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A Digital Book Based Pedagogy to Improve Course Content Accessibility for Students with and without Disabilities in Engineering or other STEMcourses (WIP)

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Abstract

Accessibility of course content plays a critical role in student success. Among all college students, students with disabilities (SWD) face numerous additional challenges when digital content is inaccessible or difficult to use. The main contributions of this paper are firstly we examined different course delivery modalities to identify components that engage both SWD and students without disabilities (SWOD) and secondly, present new accessibility features for digital book creation that were implemented at the University of Illinois. An equitable, inclusive design for everyone is our ultimate goal, but we also wanted to understand the needs, and preferences of, SWDs in particular. A national survey instrument by the Collegiate Student Assessment of Textbooks (CSAT) to study student preferences was adapted and supplemented with questions that allowed students to optionally identify as SWD with a physical, mental and/or emotional disability. This survey enabled an analysis of the textbook preferences for engineering students with and without disabilities. Results from 50 SWD and 48 SWOD indicated that SWD and SWODs prioritized similar features. The main significant difference between SWD and SWOD were in the responses about how the instructor used the textbook and the importance of graphs in the textbook. The SWDs cared strongly about the accessibility features of a textbook. The top-five desired-features among all students were: 1) The book is low-cost or free, 2) There is a search feature for the book, 3) The book is up to date, 4) The examples used in the book matched the definitions, 5) The examples used in the book are relevant. Faculty were also surveyed using the same questions, providing insight into areas of alignment in preferences between students and faculty. Data from 10 faculty revealed similar textbook preferences: 1) The book is up to date, 2) Examples are representative of the definitions provided, 3) The book is low-cost or free, 4) The book is available online and as print copy, 5) The examples are relevant. Among the textbook features, all students were least interested in being called on during class with questions from the book. Additionally, SWDs did not value features pertaining to how the instructor used the textbook. By understanding the needs of SWD and SWOD, a faculty member can be informed about techniques to increase content accessibility. Secondly, we identified and designed new accessibility functionalities, including a visual table of contents, accessibility tags, and conditional publishing on students and instructors with a focus on meeting the needs of SWD. Recommendations and techniques are offered for instructors wishing to develop digital books to provide more accessible content delivery.

Introduction

National statistics by the NSF and NCES report that 19% of the 4-year undergraduate population have a disability [1]. Students with disabilities (SWD) face numerous additional challenges when digital content is inaccessible or difficult to use. Accessibility for SWD using Universal Design of Learning (UDL)-based methodologies is recognized as a best practice [2–5].

Engineering education researchers have previously reported that SWDs preferred searchable lecture video with transcriptions for the content delivery compared with students without disability (SWOD) [2]. Furthermore, the statistical analyses reported in SIGCSE and ASEE and one-on-one student interviews in the past showed all students in a course benefited from multiple modalities of content delivery in online learning [2, 3]. In addition, previous results found students would have wanted lecture video with transcripts and/or a course textbook, unfortunately these were often unavailable [2].

Building upon the above needs and findings, we investigated a digital book-based pedagogy to facilitate content delivery for SWDs and SWODs. For this purpose, we surveyed the perspectives of both students and faculty about textbook features and prototyped a method of digital book generation using course lecture videos with transcriptions as a base.

Background

Despite the significant role of textbooks for college students' learning, surveys have found that students avoid buying assigned textbooks and access codes to online textbooks. The situation has been even more negatively impacted by the COVID-19 pandemic [6]. Among all college students, SWD students face even more challenges regarding the accessibility of course content. Universal Design For Learning, described next, is one framework to help make course accessible for all students.

Universal Design for Learning (UDL)

UDL is a pedagogical framework and set of principles to improve learning for all students by emphasizing the importance of accommodating multiple modes of student learning, action, and engagement. The three core practices of UDL are 1) multiple modes of content delivery to students for learning should be offered; 2) students should have multiple ways of expressing their learning; 3) students should be engaged with and motivated to learn in multiple ways [7]. Based on the UDL principle of multiple modes of content delivery, previously researchers have found that SWDs in engineering have a preference towards recorded lecture videos with transcripts, course textbooks, and instructor notes/slides [2].

Adoption of UDL-based technologies in engineering education

In addition to standard modalities used to deliver content, engineering classes in Computer Science, Electrical & Computer Engineering, Industrial and Enterprise Systems Engineering, and Bioengineering at the University of Illinois Urbana-Champaign have used ClassTranscribe, a new accessible video platform based on UDL principles, to provide students with multiple pathways to access video content. Using this tool, students can view and review recorded live content asynchronously, optionally read the captions and live transcriptions, read transcriptions in

alternative languages, and search for relevant content across an entire course. Recent work, presented at ASEE, explored how students searched captions of a course to learn [8]. Though captions are beneficial to students who are hard of hearing or deaf, the equivalent text representation of the audio stream benefited the class as a whole. An overview of the UDL features of this tool were presented previously [9]. Peer-reviewed course performance models and student feedback showed that searching as a new modality was correlated with positive perceptions and improved student performance [3, 9]. In addition, as an open-source extensible platform it has the potential to be used for digital book creation.

