

EXPLORING INSIGHTS FROM ONLINE STUDENTS: ENHANCING THE DESIGN AND DEVELOPMENT OF INTELLIGENT TEXTBOOKS FOR THE FUTURE OF ONLINE EDUCATION

Jeonghyun Lee,* Meryem Yilmaz Soylu, & Chaohua Ou

Georgia Institute of Technology, Atlanta, Georgia, USA

*Address all correspondence to: Jeonghyun Lee, Georgia Institute of Technology, Atlanta, GA, E-mail: jonnalee@gatech.edu

The global pandemic accelerated the shift to remote teaching, leading to a rise in digital course materials such as textbooks. However, existing literature indicates that there is limited research on how online students utilize digital textbooks as well as on the features they find valuable for their online learning experiences and desire to aid their learning. Therefore, the purpose of this research was to explore the experiences and perceptions among diverse online students and then draw implications for the design of future intelligent textbooks. This study surveyed online degree-seeking students (n = 1236) from three different institutions in the United States in 2022. Based on the mixed-method research design, this exploratory study used qualitative data from open-ended questions and quantitative data from closed-ended questions to theme patterns of response. The results indicated that most participants have used at least one digital textbook, and in general they were familiar with such features as searching, visuals, and embedded assessments. These features, associated with self-directed and multimedia learning, received more positive ratings compared to adaptive or personalized learning features such as chatbots and recommended content. In the findings of the study, surveyed participants described future intelligent digital textbooks to be ideal for self-directed learning, since they can accommodate diverse learning needs and are flexible and affordable. Overall, this study provides insights into future intelligent textbooks and other digital materials as a comprehensive learning system and supports their use for empowering online learners to go beyond text-based learning and enhancing their digital learning experience.

KEY WORDS: intelligent textbook, digital textbook, online students, artificial intelligence

1. INTRODUCTION

Advancements in technologies are catalyzing digital transformations across numerous aspects of teaching and learning in higher education. With the rapid growth of emerging technologies such as artificial intelligence (AI), digital textbooks play a significant role in

innovating educational practices and creating engaging learning experiences (D'Ambra et al., 2022; Padmanabhan, 2023). This is exemplified by the advent of intelligent textbooks, a new form of digital textbooks that are characterized by their integration of innovative features stemming from intelligent tutoring systems, student modeling technologies tailored for personalized learning, and instructional technologies such as error-sensitive feedback and adaptive navigation support (Jiang et al., 2023). Furthermore, the global pandemic impacted the ongoing evolution of digital textbooks from static e-texts to interactive AI-powered intelligent textbooks as demands for quality remote teaching and learning experiences continued to grow (Hanaba et al., 2020; Soto-Acosta, 2020).

Extant research suggests that future digital textbooks should be seen as a standalone learning system, incorporating a pedagogical framework for visual, adaptive, collaborative, and personalized experiences (Ou et al., 2022). In creating such an environment, it is crucial to involve students' perspectives as the primary end users. Past studies have examined students' awareness, preferences, attitudes, satisfaction, and intention to continue using digital textbooks. However, a review of the existing literature (e.g., Anderson & Cuttler, 2020; Lindshield & Adhikari, 2013) revealed that there is limited research on how online students utilize digital textbooks as well as features they find valuable for their online learning experiences and desire to aid their learning. Our exploratory study aimed to discover insights from adult students with regard to the use of intelligent textbooks for the future of online learning.

2. LITERATURE REVIEW

2.1 Evolution of Digital Textbooks

Digital textbooks, often referred to as e-textbooks or e-texts, are electronic versions of a textbook that can be read on a computer, mobile devices such as a phone or tablet, or e-reader (Bozkurt & Bozkaya, 2015; Dobler, 2015; Gu et al., 2015; Peterson, 2017; Rockinson-Szapkiw et al., 2013). While digital textbooks broadly include digital forms of textbooks that are interactive and/or intelligent, e-textbooks focus on integrating textbook features and reading materials in a digital form to enhance convenience and portability (Bozkurt & Bozkaya, 2015; Dobler, 2015). The digital textbook phenomenon started with the conversion of print textbooks into digital formats to increase accessibility, affordability, and equity in education in the 21st century, marking a departure from the long-standing tradition of using physical books in education since the 16th century (Bouchrika, 2023). Digital textbooks gained popularity due to their interactive technologies, making them ideal for facilitating learning independent from time and space between instructors and students (Baek & Monaghan, 2013; Chulkov & VanAlstine, 2013; O'Bannon et al., 2017; Raynor & Iggulden, 2008; Rickman et al., 2009; Ryan, 2008; Zhang et al., 2016). The pandemic further accelerated this trend since remote teaching has become the norm, which demands the use of digital course materials (Hanaba et al., 2020; Soto-Acosta, 2020).

Digital textbooks and other digital course materials have been widely adopted in higher education since the early 2000s (Nelson, 2008). Digital textbooks have made significant inroads into various academic disciplines, including mathematics (Letchumanan & Tarmizi, 2010; Turel & Sanal, 2018), English (Connor et al., 2019; Lim et al., 2021), and nursing (Liu et al., 2020), while early research focused on fields such as computer science, economics, and business (Dillon, 2001; Fernandez, 2003; Ramirez & Gyeszly, 2001). One of the reasons for the growing popularity of digital textbooks can be attributed to instructors' desire to incorporate a broader range of open educational resources (Seid-Karbasi et al., 2017) and proprietary materials, encompassing not only e-textbooks but also online practice problems (Van Horne et al., 2017). Advocates of digital textbook usage frequently put forth arguments highlighting the extensive advantages and usefulness of digital textbooks for their users, compared to traditional textbooks (Aharony, 2015; Joo et al., 2017; Jou et al., 2016; Lee, 2013; Letchumanan & Muniandy, 2013; Stone & Baker-Eveleth, 2013; Yoo & Roh, 2019). These benefits include cost effectiveness for students, enhanced portability, the ability to access multiple textbooks through a single device, visually appealing content, a wide range of learning resources, convenience, and interactive features (Gorski, 2010; Lin & Yu, 2023; Wang & Bai, 2016). Furthermore, digital textbooks incorporate diverse multimedia elements such as photographs, videos, and chatbots in the content, thus increasing learner engagement and comprehension of ideas and concepts by stimulating various cognitive processes. Overall, these advantages make digital textbooks highly beneficial for learning (Brower, 2022).

