the lessons or features in the digital textbook, perhaps as a result of their limited textbook use.

Digital textbook use and the classroom community. Students in Class B frequently contributed to whole-class discussion and responded aloud to Mrs. Rogers' questions during direct instruction. They also tended to socialize with one another during breaks or at the end of class. Yet, in spite of these frequent interactions and indications that the students were not averse to interacting with one another, rarely did students engage with the classroom community as they used their digital textbooks. Students only occasionally asked each other questions about homework problems or digital textbook features. These students did not frequently ask Mrs. Rogers for assistance while using their digital textbooks, either. With few exceptions, when students used their digital textbooks, they did so silently and independently.

Two instances of students interacting with peers involved technical difficulties with the digital textbook. Robyn relied on a peer to send her screen shots of an assignment she had not yet downloaded. Also, when Piper's iPad battery died in the middle of an assignment, she and her table partner immediately began to share one iPad, but Piper later reported she preferred not having to share a digital textbook with her partner.

Overall, students in Class B enjoyed using their digital textbooks, but use was mostly teacher-directed and limited to static features that could be found in the corresponding print textbook. Students in the study varied with regard to their awareness of various textbook features, indicating that some students had explored their textbook outside of class, even though they did not frequently use the features they found. None of the students in the study reported using some of the most interactive digital textbook features such as video, embedded assessment, and mathematical tools. Furthermore, although students used their digital textbooks in a networked environment that could have allowed for collaboration and communication, students tended to use their textbooks in isolation from their peers and did not frequently communicate with Mrs. Rogers while using their textbooks.

Comparison of print and digital textbook use in Algebra

Student print textbook use resembled digital textbook use in many respects throughout this study. In both classes, there was considerable variation among individuals, particularly with regards to the features used and community aspect of activity. That is to say, there is no generalized activity profile of textbook use for all students in either class. Comparison of textbook use between the print and digital classes acknowledges that individual differences and exceptions existed; yet, there were discernible similarities and differences between the two classes in terms of how students tended to use their textbooks.

Similarities between print and digital textbook use

Nature of student textbook use. In terms of class time, students in the print class tended to use their textbooks approximately as much as students in the digital classroom. During the eleven class periods that comprised Chapter 4, students in the print classroom used their textbooks on five days and students in the digital classroom used their textbooks in seven periods, as summarized in Table 3.2. However, the print class spent a greater portion of the first three class periods using their textbooks in class while some students in the digital classroom experienced minor technical difficulties with downloading chapters, thereby limiting use. Once all students in Class B had successfully downloaded Chapter 4 of the digital textbook, they briefly used the textbook at the end of two additional class periods, on days when students in the print class did not use their textbooks.

During Chapter 4, Mrs. Rogers tended to coordinate lesson plans between the two sections, in terms of content and pacing. Typically, she allotted the last fifteen to twenty minutes of class for students to work on homework assignments from the print and digital textbooks. On block period days, students often received additional time at the end of class, as well as time at the beginning of the period to review assignments either individually or as a whole class. In only a few instances did students use their print or digital textbooks outside of these allotted times, and these instances were brief. Thus, in the context of these two classrooms, in-class textbook use could also be referred to as in-class opportunities to check or work on assignments from the book.

Teacher role in student textbook use. The teacher played an important role in how students used both print and digital textbooks. As every student's activity profile indicates, in-class textbook use was generally teacher-directed. That is, no student independently opened his or her print or digital textbook when Mrs. Rogers did not request that students do so, either by explicitly referring them to their book or assigning homework exercises from the textbook.

Furthermore, observational and video data indicate that students used the print and digital textbook features to which Mrs. Rogers directed their attention. In interviews, nearly all students in both classes expressed a perception of their textbook primarily as a source for homework problems. In the print and digital versions of the textbook, students focused their textbook use on accessing assigned problems form the textbook. With some noted exceptions in each class, the features that tended to be used by most students were the features that Mrs. Rogers modeled or asked students to use. In the print classroom, this included specific examples to which she referred during direct instruction. In the digital classroom, this included the 'Check Answers' feature and page number entry on the table of contents tab.

There was no discernible tendency by students in either class to explore or initiate textbook use on their own. This was true for both observed textbook use within the classroom and student reported textbook use outside of the classroom. There existed exceptions in both classrooms, but no strong indication that students in one class were more or less likely to independently explore the textbook.

Minimal textbook use by students. Students used only a small proportion of the available content and features in both the print and digital textbooks. This may simply be a function of the degree to which student use reflected teacher use, but much of what each textbook offered remained unnoticed and unused throughout this study. Essentially, if Mrs. Rogers did not ask students to use particular print or digital textbook features, they did not.

The context of this study is atypical of most Algebra 1 classrooms. All students in the private school take Algebra 1 in middle school. The class included no students with identified special needs, and behavior problems are rare. Students in both classes encountered few difficulties with the mathematical content in Chapter 4. Yet, when students did experience minor trouble with homework exercises during class, their first line of defense was the teacher rather than the content and features within the textbook. In fact, only one student in the print class immediately and independently sought assistance from textbook examples to overcome difficulty with a homework exercise. Students in both classes reportedly referred to examples as resources outside of class, but data in this study does not establish the extent to which this actually occurred.

When asked to describe the type of textbook support they found helpful, eight of ten students interviewed in the print classroom and four of five students in the digital classroom voiced a preference for textbook examples that explained how to carry out algebraic procedures with step-by-step instructions. During initial task-based interviews, students from both the print and digital classrooms struggled to effectively identify and use textbook examples that did, in fact, provide the step-by-step support students reportedly desired. One student in the print classroom described an inability to view individual steps, even when they were labeled, instead getting confused and overwhelmed by the presentation of the completed example. Difficulty with parsing individual steps within completed examples may help to explain why most students did not refer to the types of examples they reportedly desired from their textbooks.

The digital textbook included a 'View in Motion' feature that allowed students to view individual steps of every exercise. With this feature, students could swipe the screen and reveal steps and explanations for each example, at their own pace. Although this feature addressed what students claimed to want from examples in their textbook, no student used this feature during class and only one student even knew this feature was available in the digital textbook.

Although nearly all of the students in both classes used their print and digital textbooks to successfully meet the objectives in the classrooms, both the print and digital textbooks were underutilized in terms of accessing available content and utilizing features that students claimed to find helpful.

Differences between digital and print textbook use

Classroom interactions and textbook use. Individual students' activity profiles indicated variation among students in terms of how they engaged within the classroom community while using their print textbooks. However, there was less variation among students using digital textbooks. The print classroom contained nineteen students whereas the digital classroom included only eight. Class size could have contributed to the overall perception of classroom interactions, but video data indicated that students in the digital classroom were not just quieter; they rarely spoke at all while using their textbooks.

The physical arrangement of the classroom provided students with ample opportunities to quietly work with a table partner or students at neighboring table (see Appendices A and B). In the print classroom, some students often chose to work with a partner or peers, discussing problems and confirming or challenging one another's responses. Other students in the same class preferred to work independently. When asked what resources they would consult for assistance with a difficult problem in the book, many of the students identified peers or Mrs. Rogers as their primary resources (as compared to textbooks). This preference was apparent during observations as students frequently asked table partners and Mrs. Rogers for assistance as they worked on problems in the textbook.

There were fewer students in the digital class seated at fewer tables, but the proximity of the students to one another still made the classroom conducive to collaboration among students. Rarely did students in the digital textbook classroom interact with one another while using their textbooks. These students were generally friendly to one another and frequently volunteered responses during whole class instruction. Yet, when students used their books to work on homework, the classroom was nearly silent. Not only did students choose not to work with other students, they tended not to ask Mrs. Rogers questions as often as did students in the print textbook classroom.

Use of print and digital textbook features. While both classrooms tended to use student exercises from their textbook, there existed some variation between the two classes in terms of the other textbook features they used or reported using. This was likely due, in part, to the differences between the print and digital versions of the textbook.