Measurement of the impact of textbook features

Objective assessment of pedagogical features of textbooks is importance to the textbook industry and educational researchers. Two standardized national instruments for assessing the impact of textbooks had been developed [10]. One of the tools is the Collegiate Student Assessment of Textbooks (CSAT). This survey instrument included nine factors for the assessment. The study measured the factor scales including purchasing for learning and understanding, as requirement and cost, and preferences for practical applications, convenience, accessibility, availability of tables, graphs, study aids, and importance of the instructor's recommendation and ease of use. We used 6 of the 9 factors; the first three purchasing factors were irrelevant because we wished to create free digital books using lecture videos as a source.

Digital book development features

Digital books comprise text and visual media content that have been structured into sections and subsections. Scholastic works designed for university level education may further provide visual elements that clearly identify definitions, examples, transcripts and captioned figures. Digital books provide a compelling, text-based alternative to live lecture and video expositions and support linear reading, searching, skimming and review activities by the student. Rather than suggest that a particular student will elect one modality over the other, the authors suggest that some students will employ multiple modalities at different times. For example, a student may prefer to attend a lecture but refer to the book when riding on a bus or working on a homework problem. Compared to the traditional print publications, digital content offers improved accessibility including screen reader compatibility and study tools including bookmarks, annotations, links, and hyperlinked references. Digital books can be created using multiple formats and platforms. Proprietary editing office tools including Microsoft Word can be used to author content which is then shared in its finalized form typically Adobe Portable Document Format (PDF). Other authoring environments include OverLeaf (a collaborative latex-editing website that generates pdf documents), MarkDown-based Wikis and Pandoc, a set of open-source build tools designed for book creation. A lesser known but powerful open standard book format is the EPUB digital book format. The most recent version of the EPUB standard is 3.2 [11]. This format can be edited, published as a physical book, and easily transformed into other formats including HTML and PDF. Though EPUB content is a set of structured HTML elements, it requires significant knowledge to create a conforming and accessible document. We therefore created an editor based on MarkDown to simplify content creation and automated the processes to convert the markdown text, equations, and captioned images into a valid EPUB document zip-archive that is comprised of embedded images, style sheets, a table of contents, meta

information, and HTML objects for each chapter of the book.

Methods

Survey Design

We developed the survey to identify which textbook features students and faculty desired for the purpose of digital book creation from lecture videos. There were 6 relevant factors listed below, from a validated national survey, the College Student Assessment of Textbooks (CSAT), to measure in our study [10].

1. Practical application to student's lives and convenience (P).
2. Accessibility (A).
3. Graphs and tables (G).
4. Study aid use (S).
5. Instructor use of the textbook (I).
6. Ease of use (E).

Table 1 shows the corresponding multiple questions for each of these factors.

The survey consisted of Likert scale questions that measured the above factors, and questions on student demographics. The Likert scale questions were organized into two groups. The first group of questions asked about student preferences about textbooks while the second asked about students' use of textbooks (the likelihood that students would use a provided textbook). The survey was approved by the university IRB and five $100 Amazon gift cards were raffled out to participants.

The survey was designed to address the following research questions:

1. What are the highest-ranked (most important) textbook features for all students?
2. What are the highest-ranked textbook features for faculty?
3. Are there differences between SWD and SWOD regarding textbook features?
4. Are there differences in interest of textbook features between students who reported as male or female?

With the ultimate aim of creating inclusive and equitable educational resources where all students can thrive, this research asked demographic information and subsequently analyzed student responses both as a single group but also aggregated by disability and genders, to better understand individuals' needs.

Demographics

The survey included students from 69 courses which were mainly in Engineering or other STEM subjects that Engineering students in the University of Illinois Urbana-Champaign took. Students

	Question	Code
1	Core ideas are presented.	P
2	Key terms are listed at he end of the chapter.	P
3	Ideas are presented on a simple level.	P
4	Glossary terms are presented at the end of a chapter.	P
5	Glossary terms are presented at the back of the book.	P
6	Concrete examples are used to help me understand and remember.	P
7	The examples used in the book are relevant.	P
8	The examples used in the book really match the definitions provided.	P
9	Ideas and examples in the textbook connect to earlier sections.	P
10	Glossary terms are presented throughout the chapter.	P
11	The book is accessible online as well as a print copy.	A
12	The book is accessible on a tablet, phone, or other mobile device.	A
13	There is a search feature for the book.	A
14	There are lots of graphs in the book.	G
15	There are lots of tables in the book.	G
16	The graphs and figures have alt text or hyperlinks.	A
17	Reviews are included that involve matching terms with definitions.	S
18	Multiple choice review questions are included throughout the chapters.	S
19	Discussion questions are included.	S
20	Reviews are included that involve fill in the blank answers.	S
21	Each section concludes with a summary of the basic points.	S
22	The concepts are simplistic.	S
23	Quizzes are given over the book content.	I
24	Homework is assigned from the book.	I
25	An instructor lectures follow the book.	I
26	An instructor calls on students in class with questions from the book material.	I
27	In-class activities involve concepts in the book.	I
28	The instructor refers back to the book often.	I
29	End of chapter summaries are included.	E
30	I understand the vocabulary used.	E
31	Key points are summarized in a bullet format.	E
32	Difficult words are defined.	E
33	There is a searchable interface.	E
34	Tough concepts are summarized with figures/tables.	E
35	It takes little effort to learn quickly from the book.	E
36	The book is low-cost or free.	A
37	The book is up to date.	P