Building upon previous research (Ou et al., 2022; Boulanger & Kumar, 2019; Ran & Jinglu, 2020), we strongly advocate for a paradigm shift in the development of future digital textbooks. It is essential to move beyond the notion of digital textbooks as mere enhancements of digital texts with a few added features or tools such as highlighting and note taking. Instead, we propose that intelligent textbooks should be approached as comprehensive learning systems grounded in a pedagogical framework that prioritizes visual appeal, adaptability, collaboration, and personalization (Ou et al., 2022). Before embarking on extensive interdisciplinary endeavors to create such a learning system and enhance students' digital learning experiences, it is imperative to incorporate their perspectives, considering that they are the ultimate beneficiaries and users of these textbooks. This is especially important for online students, given that their needs for quality instruction and appropriate learning resources are rapidly growing in the post-pandemic era.

2.2 Factors Influencing Acceptance of Digital Textbooks

Previous studies have shown mixed findings regarding students' awareness, acceptance, preferences, and attitudes toward digital textbooks, as well as their continuance intention to use them (Elias et al., 2012; Letchumanan & Muniandy, 2013). The majority of these studies conducted in higher education settings used the technology acceptance model (TAM) or its later versions, such as the unified theory of acceptance and use of technology (UTAUT)

(Venkatesh et al., 2012), to explain factors influencing user choices and preferences, along with their relationships with academic and demographic variables. The TAM comprises two primary constructs: *perceived usefulness* and *perceived ease of use*. Perceived usefulness refers to the belief that utilizing the system will enhance one's performance, while perceived ease of use entails the belief that using the system will be effortless (Davis, 1989; Davis et al., 1989).

The TAM draws on the notion that individuals are more likely to accept and adopt a technology if they perceive it as beneficial to their tasks or goals. When users believe that using a system will result in improved outcomes, such as increased efficiency or effectiveness, they are more inclined to adopt it. This belief in the system's usefulness serves as a driving force behind the intention to use it. Additionally, the TAM recognizes the significance of perceived ease of use in technology acceptance. If users perceive a system as easy to use, with minimal effort required to navigate and operate it, they are more likely to embrace it. The perceived ease of use can influence users' attitudes toward the system, making them more open to incorporating it into their routines. For instance, perceived ease of use emerged as a contributing factor in acceptance of new technologies among undergraduates (Letchumanan & Muniandy, 2013) and faculty members (Nasser Al-Suqri, 2014). In another study, it was revealed that both perceived usefulness and ease of use have an impact on the intention of using digital textbooks (Lee, 2013). Furthermore, utilizing the UTAUT model, Maduku (2015) examined undergraduate students' intention to use digital books and identified significant factors, such as performance expectancy, social influence, and facilitating conditions.

Despite the perceived advantages of digital textbooks, numerous studies have indicated that students still predominantly prefer for print books over digital alternatives in higher education and have limited experience with digital textbooks associated with their courses (Cassidy et al., 2012; Elias et al., 2012; Waters & Miikkulainen, 2014). Other studies have also echoed these findings, indicating that despite the widespread availability and benefits of digital books, many students still exhibited a preference for print books (Dewan, 2012; Walton, 2014; Woody et al., 2010). When researchers further examined factors that drive students toward print books and barriers to digital book adoption, they identified several factors, including eye strain, poor on-screen presentation, and potential distractions associated with computer usage, particularly for extended reading sessions (Wang & Bai, 2016).

Nevertheless, recent studies have revealed that students tend to perceive digital forms of textbooks as highly useful, which makes it evident that these textbooks can offer numerous benefits to learning (Joo et al., 2017; Jou et al., 2016; Stone & Baker-Eveleth, 2013). Dobler (2015) found that before using e-textbooks, less than one-fourth of the students (i.e., 22%) indicated a preference for an e-textbook, or a digital version of a textbook. However, after experiencing the textbook in digital format, 50% of students reported preferring the e-textbook over the printed version. Moreover, affordability consistently emerges as the primary reason motivating students to prefer digital over printed textbooks (McDaniel & Daday, 2018). However, there is still a lack of information about the types of features that

become influential in determining students' choice to adopt digital textbooks. Additionally, more research is needed to discover specific features related to digital textbooks that students across different class levels and fields of study would find valuable for enhancing their learning experiences. Our study aimed to address this research gap by focusing on examining perceptions about a variety of digital textbook features among students from various academic backgrounds.

2.3 Features of Digital Textbooks and Implications for Online Learning

With the support of their multitude of features that actively facilitate student learning (Junco & Clem, 2015; Koć-Januchta et al., 2020), digital textbooks transcend their role as mere supplementary resources, serving as a dynamic medium that fosters immersive learning experiences and drives improved academic performance (Anderson & Cuttler, 2020). Digital textbooks offer numerous facilities to readers, encompassing features such as links, hyperlinks, citations, downloading, bookmarking, highlighting, cross-referencing, digital annotation and note sharing, comments, dialogues around content, searching, and practicing with assignments (Dobler, 2015). Early studies reported that the commonly used features are glossary lookup and annotation, bookmarking, highlighting, and searching (McFall et al., 2006; Simon, 2001).

Students have been found to perceive e-textbooks with annotation and sharing capabilities as supportive of their learning experiences (Dobler, 2015; Lim & Hew, 2014). In particular, having digital note-sharing experience was found to foster a sense of connection among students as they shared the experience of reading digital text and had the opportunity to pose questions about the text and receive replies from peer students (Dobler, 2015). Furthermore, a recent study showed that digital textbook users prioritized features such as the ability to perform keyword searches, instructor highlights and annotations, cost, offline access, and first-day availability (Abaci et al., 2019). The study further revealed that students who actively utilized interactive features of e-textbooks were more likely to report positive learning experience and coursework completion than those who did not. The strongest sense of associations between e-textbook usage and learning was observed among students who frequently engaged with other students and instructors and took notes using their digital textbooks. A moderate sense of learning connections was found among students who frequently used bookmarking and highlighting and accessed online resources through hyperlinks.

Only a few studies have investigated online students' experiences with digital textbook-related features in higher education settings. For instance, Lindshield and Adhikari (2013) compared online students' usage and preference for a digital textbook called the *FlexBook* to that of on-campus students. It was found that most students, regardless of whether they were on campus or studying online, reported using and endorsing text and figures included in the *FlexBook*. Additionally, when it came to overall preferences, the majority of students, regardless of their mode of study, expressed a positive feeling for the organization, format,

searchability, and web accessibility of the FlexBook. In particular, online students reported significantly higher usage and appreciation of the FlexBook's animations, videos, and links compared to their on-campus counterparts. Notably, online learners highly valued the visual presentation and adaptable nature of the FlexBook. These findings suggested that both student groups appreciated various attributes of the digital textbook, such as its content, organization, and accessibility, while online students particularly valued its multimedia features and adaptability (Lindshield & Adhikari, 2013).