Beyond student exercises, students used their print textbooks primarily to view examples within the body of the textbook and check answers to odd-numbered exercises. Whereas only two students in the print class checked odd-numbered exercises, three of the five students used the digital textbook feature to check odd-numbered answers. As noted earlier, Mrs. Rogers showed students how to use this feature in their digital textbooks but did direct students in the other class to use the back of their textbooks to check answers.

The digital textbook medium allowed students to use their textbooks differently from the print textbook. Whereas no students referred to the table of contents to locate material in their print textbooks, three of five students frequently accessed pages using the 'Contents' tab and search bar in the digital textbook. Additionally, two students were able to use the zoom feature of the digital textbook to enlarge text they could not see well. The printed textbook offered no corresponding feature to assist students with visual impairments or difficulties.

Digital preferences

Students in both the print and digital classrooms possessed more prior experience with print textbooks than digital textbooks. This perspective was evident in multiple ways. For example, when students in both classes were asked to describe what they wanted from their Algebra textbook, students initially assumed that 'textbook' referred to a printed textbook. Another indicator of the prevalence of the printed textbook conventions was the use of page numbers. When one considers using web pages on the Internet, rarely are pages identified by number. Yet, the digital Algebra textbook included page numbers that corresponded with the pages of the print textbook. Throughout the study, Mrs. Rogers and her students continued to access and reference content in the digital textbook by page number rather than lesson number or tab.

Students in both classes understood the nature of this study and, from the school's perspective, they were participating in a trial to see whether the school would use print or digital textbooks in the future. Knowing this, students in both classes offered their opinions and preferences for print and digital textbooks. Overwhelmingly, students in both classes expressed a preference for digital textbooks. Among students who used print textbooks, two of ten students indicated a strong preference for print textbooks, with the other eight students expressing positive attitudes toward using digital textbooks. All of the students who used digital textbooks viewed the books favorably. One student, Blake, initially preferred printed textbooks, but by the end of the study he indicated that he liked the digital textbook. Students in both the print and digital classes suggested that digital textbooks might create distractions for some students, but none of the students who used the digital textbooks indicated that the textbook was distracting for them.

Since there were more similarities than differences between use of the two textbook formats, why did students tend to prefer digital textbooks? Across the board, digital textbook preferences were attributed to convenience and ergonomics rather than features, quality, or mathematical content. All students in both classes carried school-owned iPads with them daily. Students liked that as long as they had their iPads with them, which they usually did, they would have their digital textbooks. This allowed students to access their textbooks during other classes or at home without having to remember to bring their Algebra textbook with them. Students also complained about the weight of the print textbook and saw digital textbooks as a lighter alternative to heavy backpacks filled with printed textbooks.

Summary

Overall, results of the study indicated that although activity varied among individual students, there were a number of similarities among students in each class, allowing for meaningful comparison of print and digital textbook use in the two classes. In both classes, students used only limited portions of the textbook, most often using the textbooks as sources for homework exercises. Furthermore, textbook use tended to be teacher-directed, with limited student exploration of textbook features among students in either class. Students in both classes reported favorable perceptions of their print and digital textbooks, but the majority of students in both classrooms voiced preferences for digital textbooks.

A notable difference between students' printed textbook use in Class A and digital textbook use in Class B, pertained to the community element of activity theory. Whereas students in Class A tended to collaborate with peers and pose questions to Mrs. Rogers while using their printed textbooks, students in Class B most often used their digital textbooks in isolation from the classroom community.

Although the digital textbooks offered several interactive features with the potential to encourage multiple mathematical representations, networked communication, instant feedback, and instructional support for students, digital textbook use focused primarily on completing and verifying procedural homework exercises, both in and outside of the classroom. In fact, the teacher and students did not use the most interactive features of the digital textbook, such as videos, embedded self-assessments, a classroom clicker system, and dynamic function graphing tools. The following chapter discusses the implications of these findings.

V. Discussion and Recommendations

U.S. Secretary of Education, Arne Duncan, has encouraged schools to transition to digital textbooks, and 22 states have already undertaken initiatives to support district-adoption of digital instructional materials (Fletcher, Schaffhauser, & Levin, 2012). This move toward digital textbooks comes at a time when curriculum developers are revising products to align with the *Common Core State Standards for Mathematics*, portable wireless devices are increasingly available and affordable, high-speed digital infrastructure is expanding, and many states and school districts are experiencing budget constraints. This perfect storm provides an opportunity to consider new forms of mathematics textbooks – those delivered digitally, commonly described as 'innovative', 'motivating', and 'engaging' for students.

An underlying assumption of the 'innovative' view is that digital mathematics textbooks will provide new opportunities for student learning and that they will be used by teachers and students in productive ways to improve student learning. Yet, the nature of students' use of mathematics textbooks–print or digital–is not well understood. A number of studies in mathematics education have documented and described the complex relationship between teachers and curriculum materials (see for instance, Remillard, 2005; Herbel-Eisenmann, Lubienski, & Id-Deen, 2006; Sherin & Drake, 2009), suggesting that similarly rich relationships may exist between students and their mathematics textbooks. Research also indicates that the incorporation of various technologies in mathematics teaching and learning can bring about rich learning opportunities for students (See for instance, Kaput & Roschelle, 1997; Schwartz, 1999). Digital textbooks allow for the integration of mathematics curriculum with technology tools, potentially transforming how students experience the K-12 mathematics curriculum. Studies that seek to understand how students use both printed and digital mathematics textbooks are timely and relevant to teachers, curriculum developers, education researchers, and district leaders.

Purpose of Study

The purpose of this study is to investigate student use of print and digital mathematics textbooks in two Algebra 1 classrooms (one using print textbooks and the other using the digital format of the same textbook) taught by the same teacher. The specific research questions sought to describe student use of each textbook medium and compare use between the two media specific to the content of an Algebra 1 class. Thus, the overarching research question included a number of sub-questions.

Main Research Question: What is the nature of students' use of mathematics textbooks?

1. How do students in an Algebra 1 class use their printed textbooks?
2. How do students in an Algebra 1 class use their digital textbooks?
3. How does student use of digital textbooks compare with student use of printed textbooks in two Algebra 1 classes taught by the same teacher?

Method

Using an instrumental case study design (Stake, 1997; Creswell, 2007), the study employed a variety of qualitative methods to investigate student use of print and digital textbooks. Both of Mrs. Rogers' Algebra 1 classes at Morrison Day School were provided new textbooks, with one class receiving new print textbooks published by Houghton Mifflin Harcourt (Burger et al., 2012a) and the other class receiving the digital version of the same textbook (Burger et al., 2012b). Throughout a four-week period, students' textbook use was observed and recorded daily during an instructional unit focused on Linear Functions. A variety of student and teacher interviews also contributed to the overall characterization of student print and digital textbook use.

During each day of classroom instruction, three students in each classroom recorded their experience and use of the textbook via head-mounted video cameras. Head-mounted cameras rotated among all consenting students in each classroom. Whole class video recordings and observational field notes also documented the observed class periods. Ten students from the printed textbook classroom, Class A, and five students from the digital textbook classroom, Class B, participated in stimulated recall interviews in which they viewed and elaborated on video clips they recorded in previous class periods. In addition, four students from each class were randomly selected for initial and follow-up interviews. Of those selected, three students in Class A participated in initial interviews and two in follow up interviews. All four students in Class B participated in both initial and follow-up interviews. The teacher, Mrs. Rogers, was interviewed prior to the study and twice during the study. Table 5.1 summarizes the data sources for the study.

Table 5.1

Summary of Data Sources
(Shaded columns indicate classes during which textbooks were not used.)