Table 1: The survey questions.

were given the option not to disclose a disability or their gender. The survey collected 112 responses comprising 10 faculty and 102 undergraduate students in STEM courses. Among the students, 50 were self-identified as SWDs while 48 were SWODs. There were 40 disclosed

Faculty	Student	SWD	SWOD	Undisclosed	Male	Female	Undisclosed	Mental SWD	Female SWD	Total
10	102	50	48	4	38	54	10	40	30	112
8.93%	91.07%	49.02%	47.06%	3.92%	37.25%	52.94%	9.80%	39.22%	29.41%	100.00%

Table 2: Demographics

cognitive or mental disabilities and 30 female SWDs. The demographics are shown in Table 2.

Data Analysis

The survey data was first anonymized and cleaned. Then Cronbach's α was used to check the consistency of the data, finding metric values to be 0.64 and 0.93 for faculty and students respectively. This indicates a moderate to high consistency of the ratings within each scale.

Integer values 1-5 were assigned to the Likert usage/satisfaction responses. The Likert responses were on a scale from 1 (Strongly disagree/Do not prefer) to 5 (Strongly agree/Prefer a great deal). Values 4,5 indicated positive response, 1,2 indicated a negative response and 3 indicated a neutral response. For students' and faculty rank of textbook features, the medians of the scores were used to rank the features. The differences between SWD and SWOD respondents as well as between Female vs Male respondents were compared using a non-parametric Mann-Whitney U test due to the ordinal nature of the data [12]. Due to the large number of statistical tests performed, we also report an adjusted p-value that corrects for multiple comparisons using a false discovery rate (FDR) controlling procedure [13].

The factor level difference between SWD and SWOD responses was analyzed and for Female vs. Male by aggregating the responses for questions in each factor (factor composition is listed in Table 1) for every student before comparing SWD and SWOD responses.

Creating Digital Books from Videos

Based on our research surveys and feedback from students the following desirable features were identified:

1. The book will be most up to date according to the specific subject and instructor and use the same formalism and definitions.
2. The book contents should be focused on the course content and pedagogically equal to content presented in other formats.
3. The book should be free.
4. The book contents should be searchable.
5. The book contents can be hyperlinked to other contextual course components and vice versa.
6. The book will be available in both online and in print copy through pdf.

We created a system to automatically convert a recorded video into a digital book that includes the presented content and the spoken transcript. Creation of the book includes several automated

steps, a simple web-based editing interface and code to automatically assemble the book into the desired output format (e.g. EPUB, pdf, zip). Additional details about the conversion process can be found in the appendix.

The web interface presents the lecture transcript text inside an editable markdown component to allow additional editing. The author can also add captions to each image and edit book metadata including book title and author name. An example of the editing interface is shown in Fig. 1 and Fig. 2. In these figures, a book was being created for a probability and statistics course. As seen in Fig. 1, book chapters and subchapters can be created using the extracted images. Each book section starts with a representative image and image description. The extract of the transcript, seen in Fig. 2 below the image, is editable. The interface also allows for additional images and text to be included.

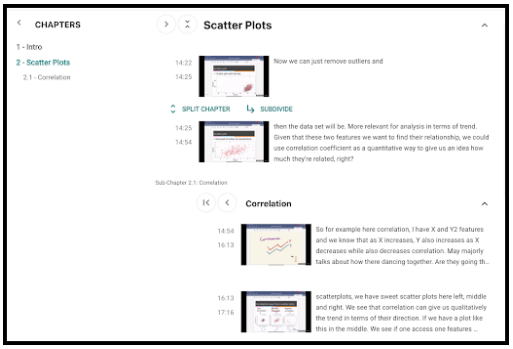

Figure 1: The digital book structure editing interface

Figure 2: The digital book chapter editing interface

Results

Top-ranked textbook features for all students and faculty

From the students responses, the top desired features of a textbook were 1) The book is low-cost or free, 2) There is a search feature for the book, 3) The book is up to date, 4) The examples used in the book really match the definitions, 5) The examples used in the book are relevant, 6) There is a searchable interface, 7) Concrete examples are used to help me understand and remember, 8) The book is accessible online as well as a print copy, 9) I understand the vocabulary used and 10) Core ideas are presented. For each of these features, more than half of the students considered it a top feature and more than 80% of the students considered it positively. Table 3 lists all the features in descending order of preference.