Although there were no statistically significant differences in general textbook format preferences between online and on-campus students, a comparison study identified a strong preference for free digital textbooks over paid printed textbooks across both the online and on-campus groups (Anderson & Cuttler, 2020). It is noteworthy that students using digital textbooks were over two times more likely to report a preference for free digital textbooks and almost three times less likely to indicate a preference for paying for printed textbooks compared to students using printed textbooks. Further analyses revealed that online students were more likely to prefer digital textbooks and rated the importance of the immediate access, convenience, portability, ability to print, and ability to store the content permanently significantly higher compared to on-campus students. Overall, further research is required to deepen the understanding of the unique experiences and perceptions among online students regarding digital textbooks and their specific features in order to develop a robust framework to design digital textbooks that are optimized for online learning.

2.4 Research Questions

Taking the aforementioned limitations into account, our study explored three research questions:

1. What do online students' prior experiences with digital textbooks look like?
2. How do online students perceive various features and resources available in digital textbooks?
3. Which features do online students prioritize for the next generation of digital textbooks?

Additionally, our study focused on examining the experiences and perceptions among diverse online student groups recruited from three different institutions (i.e., four-year university, public college, and technical college), rather than comparing between online and on-campus students.

3. METHOD

This exploratory study used a multi-method approach in order to capture a comprehensive snapshot of online students' digital textbook experiences. Specifically, the study adopted a

concurrent mixed-methods research design, in which we simultaneously collected both quantitative (i.e., closed-ended) and qualitative (i.e., open-ended) survey data, analyzed each data set, and compared and interpreted the analysis results. The data collection tool was a web survey of online students who were currently enrolled in one of three higher education institutions in the United States. For data analysis, descriptive and mean difference statistics, along with qualitative coding, were used to theme patterns of student responses and compare trends among the three institution groups.

3.1 Participants and Settings

An online survey was administered to three different institutions located within the same southern state in the United States. These institutions include a four-year engineering-focused university (Institution I); a state system, which oversees 22 technical colleges that offer technical education, custom business and industry training, and adult education programs (Institution II); and a public college that offers both associate and bachelor's degree programs (Institution III). At the time of publication, Institution I currently provided three online master's programs in analytics, computer science, and cyber security. Both Institutions I and II also offered multiple online courses and programs in various discipline areas including business, criminal justice, education, and healthcare.

Out of a total of 3370 respondents, 37% ($n = 1236$) reported that they were currently enrolled in an online degree program. In this paper, we term these students as fully online students. Of the 1236 fully online students, 29%, 64%, and 8% came from Institutions I, II, and III, respectively. Of the total respondents, 66% were female, 32% were male, and 2% were either non-binary or unknown. In terms of age, 41%, 30%, 18%, and 10% of the total respondents were 18–24, 25–34, 35–44, and 45–54 years old, respectively, and 2% were 55 years old or older. Regarding race/ethnicity, 44% of total respondents were White, 25% were Black or African American, 13% were Asian, and 8% were Hispanic/Latino. The remaining 10% reported themselves to be other (with 6% preferring not to answer). For the primary major, various disciplines of study were reported, with the top three most popular majors including computer and information sciences (26%); healthcare/medicine (22%); and business, management, and marketing (16%). The majority of the participants (69%) were undergraduate-level students, with 33% of those being freshman and 22% sophomore; while 25% were graduate-level students, mostly in master's programs. The remaining 6% reported other class standing (e.g., audit student). Table 1 presents the full distribution of participants' demographic characteristics within and across the institutions.

TABLE 1: Distribution of participants' demographic characteristics

Demographic Characteristic	Institution I (n = 356)		Institution II (n = 786)		Institution III (n = 94)		Total Institutions (n = 1236)	
	n	%	n	%	n	%	n	%
<i>Gender</i>								
Female	101	28	635	81	73	78	809	66
Male	246	69	134	17	20	21	400	32
Non-binary or unknown	9	3	17	2	1	1	27	2
<i>Age (years)</i>								
18–24	70	20	388	49	49	52	507	41
25–34	167	23	178	23	21	22	366	30
35–44	78	17	131	17	9	10	218	18
45–54	33	10	76	10	13	14	122	10
55 and above	8	2	13	2	2	2	23	2
<i>Race/Ethnicity</i>								
White	131	37	348	44	59	63	538	44
Black or African American	17	5	279	36	17	18	313	25
Asian	143	40	20	3	0	0	163	13
Hispanic/Latino	22	6	63	8	8	9	93	8
Other	17	5	32	4	5	5	54	5
Unknown	26	7	44	6	5	5	75	6
<i>Class Standing</i>								
Freshman or first-year student	22	6	345	44	36	38	403	33
Sophomore or second-year student	11	3	232	30	29	31	272	22
Junior or third-year student	6	2	83	11	16	17	105	9
Senior or fourth year student	4	1	47	6	9	10	60	5
Fifth-year student or beyond	1	0.3	14	22	1	1	16	1
Master's student	300	84	4	1	0	0	304	25
Doctoral student	1	0.3	1	0.1	0	0	2	0.2
Other	11	3	60	8	3	3	74	6

TABLE 1: (continued)

Demographic Characteristic	Institution I (n = 356)		Institution II (n = 786)		Institution III (n = 94)		Total Institutions (n = 1236)	
	n	%	n	%	n	%	n	%
	<i>Primary Major</i>							
Agriculture and natural sciences	1	0.3	8	1	0	0	9	1
Architecture/building construction	0	0	7	1	1	1	8	1
Business, management, marketing	8	2	173	22	18	19	199	16
Communications/journalism	0	0	2	0.3	5	5	7	1
Computer and information science	249	71	59	8	5	5	313	26
Education, including physical education	3	1	76	10	7	8	86	7
Engineering	66	19	13	2	1	1	80	7
Fine and performing arts	0	0	7	1	0	0	7	1
Healthcare/medicine	7	2	242	31	24	26	273	22
Humanities	0	0	3	0.4	2	2	5	0.4
Interdisciplinary	6	2	26	3	0	0	32	3
Liberal arts/general studies	0	0	4	1	2	2	6	1
Linguistics/language/literature	0	0	4	1	1	1	5	0.4
Public administration/ legal, social, and protective services	1	0.3	32	4	5	5	38	3
Social sciences	0	0	12	2	11	12	23	2
Other	12	3	107	14	11	12	130	11

In terms of primary device used to complete most of the coursework, 68% of the total respondents reported laptop use; 18% reported desktop use; and 14% reported using other devices, including 2-in-1 devices (e.g., Microsoft Surface), Chromebooks, tablets, and smart phones. A large majority of the participants (i.e., 88%) reported that they accessed their primary device by owning it, and a strong majority (i.e., 93%) either always or very often had an internet connection that was adequate to meet all of their needs as a student (93%). Almost all of the participants (i.e., 95%) reported that they did not have a disability for which they needed assistive technologies.