	Initial Interview	10/29	10/30	10/31*	11/2	11/5	11/6	11/7*	11/9	11/12	11/13	11/14*	Stimulated Recall Interview	Follow up Interview
Print Class		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		
Field notes		x	x	x	x	x	x	x	x	x	x	x		
Sabrina	x					x			x		x	x	11/14	
Ariel						x				x				
Farrah						x				x		x		
Chelsea		x					x						11/7	
Maggie	x	x					x						11/13	x
June		x					x						11/7	
Lindsay			x										10/31	
Holly			x					x		x		x	11/15	
Ellen			x										10/31	
Evalyn				x									11/5	
Mason					x									
Sydney				x							x		11/5	
Chase					x				x		x			
Miles	x			x									11/6	x
Lin					x			x						
Digital class		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		
Field notes		x	x	x		x	x	x	x	x	x	x		
Blake	x	x	x	x			x	x		x			11/12	x
Wesley	x	x		x	x						x		11/14	x
Piper			x	x		x			x		x	x	11/14	
Robyn	x	x			x			x	x			x	11/9	x
Drake	x	x	x		x	x	x		x	x		x	11/13	x
Mrs. Rogers	x				x				x					x

The two formats of the textbook in this study were commercially published by the Houghton Mifflin Harcourt company, but one classroom of students had access to a digitally enhanced and enabled version for iPad via the HMH FUSE: Algebra 1 Common Core app. The digital textbook included a number of features not available in print, and digitally presented features common to both media. During the study, both classrooms focused on lessons from Chapter 4, Linear Functions. Lessons in both textbooks included three segments: Lesson and Examples, Guided Practice, and Practice and Problem Solving. The digital textbook organized the lesson by tabs at the top of the screen. In the digital textbook, students could access features such as the glossary, answers to odd-numbered exercises, marginal notes, and corresponding examples using embedded buttons. Although these features were also available in the printed textbook, the digital textbook differed in terms of how the features were accessed. Interactive features of the digital textbook included dynamic graphing tools, embedded videos, a 'Video in Motion' feature that revealed step-by-step worked out examples, and multiple choice assessment items that provided immediate feedback. These interactive features were not available via the printed version of the textbooks.

Activity theory guided the study and provided a structure for analyzing data. Interviews and video clips were openly coded and then codes were categorized according to the seven elements of activity theory: subject, rules, community, division of labor/management, tool/artifact, object, and outcomes. Activity profiles presented classroom activity related to textbook use for each of the fifteen students who participated in stimulated recall interviews. Each activity profile focused on student activity during one lesson on which the student elaborated during the stimulated recall interview. Data from initial and follow up interviews provided insight as to how students used their textbooks outside the classroom and how students perceived the value and features of their textbook.

Results

The results of the study are presented in relation to the three research questions, all focusing on the overarching question: *What is the nature of students' use of mathematics textbooks?*

Research question 1: How do students in an Algebra 1 class use their printed textbooks?

Student-directed print textbook use inside and outside of class. Both in and outside of class, most students used their textbooks primarily as a source for homework exercises and attended to only a small portion of what the printed textbook offers. In interviews, students claimed to take their textbooks home nearly every day to do homework. This out-of-class use was primarily limited to accessing homework exercises and few students reported regular use of other textbook features outside of the classroom.

Within the classroom, students varied with regard to their use of various print textbook features. All students used the 'Guided Practice' and 'Practice and Problem Solving' portions of the textbook in nearly every class in which textbook use was observed. Additionally, students referred to textbook examples when Mrs. Rogers explicitly directed them to do so during one lesson. Lesser-used features in class included referring to answers to odd-numbered exercises in the book appendix.

Teacher-directed print textbook use. The teacher played an important role in how students used their mathematics textbooks. Although not all students used the printed textbook in exactly the same manner, they generally attended to the portions of the textbook that Mrs. Rogers directed them to use or notice. That is, students were not observed independently exploring the textbook beyond what they were directed to use in class. The one exception was a gifted student who had previously learned Prealgebra content via independent study using her textbook as a primary resource.

Student perceptions of print textbooks. Students in the study expressed favorable opinions of their printed textbooks, but perceived the textbook as a source for homework problems more than a resource for learning or reviewing content. Negative comments about the textbook included reference to cluttered pages, vagueness of directions, and the size and weight of the textbook. Some students indicated that they would consult their textbook if they encountered difficulty with a mathematics exercise, but observational data suggested that in these instances they were more likely to consult with peers or ask the teacher for assistance.

Print textbook use and the classroom community. Students varied in terms of their engagement with the other classmates during printed textbook use. Whereas some students preferred to work independently from their book, other students frequently interacted with peers and asked Mrs. Rogers for assistance. The nature of students' interactions varied from purposeful and content-focused, to social conversation.

Research question 2: How do students in an Algebra 1 class use their digital textbooks?

Digital textbook use inside and outside of class. In interviews, students reported that they frequently used their digital textbook outside of class, but that use was limited to accessing homework problems that they completed with pencil and paper. Only half of the interviewed students indicated that they would access their textbook as a resource if they were struggling with a mathematics exercise, and all four students admitted that they could/should use their digital textbooks more effectively both in and outside of class. Two students in the study were familiar with digital textbook features not discussed in class, indicating that they had explored their digital textbooks outside of the classroom. The majority of students efficiently navigated within the digital textbook using the 'Contents' feature to search by page number.

Because students' digital textbook use most often focused on accessing homework exercises, many of the textbook features were not used. Of the three tabs in each lesson, students most often used the 'Practice and Problem Solving' tab or the 'Guided Practice' tab. Half of the students also used the embedded 'Check Answers' button to check answers to odd-numbered exercises. Two students were aware of links to examples within the 'Guided Practice' tab and only one student was aware of the 'View in Motion' feature that revealed sequential steps to example problems. Although all of the students in the study knew the 'Lessons and Examples' tab included videos, none of the students had viewed any of the videos.

In summary, the most interactive features in the digital textbook were the least utilized in the study. Students did not indicate awareness or use of graphing tools or embedded assessments, did not use embedded videos, and only one student was aware of the 'View in Motion' feature. For the most part, students did not not use the features of the digital textbook that were unique to this format (i.e., features that were not available in the printed format of the book).

Teacher-directed digital textbook use. The student activity profiles indicated that virtually all of the observed student use of the textbook was teacher-directed. Although Mrs. Rogers was familiar with most of the features offered in the digital textbook, she directed students to use only a small portion of these features. Students tended to use the digital textbook features that Mrs. Rogers showed them in class. These included the 'Guided Practice' and 'Practice and Problem Solving' tabs, 'Check Answers' button, and the 'Contents' tab that allowed students to navigate the textbook by typing page numbers instead of scrolling. Mrs. Rogers did not utilize the digital textbook's embedded clicker system and she did not ask students to view videos, complete embedded assessment items, or use graphing tools.

Student perceptions of digital textbooks. Students liked their digital textbooks because they were lightweight and, as long as they had their iPads with them, they had access to their textbook. Two students expressed concerns that digital textbooks might distract some students, but no student reported that they were distracted by the digital textbook format. Although students offered their opinions regarding print and digital textbook formats, students did not comment about how the features of their digital textbooks enhanced their learning of mathematics.

Digital textbooks and the classroom community. While using their digital textbook in class, students tended to work alone. The two observed instances of student interactions during use of digital textbook were the result of technical difficulties. In one instance, a student emailed screen shots of the textbook to a peer who had not yet downloaded the chapter, and the other instance occurred when a student's iPad battery lost power and she shared a digital textbook with her table partner. The digital textbooks did not appear to promote collaboration or discussion among students, and students rarely asked Mrs. Rogers for assistance while using their digital textbooks.

Research question 3: How does student use of digital textbooks compare with student use of printed textbooks in two Algebra 1 classes taught by the same teacher?

Similarities between print and digital textbook use.

Nature of student textbook use. Whether they were using the print or digital textbook format, students primarily engaged with their textbooks for the purpose of accessing homework exercises. Both the print and digital textbook classes spent comparable amounts of time using the textbook, suggesting that neither format engaged students more often than the other.

Teacher role related to student textbook use. In both classes, observed student textbook use was almost always teacher-directed. Students did not independently seek out their textbooks or explore content and features, regardless of whether they used the print or digital textbook format. Furthermore, students used the textbook features to which Mrs. Rogers directed their attention. In the print classroom, this was mostly limited to examples and exercises. In the digital classroom, this also included embedded 'Check Answers' buttons and the 'Contents' tab. Although the digital textbook provided students with a number of instructional supports not available in the printed format, students did not tend to use these features and relied on Mrs. Rogers' notes and classroom instruction just as students who used the printed textbook.