Among these features, “Search feature”, “The book is low cost or free”, and “Accessible online and “Print a copy” belonged to the accessibility factor of a textbook. This demonstrates that students in general consider textbook accessibility a top priority. Four other top desired features belonged to the practical applications and convenience factor of a textbook. Notably, three of them were about examples. We found that students in general valued the relevancy of examples, whether the definitions match with examples, and whether the examples helped them understand the content. In contrast to the CSAT survey that was originally applied to college students of psychology major, the surveyed Engineering/STEM students considered good examples as the

most important for practical application of a textbook while two of these subscales ranked among the lowest three in the original CSAT survey [10].

The faculty's rank of textbook features is shown in Table 4. The top desired features of a textbook by the faculty were 1) The book is up to date, 2) Examples used in the book are representative of the definitions provided, 3) The book is low-cost or free, 4) The book is accessible online as well as a print copy, 5) The examples used in the book are relevant, 6) The book is accessible on a tablet, phone or other mobile device, 7) There is a search feature for the book, 8) There is a searchable interface, and 9) I believe that creating custom materials for my course is important. The data shows a similar preference pattern from the faculty when compared with students. One notable difference is that the faculty care more about the textbook being up-to-date. Overall, the top 5 desired features of textbook by students and faculties combined were 1) The book is low-cost or free, 2) The book is up to date, 3) There is a search feature for the book, 4) The examples used in the book really match the definitions provided, and 5) The examples used in the book are relevant as shown in Table 5.

Differences between SWD and SWOD

Table-6 summarizes the statistical differences between SWD and SWOD responses. After the comparison between SWD and SWOD for each question, the notable major differences were in their responses to "Ideas and examples in the textbook connect to earlier sections" ($p < 0.008$, 54% SWD vs 75% SWOD), "There are a lot of tables in the book" ($p < 0.008$, 34% SWD vs 54.17% SWOD), "In-class activities involving concepts in the book" ($p < 0.019$, 42% SWD vs 60.42% SWOD), "there are lots of graphs in the book" ($p < 0.023$, 34% SWD vs 50% SWOD), "an instructor lectures follow the book" ($p < 0.026$, 54% SWD vs 70.83% SWOD), " the instructor refers back to the book often" ($p < 0.038$, 34% SWD vs 56.25% SWOD), "the examples used in the book are relevant" ($p < 0.046$, 88% SWD vs 91.67% SWOD). Overall, SWDs had lower preferences for those features than SWODs. These findings suggest that some SWD may have disabilities that added a hardship to benefiting from in-class activities, while others who used a screen reader did not benefit from a lot of tabular data. Without additional research these interpretations are conjectures; other interpretations are possible.

We analyzed the preferences of SWD and SWOD at the textbook factor level. SWDs valued most about the accessibility and the ease of use factor of a book. More than half of the SWDs ranked accessibility as a top feature (score of 5) while the factor "the ease of use" received positive responses from 78.57% of SWDs. Practical applications and convenience were also highly valued (72.68% positive responses). In comparison, more than half of the SWODs scored ease of use, practical applications and convenience, accessibility, and study-aid with 4 points while 80.06% of SWODs considered ease of use positively (Table-7). SWDs have significantly different opinions about instructor use of the book ($p < 4.68e^{-4}$, FDR $p < 0.0015$) and the use of graphs and tables ($p < 5.16e^{-4}$, FDR $p < 0.0015$) than SWODs. Notably, only 34.69% SWDs responded positively about graphs and tables while 52.63% SWODs responded positively. As for instructor use of the book, only 40.8% SWDs considered it positively while 49.65% SWODs responded positively. The factor of how the instructor uses the book was the least important to all students, particularly for SWDs. We also analyzed the preferences of male and female SWDs, but there were no statistically significant differences.