3.2 Procedures

Upon obtaining approval from the Institutional Review Board on our proposed study protocol that involves human subjects, the online survey was administered at each of the three

institutions during October and November 2022. The survey was advertised and accessible to all currently enrolled students through the announcement system in each institution's learning management system. Data were collected for one week after the survey was open. Students who were interested in participating in the study were asked to click the given survey link and read details about the study information. To collect the informed consent form from potential participants, students were prompted to indicate whether they agreed to participate in the survey after reviewing the study information and then proceed by clicking the next button on the screen. For those who did not agree to volunteer to participate, they were directed to exit the survey. In addition, this study offered monetary compensation as a result of the study participation. Students were invited to be entered into a raffle drawing to receive a \$50 Amazon gift card as research incentive (a total of five available to each institution). To be eligible for the raffle prize, the students were asked to enter their names and school email addresses during the survey, which was separated from their responses to the survey questions and solely used for the purpose of raffle drawing.

3.3 Measures and Data Analysis

The survey consisted of 72 close-ended questions along with one open-ended question, which were designed to capture the online student participants' demographic and academic background information, prior experience and satisfaction with printed or digital textbooks, and perceived value toward a variety of textbook features for their learning experience. In terms of the questions for rating the perceived value of the given textbook features, participants were asked to rate these features on the four-point Likert scale, with 1 indicating *not valuable* and 4 indicating *very valuable*. Likert scales are widely adopted to measure individuals' attitudes, beliefs, and/or perceptions. The open-ended question asked the participants to provide three features that they wish could be added to the next generation of digital textbooks. They were allowed to skip the question or provide one or two features instead of three. Overall, the questions that were used in this survey allowed the researchers to explore general trends and perceptions toward digital textbooks among online students and thus draw insights into the design and development of advanced intelligent textbooks for the future of online education.

Regarding the analysis of multi-method quantitative and qualitative data, descriptive statistics were used to examine patterns of the quantitative response data in terms of frequency, standard deviation, and mean scores. In order to further compare the trends among the three institution sub-groups, chi-square statistics and one-way analysis of variance (ANOVA) were used. These data were analyzed by using the SPSS statistical software program. In addition to analyzing quantitative data collected from the close-ended questions, we also analyzed qualitative data collected from the open-ended question about the three desirable features that participants would like to add to future intelligent textbooks. Our coding analysis was guided by the grounded theory approach (Strauss & Corbin, 1990), which was suitable for our exploratory study. Our coding team consisted of a pair of

researchers, including the first author and her graduate research assistant. We began the analysis by generating initial codes that reflected general categories of features. Then, we expanded and revised the codes through an iterative process of carefully describing, classifying, and interpreting codes for both general features and their corresponding sub-features that emerged across cases.

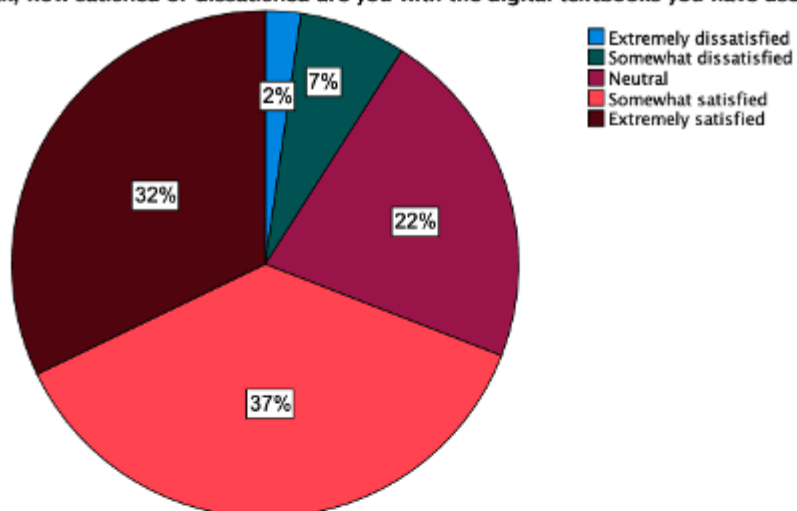
4. RESULTS

4.1 Quantitative Data: Online Students' Prior Experiences with Digital Textbooks

First, with respect to prior experience, most participants (i.e., 89%) appeared to have some experience with using digital textbooks for courses they completed. More than one-half of the total participants (i.e., 54%) reported that they had used 1–3 digital textbooks, 20% had used 4–6 digital textbooks, and 15% had used even seven or more digital textbooks. Approximately 11% of the total number of participants had never used digital textbooks for their courses. Regarding the usage of digital textbooks, many (i.e., 63%) responded that they usually read those chapters covered in their class and some others (i.e., 20%) used the textbook when they needed to review for their assignments, quizzes, or exams. However, only 10% of the total reported that they tried to read the entire book. Six percent rarely used the book, with the main reasons including finding it difficult to read on a computer or a mobile device or finding it not that useful to their study.

In general, our participants reported that they had satisfying experiences with digital textbooks, and 69% of the total chose *extremely* or *somewhat satisfied* (see Fig. 1). On the other hand, compared to their levels of satisfaction with digital textbooks that they have used, we observed that a substantial proportion of participants reported negative viewpoints toward reading digital textbooks in terms of its helpfulness in learning. About 55% of the total responded that they either strongly or somewhat agreed that reading printed textbooks is more helpful than reading digital textbooks (see Fig. 1). The participants' preferences were also examined by asking them to choose between printed and digital if the textbook for a course offers both versions. Only 28% reported that they would either buy or rent a digital version; 33% would either buy or rent a printed version; 36% would go with whichever is cheaper or available to borrow from the library; and the rest (4%) reported other opinions.