Minimal textbook use by students. Students utilized only a small proportion of the content and features in both the print and digital textbook format. Regardless of format, students did not often consult their textbook for assistance when struggling with an exercise. Some students in both classes reported using the examples in their textbooks outside of class, while other students did not refer to the textbook as a resource they would seek for assistance outside of the classroom. None of the participants in this study appeared to struggle with the content, and all reported that they felt they understood the mathematics in Chapter 4. Thus, students in this study did not often struggle with exercises and had little motive to seek assistance from the print or digital textbook.

Differences between digital and print textbook use.

Classroom interactions and textbook use. The most discernible difference in student textbook use between the two classes was engagement with the classroom community. There was variation among students in each class, but overall students tended to collaborate more in using printed textbooks and tended to work alone with the digital textbooks. Students using printed textbooks were also more apt to ask Mrs. Rogers for assistance with homework exercises from the textbook. Although the digital textbooks existed in a networked space with the potential to serve as collaborative or communicative devices, collaboration and communication was minimal among students who used digital textbooks in this study.

Digital textbooks on networked iPads provide the opportunity for "computer-supported collaborative learning" (Roschelle, 2003, p. 261), but the teacher and students did not leverage this opportunity, instead demonstrating less social participation than students who engaged with printed textbooks. For example, the clicker, an embedded feature of the digital textbook, was not used during observed lessons.

Use of print and digital textbook features. The digital textbook format allowed students to access the same content in a different manner from the printed textbook. Accordingly, students who used the digital textbook format referred to features such as the table of contents and answers to odd-numbered exercises more often than students using printed textbooks. The digital textbook also served as an assistive technology, allowing two students to zoom in on images and text they could not easily see.

Print and Digital textbook preferences. All but two students in both classes reported that they would like to use digital textbooks. The reasons for this preference had little to do with different presentation of content or features in the digital textbook format, but rather the convenience of the digital textbooks. Students conveyed that they were more likely to forget their textbook but rarely forgot their iPad. They also commented about the burdensome weight of printed textbooks and indicated that textbooks on iPads would not weigh down their backpacks.

In spite of the preference for digital textbooks, students were more accustomed to print textbooks. When using the digital textbook, both the teacher and students most often accessed content via page numbers rather than the tabs and links within the book. Features typical of print textbooks were most often noted when students were asked to describe what they expected from their Algebra textbook. When asked about features they would desire from an ideal Algebra 1 textbook, students using both the print and digital Algebra 1 textbooks initially assumed that the word ‘textbook’ referred to a printed book rather than a digital format.

Implications and Future Research

Implications

Results of this study imply that, whether in print or digital format, strategic and effective textbook use is neither automatic nor intuitive for all students. Students used both print and digital textbooks as they were expected and as their teacher directed. This places an onus on classroom teachers and those who prepare textbooks to help students develop the competencies necessary to effectively use the tools and resources at their disposal. As mathematics teachers in 45 states begin to implement Standards for Mathematical Practice in the *Common Core State Standards for Mathematics*, textbooks should not be overlooked when teaching students to “Use appropriate tools strategically” (CCSSI, 2010, p.5).

There existed an observable relationship between how the teacher used the textbook and how students used their textbook. Students’ textbook use reflected what the teacher asked of students and the features they used were most often those that they had seen or used in class. Although mathematics textbooks serve as resources for both teachers and students, teachers and students use these resources in different ways. Whereas textbooks can help teachers guide and pace instruction and even influence teachers' pedagogy (Herbel-Eisenmann, Lubienski, & Id-Deen, 2006), students may refer to their textbook for explanations of 'big ideas' of the course or 'underlying concepts' of problems, examples to explain material or help complete homework, or to highlight important equations and definitions (Weinberg et al., 2012). However, when students do not have compelling reasons to engage with mathematics via their textbooks, print or digital, the potential of rich mathematical tasks and explanation, interactive features, mathematical representations, or collaborative tools remains unrealized. In order to maximize the potential of innovative, classroom teachers must provide reason for students to not only use their textbooks, but also meaningfully engage with the mathematics represented in their textbooks for deeper learning experiences.

In this study, students referred to their textbook mostly to access homework and find examples to help complete that homework, supporting what Weinberg et al. (2012) found among undergraduate students. The manner in which students used their textbooks aligned with the object of their action (to complete procedural homework exercises) and also with how they were taught and expected to use the textbook. If teachers intend for their students to attend to interactive and exploratory features of digital textbooks, they will likely need to provide students with the motivation and purpose for doing so. Although it has been alleged that digital textbooks filled with videos and instructional supports might supplant the classroom teacher, this study found no evidence to support this claim. That is, students did not independently use most of the textbook features available to them, despite favorable opinions of both the print and digital textbooks. While students expressed preferences for digital textbooks, they did not engage with the content of the books on their own volition, as Tom Woodward suggested in the 2012 SETDA report (Fletcher, Schaffhausen, & Levin).

The digital textbook used in this study, HMH FUSE: Algebra 1 CC, included features such as video clips, assessments, interactive tools, and a classroom clicker system, features that have been described as motivating and engaging (Fletcher, Schaffhauser, & Levin, 2012). Yet, neither the teacher nor the students used these features and, therefore, is it not clear if they are, in fact, motivating or engaging. In this case, the digital textbook was new to both the teacher and students so that may have limited the extent to which the enhanced features were used. Also, students did not feel the need to use some features, because they did not struggle with the material. For instance, after listening to their teacher lecture and explain the slope formula, students appeared to grasp the content and therefore had little reason to watch a video of someone else lecturing and explaining the slope formula.

In addition, the work students were asked to do in the classroom was generally procedural in nature, matching the examples they were shown how to do by the teacher. For non-struggling learners, features that overlap with classroom instruction may be deemed superfluous. If, on the other hand, students had been challenged to solve problems or to apply the material to more complex situations, they may have been more compelled to use the digital textbook features at their disposal. This may also hold true for print textbooks, as students in both classes attended to only a small portion of the features and material available in their textbooks.

As district leaders consider transitioning to digital textbooks, it is important to consider not only the nature, range, and quality of interactive features in digital mathematics textbooks, but also the preparedness of teachers to use electronic curricular enhancements and the extent to which such features engage learners in mathematics study (Fletcher, Schaffhauser, & Levin, 2012). Teachers will likely require professional development focused on enacting new tools embedded in digital mathematics textbooks, as well as aligning instruction so as not to make digital textbook features redundant or of limited utility to students.

Future Research

The study of student use of print and digital textbooks was exploratory and considered questions not previously addressed in research literature. The results of the study provide a foundation for future research and raise of a number of potential questions for future consideration. Future research regarding student textbook use and digital textbooks should consider a variety of classroom environments, across multiple mathematics topics, over an extended period of time, and with more robust mathematics textbooks (e.g., a wider range of features that might be unique to a particular format). Additionally, future studies should be designed to minimize some of the limitations of this study, particularly allowing for comparison of textbook use related to the same lesson.

Few students in the study struggled with the mathematical content of the lessons. Future research should consider how students who struggle use their mathematics textbooks as a learning resource or how student of various abilities use their textbook in situations where they are challenged by the content. This is particularly salient for digital mathematics textbooks that provide interactive features to support students in a variety of ways.

Rather than restricting study to a single unit or topic, studies are needed that consider how students use mathematics textbooks across the mathematics curriculum, since students may use their textbooks in different ways for different topics. It is also be important to investigate how students use their digital mathematics textbooks as they become more accustomed to the new medium and its features.

Presently, most of the available digital textbooks were developed from commercially published printed mathematics textbooks. There is a timely need for robust digital mathematics textbooks that support students' conceptual understanding in meaningful ways. As these resources emerge, studies should consider how students use high quality digital mathematics textbooks that are based on effective teaching models. Research should also consider the extent to which digital mathematics textbooks support not only the content standards in the *Common Core State Standards for Mathematics*, but also how interactive and collaborative features can support student development of the standards for mathematical practice. Future studies should also consider affordances and challenges of printed and digital textbooks as transformative learning tools. While this study employed activity theory to frame how students used their textbooks, future studies could extend the work and utilize activity theory for considering how students learn and deepen mathematical understanding when using print and digital textbooks as learning tools.