	Question	Mean	Median	STD	Positive rates
1	The book is low-cost or free.	4.578	5.0	0.849	88.24%
2	There is a search feature for the book.	4.539	5.0	0.792	90.2%
3	The book is up to date.	4.500	5.0	0.887	86.27%
4	The examples used in the book really match the definitions provided.	4.490	5.0	0.741	87.25%
5	The examples used in the book are relevant.	4.480	5.0	0.714	89.22%
6	There is a searchable interface.	4.471	5.0	0.792	87.25%
7	Concrete examples are used to help me understand and remember.	4.461	5.0	0.767	88.24%
8	The book is accessible online as well as a print copy.	4.324	5.0	1.055	82.35%
9	I understand the vocabulary used.	4.304	5.0	0.952	84.31%
10	core ideas are presented.	4.265	5.0	0.911	82.35%
11	Ideas are presented on a simple level.	4.235	5.0	1.007	76.47%
12	Difficult words are defined.	4.225	5.0	1.043	77.45%
13	Each section concludes with a summary of the basic points.	4.216	4.5	0.940	78.43%
14	It takes little effort to learn quickly from the book.	4.176	4.0	0.861	78.43%
15	Key points are summarized in a bullet format.	4.118	4.0	1.008	74.51%
16	Tough concepts are summarized with figures/tables.	4.108	4.0	0.964	79.41%
17	End of chapter summaries are included.	4.029	4.0	1.076	71.57%
18	Key terms are listed at the end of the chapter.	4.010	4.0	1.182	69.61%
19	Ideas and examples in the textbook connect to earlier sections.	3.951	4.0	0.958	65.69%
20	The concepts are simplistic.	3.931	4.0	1.180	70.59%
21	The book is accessible on a tablet, phone, or other mobile device.	3.814	4.0	1.249	65.69%
22	An instructor lectures follow the book.	3.706	4.0	1.207	62.75%
23	Glossary terms are presented throughout the chapter.	3.647	4.0	1.232	58.82%
24	Multiple choice review questions are included throughout the chapters.	3.618	4.0	1.081	51.96%
25	Glossary terms are presented at the end of a chapter.	3.480	4.0	1.295	50.98%
26	In-class activities involve concepts in the book.	3.382	4.0	1.290	50.98%
27	Reviews are included that involve matching terms with definitions.	3.490	3.5	1.257	50.0%
28	There are lots of tables in the book.	3.373	3.0	1.071	45.1%
29	There are lots of graphs in the book.	3.363	3.0	1.106	43.14%
30	Quizzes are given over the book content.	3.324	3.0	1.299	46.08%
31	The instructor refers back to the book often.	3.284	3.0	1.238	45.1%
32	Homework is assigned from the book.	3.206	3.0	1.300	42.16%
33	Glossary terms are presented at the back of the book.	3.196	3.0	1.267	41.18%
34	The graphs and figures have alt text or hyperlinks.	3.157	3.0	1.311	40.2%
35	Reviews are included that involve fill in the blank answers.	3.059	3.0	1.233	34.31%
36	Discussion questions are included.	3.049	3.0	1.189	34.31%
37	An instructor calls on students in class with questions from the book material.	2.431	2.0	1.361	21.57%

Table 3: The students' rank of textbook features

Differences between male and female students

At the individual question level, female students had significantly lower preference to "an instructor calls on students in class with questions from the book material" than male ($p < 0.001$,

	Question	Mean	Median	STD	Positive rates
1	The book is up to date.	4.8	5.0	0.632	90.0%
2	The examples used in the book really match the definitions provided.	4.7	5.0	0.675	90.0%
3	The book is low-cost or free.	4.7	5.0	0.675	90.0%
4	The book is accessible online as well as a print copy.	4.6	5.0	0.843	80.0%
5	The examples used in the book are relevant.	4.3	5.0	1.160	70.0%
6	The book is accessible on a tablet, phone, or other mobile device.	4.2	5.0	1.135	70.0%
7	There is a search feature for the book.	4.2	5.0	1.135	70.0%
8	There is a searchable interface.	4.2	5.0	1.135	70.0%
9	I believe that creating custom materials for my course is important	4.2	5.0	1.317	80.0%
10	Core ideas are presented.	4.4	4.5	0.699	90.0%
11	I understand the vocabulary used.	4.3	4.5	0.823	80.0%
12	I care about accessibility	3.9	4.5	1.595	80.0%
13	Concrete examples are used to help me understand and remember.	4.3	4.0	0.675	90.0%
14	In-class activities involve concepts in the book.	4.2	4.0	0.789	80.0%
15	Ideas and examples in the textbook connect to earlier sections.	4.0	4.0	0.943	80.0%
16	Tough concepts are summarized with figures/tables.	3.8	4.0	1.229	60.0%
17	I try to make all course materials accessible	3.7	4.0	1.494	80.0%
18	Each section concludes with a summary of the basic points.	3.7	4.0	0.949	60.0%
19	Difficult words are defined.	3.7	4.0	1.160	60.0%
20	Key points are summarized in a bullet format.	3.3	3.5	0.823	50.0%
21	It takes little effort to learn quickly from the book.	3.6	3.0	1.265	40.0%
22	End of chapter summaries are included.	3.3	3.0	1.160	40.0%
23	The graphs and figures have alt text or hyperlinks.	3.2	3.0	1.317	40.0%
24	Ideas are presented on a simple level.	3.1	3.0	1.287	40.0%
25	There are lots of graphs in the book.	3.0	3.0	1.155	30.0%
26	Homework is assigned from the book.	3.0	3.0	1.155	20.0%
27	Discussion questions are included.	2.9	3.0	0.568	10.0%
28	Quizzes are given over the book content.	2.9	3.0	0.738	20.0%
29	There are lots of tables in the book.	2.8	3.0	0.789	10.0%
30	Glossary terms are presented at the end of a chapter.	2.7	3.0	1.160	30.0%
31	Reviews are included that involve matching terms with definitions.	2.7	3.0	1.252	20.0%
32	I use Universal Design for Learning (UDL) principles in my course	2.6	3.0	1.506	30.0%
33	Multiple choice review questions are included throughout the chapters.	2.5	3.0	0.972	10.0%
34	Reviews are included that involve fill in the blank answers.	2.5	3.0	1.080	10.0%
35	Key terms are listed at the end of the chapter.	2.7	2.5	1.337	30.0%
36	Glossary terms are presented throughout the chapter.	2.7	2.5	1.160	20.0%
37	The concepts are simplistic.	2.5	2.0	1.080	10.0%
38	Glossary terms are presented at the back of the book.	2.3	2.0	1.160	20.0%