Overall, how satisfied or dissatisfied are you with the digital textbooks you have used?



How much do you agree or disagree that reading printed textbooks helps you learn better than reading digital textbooks?

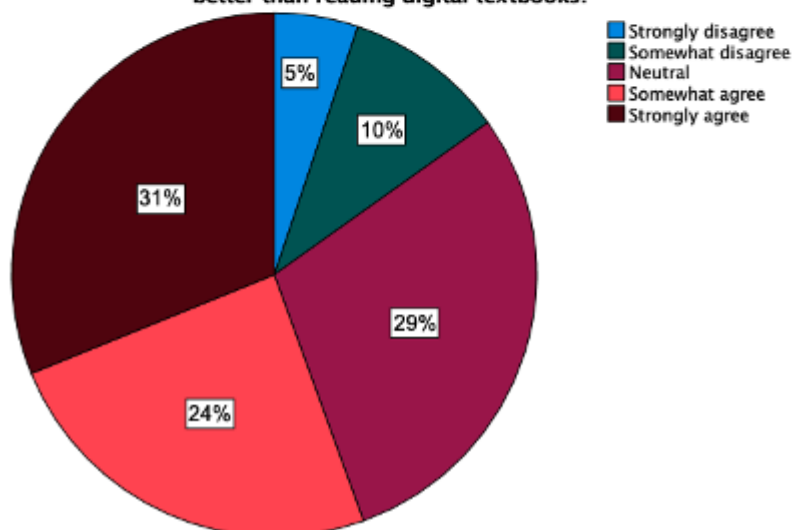


FIG. 1: Satisfaction with and perceived helpfulness of digital textbooks (in percentages)

To better understand how students' characteristics might affect the usage of digital textbooks, the participants were divided into three groups based on their affiliated institutions and then compared. We observed that participants who came from the public college (i.e., Institution III) had much more experience with digital textbooks, as indicated by only 3% of them reporting no experience, compared to 13% from the graduate-level programs (i.e., Institution I) and 11% from the technical college system (i.e., Institution II); within each institution group, $\chi^2(8, N = 1236) = 21.52, p < 0.01$. See Appendix A for detailed information. Similarly, the levels of overall satisfaction with digital textbooks varied among the participants across the three institutions. On the five-point Likert scale (with 1 being *very dissatisfied* and 5 being *very satisfied*), participants from Institution I reported significantly lower levels of satisfaction ($M = 3.71, SD = 0.96$), compared to those from the other two institutions that mainly offered associate or bachelor's degrees ($M = 3.97, SD = 1.01$ from Institution II; $M = 4.03, SD = 0.98$ from Institution III) [$F(2, 1101) = 8.26, p < 0.001$]. In contrast, the Institution I group reported significantly lower mean scores on the helpfulness

of reading printed textbooks ($M = 3.40$, $SD = 1.17$) compared to the Institution II group ($M = 3.77$, $SD = 1.16$) and Institution III group ($M = 3.71$, $SD = 1.10$) [$F(2, 1101) = 11.10$, $p < 0.001$]. These findings suggest that the degree of exposure to digital textbooks might be a factor in determining the level of satisfaction with using digital textbooks for courses, but not necessarily improving the perceived helpfulness in learning. Additionally, the participants' preference toward digital textbooks appeared to be similar across the three sub-groups. For example, the percentages of those who selected either buy or rent a digital version of a textbook were similar: 30%, 27%, and 31% for Institutions I, II, and III, respectively.

4.2 Quantitative Data: Online Students' Perceptions about Digital Textbook Features and Resources

Next, we examined the participants' perceived value toward various features and supplemental resources that are commonly available in digital textbooks. The participants' ratings were compared not only by the institution sub-group but also by whether they had previously interacted with the given features or resources.

We used two sets of questions about 11 common features of digital textbooks that asked the participants to rate how valuable each feature is to their learning. One question set was specifically designed to capture perceptions of those students who had used at least one digital textbook, and therefore had interacted with any of the given features (i.e., the experience group); while another question set was intended for those who had no prior experience with digital textbooks and their embedded features (i.e., the no experience group). Then, we compared the mean scores of the ratings between the two participant groups (see Fig. 2). As a result, we observed that both groups generally provided similar levels of ratings regarding each of the given features. The average rating scores ranged from 2.93 to 3.70 for the experience group and from 3.05 to 3.72 for the no experience group.

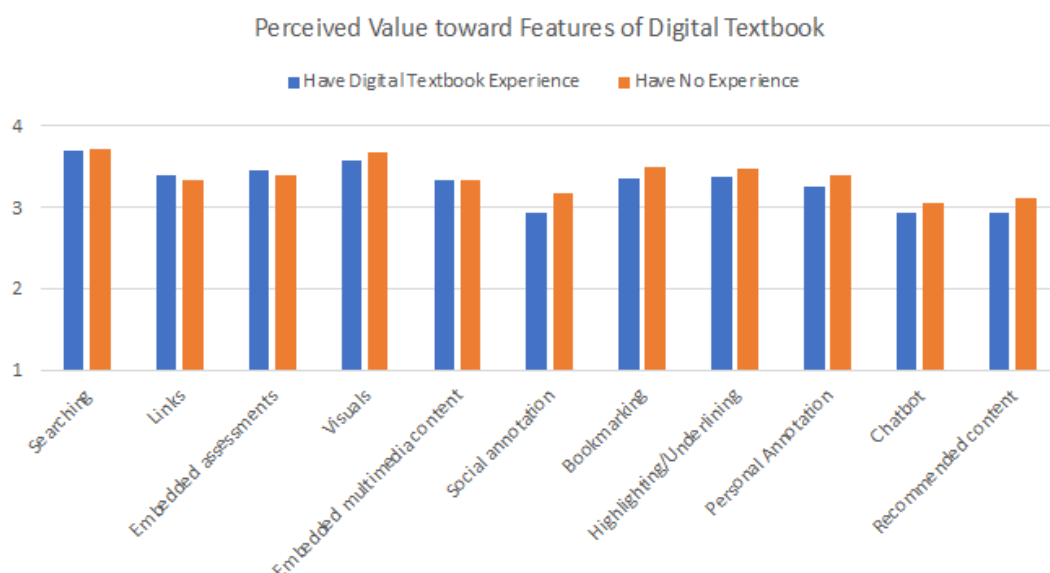


FIG. 2: Perceived value toward features of digital textbooks in average rating scores