Limitations

While the study yielded insights regarding students' print and digital mathematics textbook use, a number of limitations must be acknowledged. These limitations include an atypical sample of Algebra 1 students, the newness of the materials to students and the teacher, individual differences among students in the two classes, self-reported student data regarding out-of-class textbook use, and limitations of researcher resources.

The students and classes involved in this study were not a representative sample of U.S. Algebra 1 students. In this private school, students typically took Algebra 1 in Grade 7, although the classes also included some students in Grade 6 and Grade 8. Admission to the school is competitive and there are high levels of parental involvement. Neither of the classes included students noted to be struggling learners, English language learners, or with behavioral challenges. Thus, Mrs. Rogers did not encounter many of the challenges that Algebra 1 teachers in more representative schools might face. She also enjoyed a considerable amount of autonomy in terms of curriculum and pacing decisions.

When data collection commenced, students in both classes had been using their new textbooks for approximately one month. The study provided new textbooks for both classes, but these were not received until early October. Thus, the print and digital textbooks were fairly new to both the teacher and to students, and both classes had begun the school year using a different textbook. This presented a considerable limitation to the study, since textbook use may well have been influenced by a lack of familiarity with the new materials.

Although the study compared student use of textbooks in two Algebra 1 classes in the same school, with the same teacher, using textbooks with the same mathematical content, the two classes differed in important ways. Whereas Class A included nineteen students, a disproportionate number of female students, and sixth and seventh graders; Class B was comprised of only three female and five male eighth grade students.

Another limitation of the study is the self-report data regarding out-of-school mathematics textbook use. Initial, task-based interviews aimed to mimic how students might use their textbooks to assist with textbook exercises outside of the classroom environment. However, this data source failed to produce rich data so findings regarding textbook use outside of the classroom relied mostly on students' self-reports.

Data collection for the study was intensive, involving 28 classroom observations and 32 interviews within the span of approximately one month. As a single researcher, this sometimes posed logistical constraints that limited the study. For instance, because I could typically interview a maximum of two students per day, I was unable to conduct stimulated recall interviews with students from both the print and digital classrooms relating to the same lesson.

Summary

Mathematics textbooks are a ubiquitous part of many students' school mathematics experiences (Tyson-Bernstein & Woodward, 1991) and an increasing proportion of these important tools are being conveyed in digital formats (Herff Jones Inc., 2012). This study examined how students engaged with both print and digital Algebra 1 textbooks in classroom contexts, considering how students used their textbooks and for what purposes.

Both groups of students used commercially published Algebra 1 textbooks in settings that emphasized mathematical procedures and definitions. In this context, there existed few differences between how one class of students engaged with the additional features offered in the digital textbook and how the other class of students engaged with the same textbook in printed form. The features of the textbook to which students attended were the features to which the teacher directed students' attention. That is, students were no more likely to independently explore and utilize their digital textbooks than the printed textbooks. In fact, students in both classes viewed the textbook primarily as a source for homework exercises, regardless of whether they used the print or digital textbook format.

In this study, neither print nor digital textbooks were used to their fullest potential, and students overlooked many features and supports in both textbook formats. Notably, the most interactive features in the digital textbooks were among the least used. Yet, the majority of students in both classes expressed a preference for digital textbooks, perceiving them to be more convenient alternatives to their heavy printed textbooks.

Digital textbooks for K-12 education continue to gain momentum and textbook publishers are accelerating the development of digital textbook options. This study challenges the assumption that digital textbooks are inherently more engaging or motivating for students and suggests that students do not always utilize much of what mathematics textbooks have to offer, whether in print or digital formats. In order to capitalize on the potential that digital textbooks offer for integrating mathematics curriculum with technological learning tools, students must not only understand how to use these powerful resources, but also have a motive to engage more deeply with the mathematical content conveyed in the materials.

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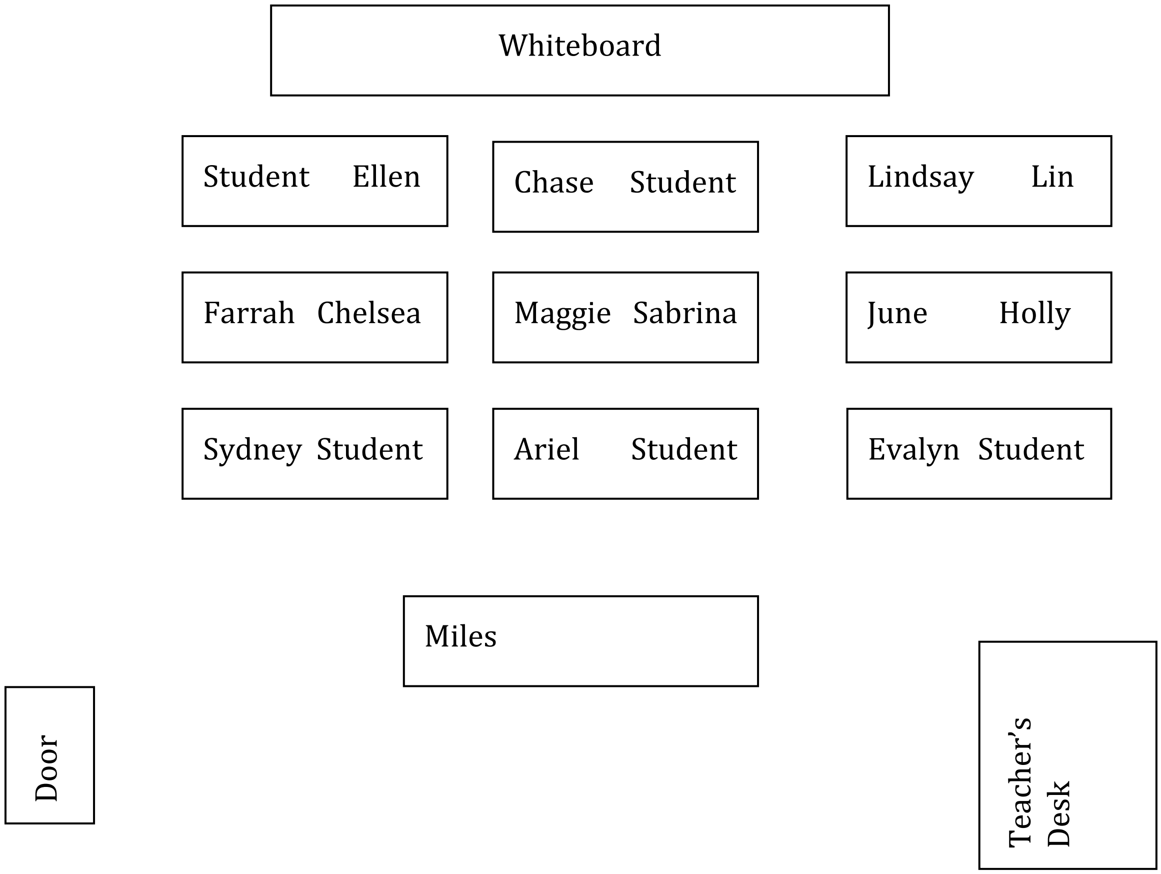
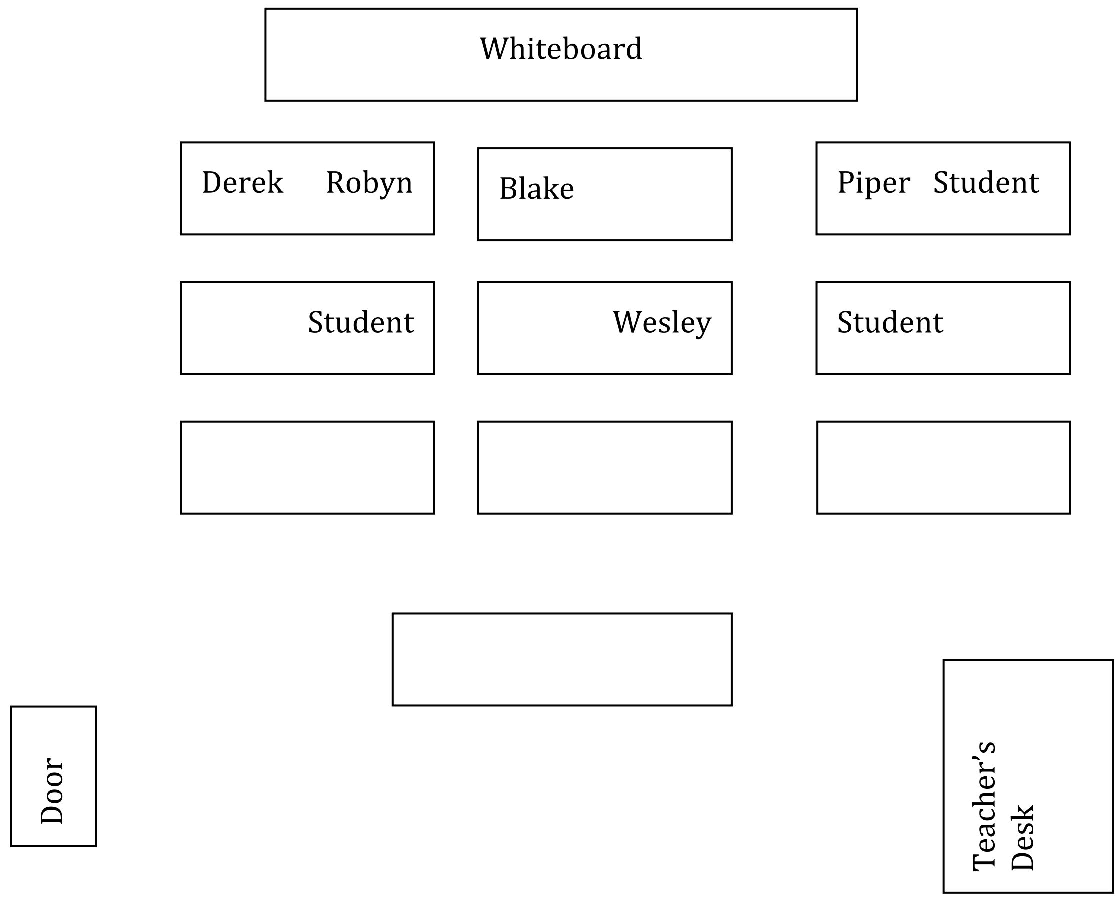
Appendix A