Table 4: The faculty's rank of textbook features

	Question	Mean	Median	Positive rates
1	The book is low-cost or free.	4.589	5.0	88.39%
2	The book is up to date.	4.527	5.0	86.61%
3	There is a search feature for the book.	4.509	5.0	88.39%
4	The examples used in the book really match the definitions provided.	4.509	5.0	87.5%
5	The examples used in the book are relevant.	4.464	5.0	87.5%

Table 5: The top combined rank of textbook features

Question	Mean SWD	Mean SWOD	Median SWD	Median SWOD	Positive SWD	Positive SWOD	p value	corrected p value
Ideas and examples in the textbook connect to earlier sections.	3.68	4.208	4.0	4.0	54.0%	75.0%	0.008	0.157
There are lots of tables in the book.	3.08	3.646	3.0	4.0	34.0%	54.17%	0.008	0.157
In-class activities involve concepts in the book.	3.06	3.688	3.0	4.0	42.0%	60.42%	0.019	0.192
There are lots of graphs in the book.	3.10	3.604	3.0	3.5	34.0%	50.0%	0.023	0.192
An instructor lectures follow the book.	3.46	3.938	4.0	4.0	54.0%	70.83%	0.026	0.192
The instructor refers back to the book often.	3.04	3.521	3.0	4.0	34.0%	56.25%	0.038	0.235
The examples used in the book are relevant.	4.36	4.625	4.5	5.0	88.0%	91.67%	0.046	0.245

Table 6: Statistical comparison of SWD and SWOD responses

FDR $p < 0.017$, 14.81% female vs 28.95% male). This question received the lowest responses among all questions. Female students also reported to have lower preference in "A lot of graphs" and "Homework assigned from textbook" compared to male students (see Table-8).

The analysis at the textbook factor level revealed female students were significantly less interested in the instructor use of book than male students ($p < 1e^{-5}$, FDR $p < 5e^{-4}$) and female students were less interested in graphs and tables ($p < 0.0055$, FDR $p < 0.017$).

Factor	Mean SWD	Mean SWOD	Median SWD	Median SWOD	Positive SWD	Positive SWOD	p value	corrected p value
Instructor Use	3.023	3.417	3.0	3.0	40.8%	49.65%	$4.68e^{-4}$	0.0015
Graph	3.092	3.632	3.0	4.0	34.69%	52.63%	$5.16e^{-4}$	0.0015
Practical	4.009	4.153	4.0	5.0	72.68%	73.11%	0.032	0.063
Accessibility	4.160	4.004	5.0	4.0	77.2%	69.58%	0.042	0.063
Ease	4.183	4.244	4.0	5.0	78.57%	80.06%	0.311	0.372
Study_Aid	3.503	3.624	4.0	4.0	51.0%	55.75%	0.372	0.372

Table 7: Statistical comparison of textbook factors for SWD and SWOD responses

Question	Mean Male	Mean Female	Median Male	Median Female	Positive Male	Positive Female	p value	corrected p value
An instructor calls on students in class with questions from the book material.	2.974	2.019	3.0	1.5	28.95%	14.81%	< 0.001	0.017
There are lots of graphs in the book.	3.658	3.148	4.0	3.0	63.16%	27.78%	0.018	0.325
Homework is assigned from the book.	3.553	2.981	3.0	3.0	47.37%	37.04%	0.042	0.522

Table 8: Three questions had statistically significant differences for male and female respondents

Digital book developed via lecture videos with UDL features

The digital books created using ClassTranscribe can be shared and downloaded in multiple formats including EPUB, PDF, and a zip file of images. The EPUB document can further be edited, transformed into other formats, and refined using commercial and free open source tools, e.g., Calibre [14]. The book content can be viewed directly on all modern laptop, mobile platforms and ebook devices e.g. Apple's OSX operating system includes Preview and Book applications that can display PDF and EPUB content respectively and also support text-search of the content. Similar tools exist for Windows, Linux and mobile platforms.

All of our digital books can be generated with a visual table of contents (Fig. 3). Preview images for each chapter are generated from the corresponding section in the lecture video. This allows students to preview the content in each chapter and more easily find the information they are looking for. Additionally, clicking on either the image or chapter name brings readers directly to the beginning of the corresponding chapter.