Interestingly, both groups rated keyword searching and visuals that help illustrate related content as the most valuable features of digital textbooks to their learning. Furthermore, both groups perceived that social annotation (e.g., being able to comment or ask questions on specific texts), chatbot (e.g., getting automated responses regarding questions about the textbook content), and recommended content (e.g., content recommended based on a student's reading history) as the least valuable features. Additionally, in the mean level, the experience group showed slightly more positive perceptions compared to the no experience group toward those features closely related to self-directed learning, including embedded assessment (e.g., practice exercises and quizzes for feedback) and links (e.g., hyperlinks that direct the student to relevant places within or outside the textbook). On the other hand, the no experience group rated the bookmarking and highlighting/underlining features designed to enhance personalized learning more positively compared to the experience group. Other features that both groups rated as moderately valuable to learning included personal annotation (e.g., taking personal notes while reading) and embedded multimedia content that the student can click to play without navigating away from the textbook.

We further compared the ratings of these digital textbook features among the three institution sub-groups. We observed that, on average, the participants from Institution I generally provided the lowest ratings and those from Institution II reported the highest ratings. This pattern consistently appeared across almost all of the 11 features, except for the searching feature (see Table 2). Moreover, the one-way ANOVA test results indicated statistically significant differences among the three sub-groups in perceiving how valuable each of those features was in their online learning. However, the participants' ratings did not significantly differ regarding the searching feature [$F(2, 1065) = 0.69, p = 0.50$]. These results imply that, compared to the graduate-level students, technical or public college students might find the features of digital textbooks as more desirable in their online learning situations. It is also possible that the graduate students might have higher expectations about the features and functionality that digital textbooks can offer for their advanced learning.

Additionally, we asked the participants to rate their perceived value of a variety of supplemental resources that textbooks, whether digital or non-digital, typically include to support learning. Similar to the question about textbook features, the respondents were allowed to select the not applicable option if they had no experience with the given resource type. Notably, across all 10 types of supplemental resources, only about 10% of the total respondents reported that they had prior experience with each resource type and provided their ratings on the four-Likert scale. The average scores of the ratings (see Fig. 3) showed that the participants generally perceived the following as most valuable: resources that provided self-check questions to practice and check understanding of the book content; review questions that help the student reflect on what has been learned from the chapter; and flashcards used for defining and explaining glossary, concepts, or procedures. These trends suggest extra materials that can help online students' self-test knowledge and

TABLE 2: Mean and standard deviation of perceived value scores by institution sub-group

Digital Textbook Feature	Institution I		Institution II		Institution III	
	Mean	SD	Mean	SD	Mean	SD
Highlighting/Underlining	3.13	0.99	3.5	0.82	3.4	0.82
Links	3.28	0.86	3.45	0.77	3.35	0.88
Searching	3.72	0.66	3.68	0.67	3.75	0.55
Bookmarking	3.12	0.96	3.45	0.84	3.38	0.84
Personal annotation	2.94	1.02	3.39	0.87	3.32	0.88
Social annotation	2.37	1.08	3.14	1.00	3.03	0.98
Recommended content	2.45	1.03	3.14	1.00	2.97	0.99
Visuals	3.49	0.74	3.63	0.67	3.62	0.62
Embedded multimedia content	3.15	0.90	3.42	0.82	3.37	0.80
Embedded assessments	3.28	0.84	3.54	0.73	3.43	0.73
Chatbot	2.33	1.03	3.17	0.97	3.03	1.08

Note: SD – standard deviation.

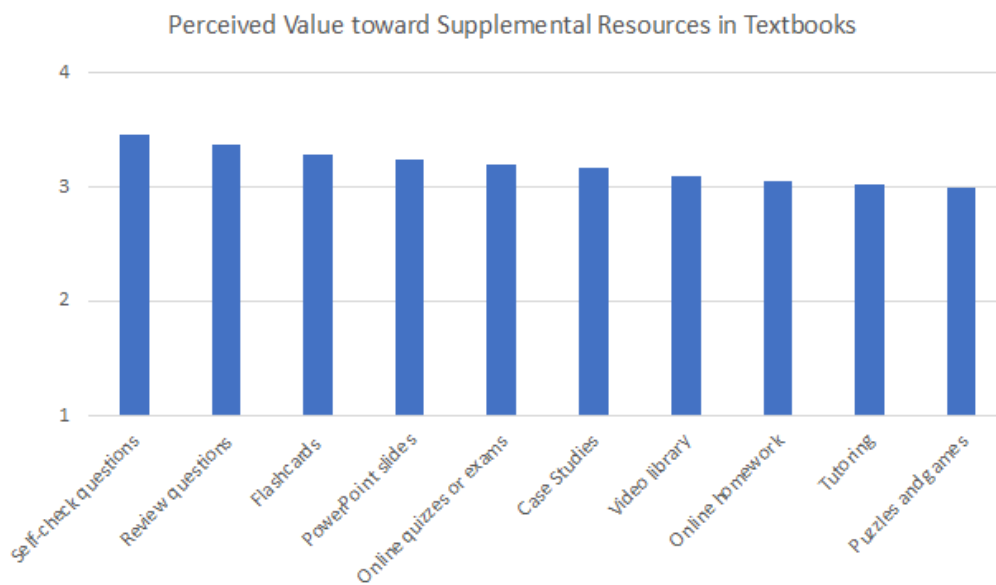


FIG. 3: Perceived value toward supplemental resources in textbooks in average rating scores

concepts they have learned from textbooks may be beneficial. Alternatively, resources rated as the least valuable to learning included puzzles and games designed to help the student reflect or apply concepts, paid tutoring sessions provided by the publisher, and online homework or extra student assignments requiring completion and submission on the book publisher's platform.

4.3 Qualitative Data: Desirable Features of Digital Textbooks for Online Students

The open-ended question on desirable features for the next generation of digital textbooks resulted in 671 features that were analyzable, from a total of 524 participant responses. Among those 524 participants, 34%, 60%, and 6% came from Institutions I, II, and III, respectively. The results of our coding analysis revealed various themes under two realms of experience, learning and usability. We were able to capture 656 mentions of learning-related features and 232 mentions of usability-related features. Within the learning realm, six themes emerged including: (1) multimedia learning, (2) self-directed learning, (3) personalized learning, (4) collaborative learning, (5) adaptive learning, and (6) teacher engagement, in the order of frequency. Within the usability realm, four themes, including (1) easier and flexible access, (2) more user control, (3) easier navigation, and (4) more affordable options were identified in the order of frequency. The results of the coding and example quotes are provided in Tables 3 and 4.