Seating Arrangement for Class A (Not to scale)



Appendix B

Seating Arrangement for Class B (Not to scale)



Appendix C

Protocol for Initial Student Task-based Interview

(In this interview, students are presented with a task from their current Algebra I chapter. Students may use their classroom textbook, digital or print, as a resource for completing the task. The interview also targets students' general use of their mathematics textbook, in school and at home.)

I. General use of mathematics textbooks

A. In class

1. On a typical day, tell me about how you use your mathematics textbook during Algebra I.
2. How often do you use your Algebra I textbook in class?
3. For what purposes do you usually use your textbook in Algebra I class?
4. How do you think you could use your textbook more effectively during class?
5. Consider the last class in which you used your Algebra I textbook.
   a. What was your goal or purpose for using your textbook?
   b. To what extent do you think those goals were achieved?
   c. How do you know?

B. Outside of class

1. To what extent do you typically use your Algebra I textbook outside of the classroom (e.g., at home, during study halls)?
2. For what purposes do you usually use your Algebra I textbook outside of class?
3. How do you think you could use your Algebra I textbook more effectively outside of class?
4. Consider the last time you used your Algebra I textbook outside of class.
   a. What was your goal or purpose for using your textbook?
   b. To what extent do you think that goal was achieved?
   c. How do you know?

II. Task [Present student with a task from their current Algebra I textbook.] (students should have their primary Algebra I textbook with them for this interview)

A. Say to student: This task goes with the chapter you are currently studying in Algebra I and you are encouraged to use your textbook as you solve this. I would like to observe and record you as you work on this task and will ask you some questions along the way.

B. As the student completes the task, pose questions such as the following, when appropriate:

1. [If the student is ‘stuck’] Is there something in the book that might help you with that?
2. [When the student chooses to use the book] I see that you are using your book to help you with this. In what ways do you think the book will be helpful for you right now?
3. [As the student uses different features of the textbook] I see that you are referring to the <u>insert feature</u>. Why? [When finished] To what extent did you find <u>insert feature</u> helpful for this task? How so? (Features might include examples, videos or applets in the digital textbook, explanations, or the glossary.)

C. When the student has completed the task:

1. How did the textbook help you in solving the problem?
2. [If the student did not use the textbook as a resource] Why did you choose not to use the textbook as you solved this problem? In what ways do you think the book could have been helpful?
3. Do you think your response is correct? How could you verify you are correct?

A cheetah can reach speeds of up to 103 feet per second. Use dimensional analysis to convert the cheetah's speed to miles per hour. Round to the nearest tenth.

(*Lesson 1-8*)

For maximum safety, it is recommended that food be stored at a temperature between 34° F and 40° F inclusive. Write a compound inequality to show the temperatures that are within the recommended range. Graph the solutions. (*Lesson 2-6)*

Appendix D

Protocol for Final Student Interviews

I. General use of mathematics textbooks

A. In class

1. On a typical day, tell me about how you use your mathematics textbook during Algebra II.
2. How often do you use your Algebra I textbook in class?
3. For what purposes do you usually use your textbook in Algebra II class?
4. How do you think you could use your textbook more effectively during class?
5. Consider the last class in which you used your Algebra II textbook.
    a. What was your goal or purpose for using your textbook?
    b. To what extent do you think those goals were achieved?
    c. How do you know?
6. Explain how your use of the textbook during Algebra has changed since our first interview?

B. Outside of class

1. To what extent do you typically use your Algebra I textbook outside of the classroom (e.g., at home, during study halls)?
2. For what purposes do you usually use your Algebra I textbook outside of class? Can you give me an example?
3. How do you think you could use your Algebra II textbook more effectively outside of class?
4. Consider the last time you used your Algebra II textbook outside of class.
    a. What was your goal or purpose for using your textbook?
    b. To what extent do you think that goal was achieved?
    c. How do you know?
5. Explain how your use of the textbook outside of Algebra class has changed since our first interview?

II. Knowledge of textbook features

1. Give me a tour of your textbook.

Appendix E

Classroom Observation Protocol
Adapted from Inside the Classroom: Observation and Analytic Protocol
(Horizon Research, Inc., 2000)

Observation date: ________________ Time Start: ____________ Time End: __________

Circle one: Print Algebra I Textbook Digital Algebra I Textbook

Video Cameras:

Student Names	Consent Status	Head Camera Worn Today (Circle one)			
Student		1	2	3	
Sabrina	yes	1	2	3	
Student		1	2	3	
Ariel	yes	1	2	3	
Farrah	yes	1	2	3	
Chelsea	yes	1	2	3	
Maggie	yes	1	2	3	
June	yes	1	2	3	
Lindsay	yes	1	2	3	
Holly	yes	1	2	3	
Student		1	2	3	
Ellen	yes	1	2	3	
Student		1	2	3	
Evalyn	yes	1	2	3	
Miles	yes	1	2	3	
Sydney	yes	1	2	3	
Chase	yes	1	2	3	
Mason	yes	1	2	3	
Lin	yes	1	2	3	

A. The Physical Environment

1. Describe the physical environment of the classroom.

B. Purpose of the Lesson:

1. According to the teacher, the purpose of this lesson was:

2. Based on time spent, the focus of this lesson is best described as: (Check one.)

    - o Almost entirely working on the development of algorithms/facts/vocabulary
    - o Mostly working on the development of algorithms/facts/vocabulary, but working on some concepts
    - o About equally working on algorithms/facts/vocabulary and working on mathematics concepts
    - o Mostly working on mathematics concepts, but working on some algorithms/facts/vocabulary
    - o Almost entirely working on mathematics concepts

C. Lesson Arrangement and Activities

In question 1 of this section, please divide the total duration of the lesson into instructional and non-instructional time. In question 2, make your estimates based only on the *instructional time* of the lesson.