All of the digital books can also be outputted in the PDF format. To make it accessible, PDF tags were added to enable rapid navigation to the start of each chapter. Thus, students can click on the tag to navigate to the beginning of the corresponding chapter. Tags in a PDF document can also

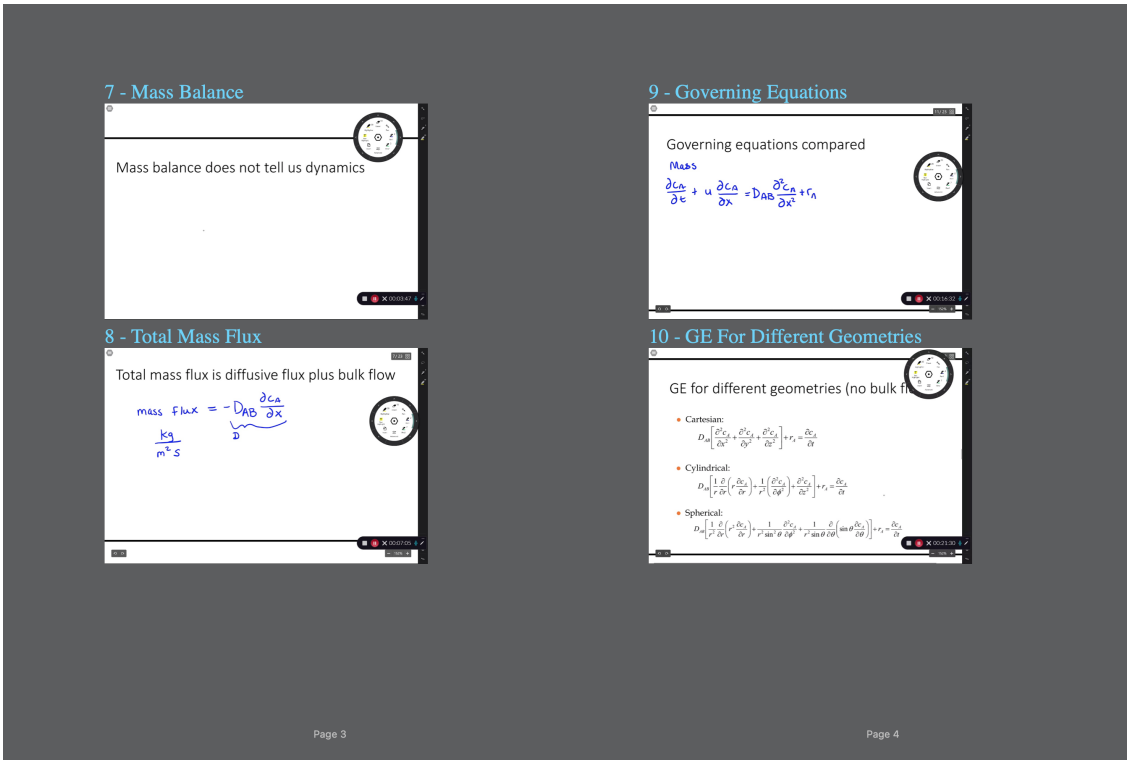

Figure 3: Example of automatically generated visual table of contents. The generated visual table of content creates two images per page.

be verified and reviewed using the Adobe Acrobat Reader application.

Limitations

Notwithstanding a survey response size of 112 respondents, some statistically significant results were identified. However, this sample size is a limiting factor in the power of the statistical tests reported here. We expect that with additional respondents, we may find additional statistically significant results.

Using our tool, it is now possible to efficiently create textbooks (both printed and in digital format) that is pedagogically-equivalent content as a lecture video. This approach has some limitations and opens several new research directions that we now discuss.

A digital book requires accurate and correct text and image content, which are primarily sourced from the recorded lecture video. ClassTranscribe uses Microsoft Azure Cognitive Services, a commercial cloud-based automated speech to text (STT) service to transcribe the lecture audio. To improve accuracy of the transcript (“byte” vs. “bite”), text is first automatically extracted from the video image frames and provided as a set of phrase hints for the STT service. Secondly, captions are edited for correctness using a crowd-source approach (described in a previous ASEE paper [3, 9]). The accuracy of the captions is dependent on the quality of the audio source and may degrade with speakers who are quiet or have a strong non-native accent. Though it is possible to ask students, or teaching assistants to edit the caption mistakes prior to textbook generation, an ideal process would not require this manual step.

Rethinking books

Digital content creates opportunities for novel methods to organize and present information that may have a positive impact on student learning outcomes. We identified three digital book features to implement that are discussed here from both student-facing and instructor-facing perspectives.

Firstly, the utility of a visual table of contents to supplement a text-based table of contents. Digital books comprise both text and images. To address the linear, sequential aspect of a paginated book, books provide a table of contents, which in digital context can include hyperlinks so that the reader can navigate directly to the material. However, unlike texts of chapter headings, images are more easily remembered, evocative, and identified. Using a template of including a representative slide at the start of each chapter, we generated a hyperlinked visual-table-of-contents at the start of each book, where each chapter's main image is included in a tabular form. This enables a sighted-reader to perform a rapid non-linear image search by glancing through the main images and then using the hyperlink to jump to desired contents. The non-sighted reader can perform equivalent navigation using the text table of contents.

There are open questions about how to create and optimize a visual-table-of-contents and related summaries for student learning. Addressing these questions is beyond the scope of this paper but could be the foundation for future research or improving the design of book content. For example, should this design method be extended to include a hyperlinked visual table of equations? Could a table of contents be personalized (e.g., a dated list of the student's study history in the book)?