TABLE 3: Results of desired features of digital textbooks: learning related

Desired Feature (Total Number of Mentions)	Desired Sub-Feature	Example Quote	Number of Mentions
Multimedia learning (215)	Text-to-speech	“Built-in text-to-speech readers; read it out loud to me so I can take notes at the same time.”	67
	Interactive visuals	“Interactive animations; immersive 3D or AR/VR content; flash cards or games.”	52
	Embedded video/animation content	“Videos in the text to help better explain; embedded video solutions for end-of-chapter practice problems.”	49
	Audio book/dictation/recording	“Audiobook version of the whole textbook; Ability to record notes/thoughts.”	47
Self-directed learning (181)	Links to relevant examples and resources	“Feature that links to other related material in that domain; more related hyper link to resources.”	66
	Better searching	“Being able to search the word to find the chapter; Easier search tools.”	49
	Summary of chapter or section	“Chapter summaries of important content; AI based summary of the text.”	30

TABLE 3: (continued)

Desired Feature (Total Number of Mentions)	Desired Sub-Feature	Example Quote	Number of Mentions
Self-directed learning (181)	Dictionary/mouse-over word definition	“Hover over a word for the definition; auto-dictionary when words are highlighted; glossary.”	27
	Study guide	“Study guides or outlines for the content; AI based summary of the text.”	9
Personalized learning (151)	Highlighting, underlining	“Able to compile my highlighted text; show sentences underlined by most users like kindle does.”	53
	Personal annotation	“Inserting my own images/notes from class; add drawing or hand-written annotation.”	53
	Bookmarking	“More intuitive bookmarking feature.”	22
	Chatbot	“AI assistance (online bot that asks questions on topic.”	17
Collaborative learning (44)	Language translation	“Translation to other languages without needing a new book.”	6
	Communicating and collaborating with peers	“Text chat so students can have a conversation about the topic.”	26
Adaptive learning (37)	Social annotation	“Notes added from classmates; social annotation for classes inside of the digital textbook.”	18
	Adaptive embedded assessment with answers and feedback	“Add more self-tests; data analyzer of your progress and learning demonstration based on individual or cumulative tests.”	30
Teacher engagement (30)	Recommended content	“Smart recommendations on additional relevant content based on the material being covered.”	7
	Support from teacher/TA	“Being able to contact a professor while reading; email TA directly.”	23
	Teacher annotation	“Teacher content/notes added by teacher to emphasize important topics.”	7
Grand total			656

TABLE 4: Results of desired features of digital textbooks: usability related

Desired Feature (Total Number of Mentions)	Desired Sub- Feature	Example Quote	Number of Mentions
Easier and more flexible access (136)	Access from multiple devices	“Compatibility—being able to use on different devices; synchronization of notes across kindle, laptop, tablet, and phone.”	51
	Printable	“Page-to-page access that allows printing.”	45
	Downloadable or offline access	“Digital download for easier scrolling; ability to access e-book outside of online learning app.”	32
	Accessibility	“More accessibility for those who are disabled.”	8
More user control (52)	Changing font	“Mobile friendly so that size changes based on screen size; the ability to choose fonts that are personally easier for you to read.”	26
	Switching reading mode	“Dark mode friendly; eye comfort mode during long time reading.”	15
	Zooming	“Better zooming/enlarging.”	8
	Interface design	“Well-balanced textbook design.”	3
Easier navigation (24)	Between pages	“Easier access to enter and exit pages without closing the app; Scroll down option versus arrow page by page.”	16
	Between chapters	“Chapter tabs in the scrollbar; a table of contents that has links to each chapter.”	8
More affordable options (20)		“Making them affordable over high book prices; include free printed rentals.”	20
Grand total			232

In terms of the desired features relevant to online learning experience, the participants frequently mentioned various kinds of enhanced multimedia features that are typically unavailable in traditional paper textbooks, such as text-to-speech, interactive visuals, embedded video/animation content, and audio features such as recording. We also observed that the participants often perceived features that enable them to engage with self-directed learning as desirable for their future learning. These features include links to real-world examples or other resources relevant to the textbook topic, keyword searching tools, embedded dictionary, and chapter summaries or customized study guides. In addition to features that are related to personalized learning many participants were interested in collaborative features and social annotation features through which they can communicate with or seek help from their peers and teachers regarding the textbook content. It was

notable that the participants occasionally mentioned those features that use emerging technologies such as artificial intelligence in the form of chatbots, adaptive assessments, and smart recommendations based on the student's learning progress and needs.

With respect to features that are designed to enhance the usability of future digital textbooks, more than one-half of the responses pertained to promoting easier and more flexible access, compared to what current textbooks can offer. Such features included not only improving accessibility for disabled students, but also allowing users to access the textbook content from multiple devices (i.e., compatibility) and print or download pages. The participants also frequently noted they would like to see the type of features that can give users more control of font style, layout, and/or formatting on the digital textbook according to their preferences. Other usability-related features that were occasionally mentioned included enabling users to easily navigate between pages and chapters without having to manually scroll down or click around the next or previous page button as well as providing users with more affordable options to access digital textbooks through rental services or options to purchase the content at cheaper prices.

5. DISCUSSION

Our study findings reflect perspectives of diverse online student populations and thereby provide some useful implications for the design and development of intelligent textbooks for online education. Overall, these perspectives include those from online degree-seeking students who came from various demographic (e.g., age, gender, and race/ethnicity) and academic backgrounds (e.g., types of degree sought, class standing, and primary major). This study further explored the students' perspectives based on their levels of experience with digital textbooks.

The first research question examined online students' prior experience with and attitudes toward digital textbooks. Most participants across the three institution groups appeared to have at least some experience with using digital textbooks associated with their enrolled courses. However, our findings implied that the exposure to digital textbooks alone may not necessarily lead to a behavioral change toward adopting this new technology among online students. Our survey findings revealed a notable sense of resistance toward digital textbooks among many participants when they were given the choice between digital and traditional printed textbooks despite having positive prior experiences. This is consistent with findings from previous studies conducted among on-campus students (Cassidy et al., 2012; Dewan, 2012; Walton, 2014; Woody et al., 2010). These findings suggest that digital textbooks and supplementary digital resources need to be enriched and enhanced to become truly effective for student learning. Furthermore, since online students often have to independently navigate through extensive learning content, it becomes crucial for instructional designers and developers to engage in user research and usability testing. This will provide valuable insights into the specific needs of online students and ensure that the features in intelligent textbooks are intuitive and efficient and align with their expectations.