1. Approximately how many minutes during the lesson were spent:
    a. On instructional activities? _________ minutes

    b. On housekeeping unrelated to the lesson/interruptions/other non-instructional activities? _________ minutes

       Describe:

    c. Check here if the lesson included a major interruption (e.g., fire drill, assembly, shortened class period): ☐

2. Considering only the *instructional time* of the lesson (listed in 1a above), approximately how much of this time was spent in each of the following arrangements?
   a. Whole class _______% b. Pairs/small groups ________% c. Individuals ______%

D. Instructional Materials

1. Which best describes the source of the **instructional materials** upon which this lesson was based? (check all that apply)
   - o Materials designated for this class/course, from a commercially published textbook/program
   - o Materials designated for this class/course, developed by district, school, or other non-commercial source
   - o Materials selected or adapted by the teacher, from a commercially published textbook/program
   - o Materials selected or adapted by the teacher, from a non-commercial source
   - o Materials developed by the teacher

   Describe the instructional materials used:

E. Observational Notes. *Particularly document activities that might not be evident from the whole-class video recording.*

Observations should focus primarily on students who are wearing head cameras, noting what may not be identifiable from their cameras' perspectives. Examples include: gestures, teacher's or other students' actions/interactions with the student, teacher or student initiated curriculum use, etc.

Time Stamp	Observed Activities	Memos

Time Stamp	Lesson Activities	Memos

Appendix F

Classroom Observation Protocol
Adapted from Inside the Classroom: Observation and Analytic Protocol
(Horizon Research, Inc., 2000)

Observation date: ________________ Time Start: ____________ Time End: _________

Circle one: Print Algebra I Textbook Digital Algebra I Textbook

Video Cameras:

Student Names	Consent Status	Head Camera Worn Today (Circle one)			
Student	No	1	2	3	
Blake	Yes	1	2	3	
Wesley	Yes	1	2	3	
Student		1	2	3	
Student		1	2	3	
Piper	Yes	1	2	3	
Robyn	Yes	1	2	3	
Derek	Yes	1	2	3	

A. The Physical Environment

Describe the physical environment of the classroom.

B. Purpose of the Lesson:

1. According to the teacher, the purpose of this lesson was:

2. Based on time spent, the focus of this lesson is best described as: (Check one.)

- o Almost entirely working on the development of algorithms/facts/vocabulary
- o Mostly working on the development of algorithms/facts/vocabulary, but working on some concepts
- o About equally working on algorithms/facts/vocabulary and working on mathematics concepts
- o Mostly working on mathematics concepts, but working on some algorithms/facts/vocabulary
- o Almost entirely working on mathematics concepts

C. Lesson Arrangement and Activities

In question 1 of this section, please divide the total duration of the lesson into instructional and non-instructional time. In question 2, make your estimates based only on the *instructional time* of the lesson.

0. Approximately how many minutes during the lesson were spent:

a. On instructional activities? _________ minutes

b. On housekeeping unrelated to the lesson/interruptions/other non-instructional activities? _________ minutes

Describe:

c. Check here if the lesson included a major interruption (e.g., fire drill, assembly, shortened class period): ☐

2. Considering only the *instructional time* of the lesson (listed in 1a above), approximately how much of this time was spent in each of the following arrangements?

a. Whole class _______% b. Pairs/small groups ________% c. Individuals ______%

D. Instructional Materials

1. Which best describes the source of the **instructional materials** upon which this lesson was based? (check all that apply)

- o Materials designated for this class/course, from a commercially published textbook/program
- o Materials designated for this class/course, developed by district, school, or other non-commercial source
- o Materials selected or adapted by the teacher, from a commercially published textbook/program
- o Materials selected or adapted by the teacher, from a non-commercial source
- o Materials developed by the teacher

Describe the instructional materials used:

E. Observational Notes. *Particularly document activities that might not be evident from the whole-class video recording.*

Observations should focus primarily on students who are wearing head cameras, noting what may not be identifiable from their cameras' perspectives. Examples include: gestures, teacher's or other students' actions/interactions with the student, teacher or student initiated curriculum use, etc.

Time Stamp	Observed Activities	Memos

Time Stamp	Lesson Activities	Memos

Appendix G

TEACHER INTERVIEW PROTOCOL

Adapted from Inside the Classroom Teacher Interview Protocol (Horizon Research, Inc., 2000) and $(MS)^2$ Teacher Interview (Reys, 2003)

I. General/background questions specific to first interview

1. I'd like to know a bit more about the students in this class. Tell me about the ability levels of students in this class. How do they compare to students in the school as a whole?
   Are there any students with special needs in this class?
   Are there any students for whom English is not their first language?
   Are there any students with learning disabilities?

2. Is student absenteeism or mobility a problem for you in this class?
3. What have the students experienced prior to the chapter and lessons I will be viewing in the coming weeks?

II. Questions to be asked in the first three interviews.

1. What mathematics topics/concepts do you plan to teach to this class next week?
2. What are your instructional goals for the lessons you plan to teach?
3. How will you assess whether students meet the instructional goals you have for the lessons next week?
4. What led you to teach the topics in these lessons?
5. What resources did/will you use to plan next week's lessons?
6. What do you like about these resources/materials/activities?

7. *If the lessons are based on one resource/material*: Do you plan to use the lessons essentially as they were organized in the [name of resource/material] or will you modify them in important ways?
8. *If the lessons are based on more than one resource/material*: Do you plan to use the lessons essentially as they were organized in any one of these resources/materials? *If yes*: Will you modify them in important ways?
9. *If modified*: Can you describe the modifications you plan to make and your reasons for making them?
10. How do you think the lessons will differ between the two sections of Algebra I?
11. To what extent will the textbooks for each class influence what or how you plan to teach next week's lessons? Will you use all of the activities/problem sets in the textbooks? If no, how will you decide what to use and what to skip?
12. What parts or features of the textbooks will you use most often this week? What parts or features of the textbooks do you think your students will use most often this week?

III. Questions to be asked in the final interview, only.

1. To what extent do you think students in the two Algebra classes achieved the instructional goals for the last chapter? How do you know?
2. What differences did you notice between the two classes?
3. To what extent do you agree that the textbooks determined **what** you taught in the last 3 weeks? Did it differ between the two textbooks?
4. In what ways did the two textbooks influence **how** you taught in the last 3 weeks? Did it differ between the two textbooks?
5. How would you rate the overall quality of the two textbooks?
6. What are the strengths of each textbook?
7. What are the weaknesses of each textbook?
8. What challenges did you encounter in the class with print textbooks over the last 3 weeks? The class with digital textbooks?
9. What challenges did your students encounter in the class with print textbooks over the last 3 weeks? The class with digital textbooks?
10. What differences did you notice in the ways in which students used the digital textbooks compared to those using print textbooks?

Appendix H

Algebra I: Chapter 4.1 Notes

____

Recall: What is a function?

Identifying Linear Functions from a graph:

- A function is linear if its graph is a _______________________ !

Tell whether the graph represents a linear function:

a) b) c)

Identifying Linear Functions from a table:

- A function is linear if you find a ______________________ change in the

  ______ AND _______ values in its table or T-chart

Tell whether the table represents a linear function:

a) b) c)

Identifying Linear Functions from its equation:

- A function is linear if the variables in the equation have exponents of ______
- A function is linear if __________ exponents are multiplied together
- A function is linear if __________ of the variables appear as
  ______________________ of

  fractions, as ____________________, or as ________________________ ________________ .

Tell whether each equation is linear or non-linear. If it is linear, then graph!

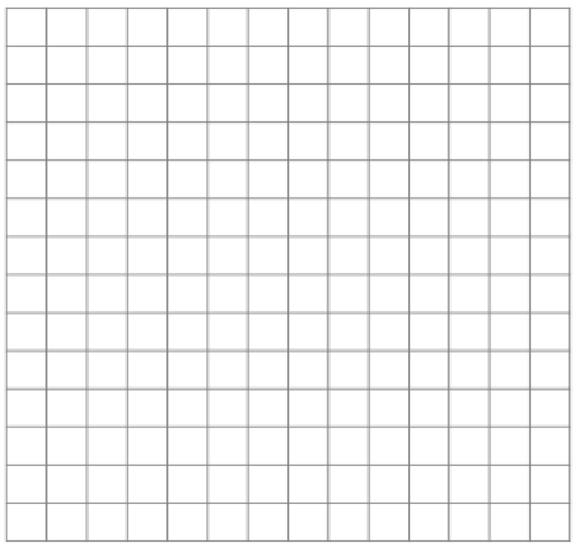
a) b) c)

Appendix I

Algebra I – Chapter 4.2 Notes

____

EXAMPLE 1 Amanda's mom gave her $35 to pay for her school lunch. Lunch at school costs $2.50 per day. Let the x-axis represent the number of days she eats lunch and the y-axis represent the number of money she has left. Draw a graph of this situation:



The **y-Interept** of a graph: ______________________________

____

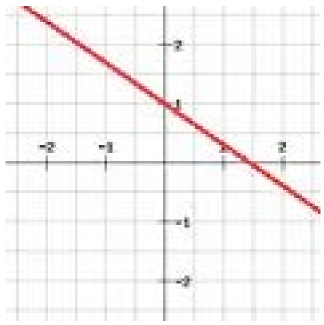
The **x-intercept** of a graph: ______________________________

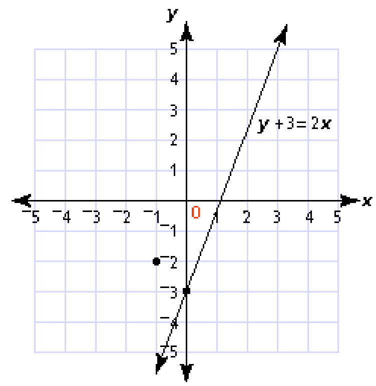
____

What is the y-intercept in EXAMPLE 1? What does this tell us?

What is the x-intercept in EXAMPLE 1? What does this tell us?

How to find intercepts from a graph.

a) 

b) 

How to find intercepts from an equation.

a)

b)

<u>EXAMPLE 2</u> The Student Council bake sale sells cookies for $.50 and sodas for $2.00. Write an equation that will help you solve how many cookies and sodas you can purchase for exactly $8.00.

Find the intercepts of the equation and use them to graph the line described by the equation.

Appendix J

Algebra I: Chapter 4.3 Notes

____

EXAMPLE In 1985, the cost of sending a 1-ounce letter was 22 cents. In 1988, the cost was 25 cents. How fast did the cost change from 1985 to 1988? In otherwords, at what ***rate*** did the cost change?

A RATE OF CHANGE is ______________________________

____

____

____

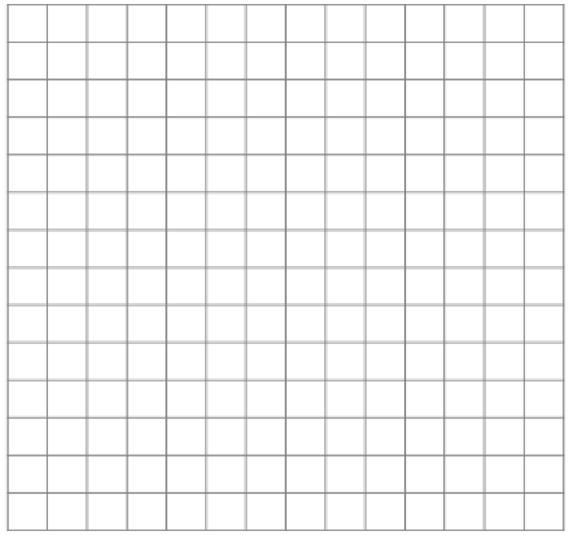
How to Find Rates of Change from a Table

The table shows the cost of mailing a 1-ounce letter in different years. Find the rate of change in cost for each time interval. During which time interval did the cost increase at the greatest rate?

Year (X)	1988	1990	1991	2004	2008
Cost in Cents (y)	25	25	29	37	42

How to Find Rates of Change from a Graph

Postage Costs



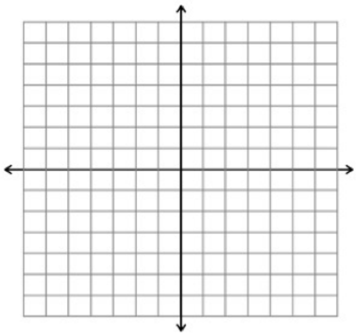
You will notice that <u>the rate of change</u> in the previous example <u>changes</u>!
The rate of change on a single linear function is constant!
The "Rate of Change" of a Linear Function is called " ______________ "

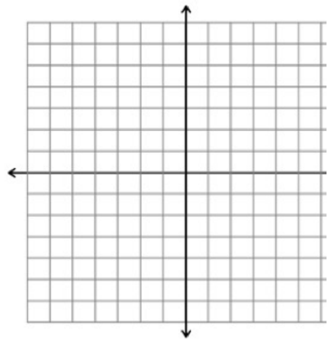
Some mathematician once said:
"...Rate of Change = Slope ..."

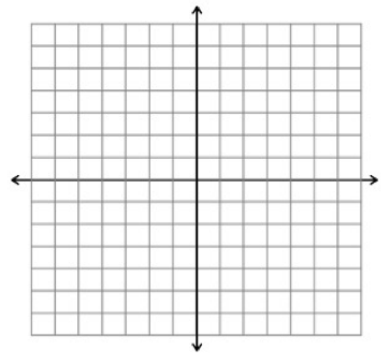
<u>How to Find the "Slope" on the Graph of a Linear Function</u>

1) **Pick two points on the line**
2) **Find the "change in y" and the "change in x"**
3) **Write the Slope as a ratio of the "change in y" OVER the "change in x"**

EXAMPLES:







How to Find the Slope of a Line

Slope = ____________________

Rise:

____(_______________)

Run:

____(_______________)

Appendix K

<u>Chapter 4 Book FUN Assignment!!</u>

Using your textbook, you will complete the following tasks. You may use any part of your book to help you complete the problems.

1) Find an example in your book of a table or set of ordered pairs which represents a **function** and one that does not.
   State the page number and give the two examples. Explain why is a function or why it is not.

2) Find an example of a graph that represents a linear function and one that represents a non-linear function.
   State the page number and give the two examples. Explain why linear or why it is not.

3) Find an example of a table that represents a linear function and one that represents a non-linear function.
   State the page number and give the two examples. Explain why is linear or why it is not.

4) Find an example in your textbook that gives the graph of a situation that has a changing "rate of change".
State the page number and give the example. Explain how you know the rate of change is not constant.

5) Find an example in your textbook that gives the graph of a linear function with a positive slope
State the page number and give the example. Find the slope-intercept form of this graph.

6) Find an example in your textbook that gives the graph of a linear function with a negative slope.
State the page number and give the example. Find the slope-intercept form of this graph.

7) Find an example in your textbook that gives the graph of a linear function with an undefined slope
State the page number and give the example. Find the equation of the special line.

8) Find an example in your textbook that gives the graph of a linear function with an slope of zero.
State the page number and give the example. Find the equation of the special line.

VITA

Amanda Thomas is a native of Missouri and grew up in the Lake of the Ozarks area. Prior to earning a Ph.D. from the mathematics education program at the University of Missouri, she earned a Bachelor of Arts degree from Columbia College and a Master of Liberal Arts degree from the Mathematics for Teaching program at the Harvard University Extension School. Amanda also taught high school mathematics for three years at Morgan County R-1 school in Stover, Missouri.

Amanda's research interests focus on mathematics textbook use, particularly relating to classroom use of digital instructional materials. She is also interested in innovative use of technology in mathematics classrooms. As a fellow for the Center for the Study of Mathematics Curriculum (CSMC) at the University of Missouri, Amanda also participated in research focusing on the Common Core State Standards for Mathematics (CCSSM) and co-authored peer-reviewed publications relating to the CCSSM.

In August 2013, Amanda, her husband Michael, and three children will relocate to Pennsylvania where she has accepted an Assistant Professor of Education position at Penn State Harrisburg.