Moreover, our findings emphasize the importance of addressing varying levels of expectations and satisfaction with digital textbooks based on such factors as online students' academic background and class level. Understanding these nuances can further enhance the effectiveness of digital textbooks for different online student populations, and therefore improve the overall experience of online students using digital textbooks.

The second research question delved into how online students would perceive various features and resources available in digital textbooks. Our findings suggested that online students tended to prefer to see multimedia-related features with enhanced visual elements, interactivity, and modality. Indeed, such features offer unique advantages over traditional textbooks since they provide an immersive learning experience that traditional formats cannot typically afford. In addition, consistent with previous research studies conducted on on-campus students (Dobler, 2015; Lim & Hew, 2014; O'Bannon et al., 2017), our study found that participants from all three institutions commonly recognized the search feature of digital textbooks as highly valuable to their learning. However, surprisingly, participants in general did not place significant value on the personal annotation feature, which is contrary to findings from previous studies that examined traditional residential students (Abaci et al., 2019; Lim & Hew, 2014; McFall et al., 2006; Simon, 2001). It was notable that this trend was even more pronounced among the online graduate students from Institution I.

On the other hand, our findings indicated that AI-supported features, such as chatbots and recommended content, ranked among the least valuable aspects of digital textbooks for enhancing learning performance. One possible explanation for these low ratings could be the limited exposure or experience online students have had with these features. In fact, we observed that the students' experiences with intelligent features currently available in digital textbooks remained quite limited. Their lack of familiarity with the AI-based tools might influence their perception and result in lower ratings. We should consider taking steps to raise awareness among online students regarding these features and help them better understand how they can benefit their learning. For example, publishers should consider developing learner guides that demonstrate how to effectively utilize a variety of intelligent features, including interactive multimedia content embedded in digital textbooks based on evidence supporting the benefits of using those features in online learning.

The final research question examined the types of features that online students would like to prioritize for the next generation of digital textbooks. Despite the limited experience with intelligent features of digital textbooks among the participants in general, our findings suggest that AI technologies have potential to enhance the capabilities of future digital textbooks as envisioned by online students. In other words, AI technologies are poised to play an essential role in building a learning platform that aligns with the goals researchers and developers of intelligent textbooks have tried to achieve, aiming to make digital textbooks effective for self-directed and personalized learning, adaptive content, and collaborative interactions (Ou et al., 2022; Clinton-Lisell et al., 2023). Our findings also corroborate the emerging pedagogical framework for designing interactive and intelligent components of digital textbooks (Ou et al., 2022). Particularly, our study highlights the high

value participants placed on features that can promote self-directed learning, irrespective of their prior academic experience. To support self-directed learning among online students, the utilization of chatbots or intelligent tutors can be instrumental in providing timely assistance when students encounter learning challenges or generating automated feedback on practice questions. AI technologies can also be used to improve customized reading experiences or offer adaptive content, including assessments with personalized answers and feedback based on individual learners' levels of understanding of the textbook content. In terms of encouraging collaborative learning, AI-based social matching systems (Wang et al., 2022) can facilitate connections among online students, enabling active engagement in the social annotation process or providing opportunities for shared reading and collaborative learning.

Finally, our qualitative findings highlighted the need to consider making intelligent textbooks more affordable and more easily accessible to cater to diverse online student groups. Consistent with prior research (McDaniel & Daday, 2018), the cost effectiveness of textbooks appears to significantly influence students' preferences for digital or printed formats in online learning environments. Our study revealed that a considerable number of participants reported a tendency to make their textbook choice based on affordability, either by purchasing it in either format or by opting to borrow it from the library if available. It is also noteworthy that our participants often mentioned their needs for accessing textbook content in various modes, via printing, audio, or text-to-speech options. In light of these findings, publishers and educational institutions may consider developing strategies aimed at enhancing students' experiences with digital textbooks in online learning environments. These strategies may include offering more cost-effective alternatives and more flexible options to access the content to meet students' preferences and reduce financial burdens.

However, our study has several limitations. First, given the exploratory nature of this study, future research should conduct qualitative studies involving semi-structured interviews or focus groups to get an in-depth understanding of online students' needs and usage of digital textbooks. Additionally, while our study adds value to existing literature by comparing varying perspectives among students who came from diverse disciplines and programs, our data set reflects somewhat unbalanced sample sizes across the three institutions. Further research is needed to replicate the comparison analysis with expanded and evenly distributed data to validate our findings and test how not only students' institution but also their major would be related to their perceptions toward digital textbooks. In addition, our findings primarily relied on students' reflections of their prior experiences with textbooks or pre-conceived notions about textbook features, instead of directly testing the usability of such features. Future studies should consider investigating how online students interact with various digital textbook features that are interactive and intelligent in actual learning situations.

6. CONCLUSIONS

In conclusion, our survey study examined diverse online students' perspectives toward the usage and value of digital textbooks, providing valuable insights into what the future of intelligent textbooks will look like. Based on our study findings, we observed that the exposure to digital textbooks alone is insufficient to drive widespread adoption or increase perceived helpfulness in learning among online students, suggesting the need to develop evidence-based learning guides for digital textbook users. Additionally, despite online students' limited awareness or experience with intelligent features, our findings underscore the potential of AI technologies to augment future digital textbooks and thereby enhance online learning and engagement. Furthermore, addressing the affordability and accessibility of digital textbooks appears to be crucial to meet the diverse needs of online students. By considering these findings, publishers and educational institutions can pave the way for facilitating a more effective and inclusive digital textbook learning experience.

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APPENDIX A.

In Table A1, we compare students' prior experiences with digital textbooks.

TABLE A1: Comparison of students' prior experience with digital textbooks

Number of Digital Textbooks Used	Institution I		Institution II		Institution III		Total Institutions	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
1–3	176	49	440	56	52	55	668	54
4–6	70	20	157	20	21	22	248	20
7–9	20	6	56	7	9	10	85	7
More than 9	44	12	50	6	9	10	103	8
None	46	13	83	11	3	3	132	11
Total	356	100	786	100	94	100	1236	100