Secondly, use of accessibility tags in EPUB/PDF formats to increase the equity and utility of book content. To create inclusive materials that facilitate learning by everyone, some users employ alternative technological means of access. For example, a screen reader browser application can read aloud a web page structure and allow a student who is blind to navigate, interact with, and listen, using text-to-speech technologies, to the desired portion of a web page. Other users may use a braille output device. However, most web pages, PDF documents today are structured for visual rendering but not for audio rendering or other non-visual interactivity. To be effective, a screen reader needs additional semantic annotations about the purpose of a portion of each section of a web page or document. Semantic annotations provide "the meaning" or purpose of a set of elements. For example, a list of links inside a " " tag may be the navigation menu that a screen reader should be able to provide rapid access to. Web HTML documents including EPUB books use ARIA tags and attributes to provide the missing semantic information. To ensure that the EPUB book content is accessible to all students, including those who use screen readers, the ARIA specification was used [15] to add accessibility tags in the generated documents.

Conditional publishing is another unique opportunity that arises from digital content formats. Use of conditional publishing in digital content allows the user to specify particular attributes of the content to be published. This may be advantageous to students that prefer to study specific topics within a chapter or to track overarching concepts throughout multiple chapters. Per students' needs, instructors are able to select tags associated with a particular topic in EPUB books and publish only the selected content. Consistent with UDL principles, conditional publishing can optimize the development of content in a variety of formats. For example, instructors can annotate keywords or add embedded solutions directly into an EPUB book. Instructors can also easily change content (e.g., examples, external links, supplemental videos) based on the

performance of students for a particular term.

Using our tools, faculty can easily produce accessible digital books and share them on platforms such as the Open Education Resources Commons [16].

Conclusions and Future Work

Using the College Student Assessment of Textbooks survey instrument, engineering students and faculty were surveyed to identify the most important features of textbooks for engineering and STEM education. The most desirable textbook features reported by students were searchable, low cost, relevance, definitions included, concrete examples, up to date, digital and printed options available, and "core ideas presented." Using these results and the principles of Universal Design for Learning new features were designed and added to ClassTranscribe to be able to better create valuable instructional books from videos. Though PDF and EPUB files are static formats, search could be partially supported by creating both a text-based table of contents and visual table of contents to allow rapid navigation by all students. To support students with low vision, text descriptions for each chapter image are requested and accessibility tags are automatically added to the final content. In addition, modern PDF and EPUB book reader tools now provide text indexing and searching.

We look forward to better understanding how textbooks can lead to student success and to working with students who are blind or have low vision to further optimize and ensure that PDF and EPUB files are fully accessible. The next feature to be implemented will be conditional publishing and we look forward to reporting on its use by engineering faculty in a future paper.

We recognize that students' reported desired features are not equivalent to features that affect learning outcomes. In previous work, using a learning analytics approach we found use of our accessible search video platform led to increased students' final exam performance, both within each quartile group, and compared to other semesters [9]. We look forward to performing similar research based on digital textbook use. There are many open research questions in this area. For example, researchers in [10] did not find any factors that directly correlated textbooks to student performances. The adoption of textbook creation technology that is rapid, low cost, accessible and equivalent to other course resources will open up other new research questions, practices and opportunities. For example, how can we encourage more instructors to create inclusive and accessible materials and adopt UDL approaches? How are students using these resources? Can we engage students using a crowd-sourced approach to create accessible textbooks? Should textbooks be embedded into curriculum and content (e.g. quizzes and post-quiz question review)? We are excited to use these findings and new book creation technology to help make education at the University of Illinois Urbana-Champaign more accessible, more inclusive and invite others to join us. We invite faculty who are interested in creating digital textbooks or accessible videos for their courses to contact hl314@illinois.edu (Hongye Liu).

Appendix

Creating Digital Books from Lecture Videos

A lecture recording of 50 minute video at 30 frames per second comprises 90,000 image frames. The majority of these images are duplicates and do not need to be included in the book. Thus the

first automated step is to identify unique image frames to be included in the book. This is a critical step, known as the "Scene Detection Problem." A naive approach counts the number of pixels that have changed in significant brightness since the previous frame. This is only sufficient for visually simple and static content (e.g., a sequence of non-animated PowerPoint slides), however for other delivery styles commonly used in engineering education (e.g., talking presenter, inked annotations, live coding) it cannot distinguish between actual new content to include and movement that should be ignored. Thus it produced too many false positives (unnecessary images in the book) to be useful. To successfully process a greater variety of engineering content new scene detection approaches were required and these are the focus of our companion 2022 ASEE paper [17] which also discusses the use of scene-detection outside of the scope of book generation.

Identification of each slide or scene, reduces a longer lecture video into a series of images with associated start and end times. Each scene represents a potential chapter or sub-chapter in the digital book. All of the captions (generated using automated speech-to-text and optionally hand-edited) between the start and end times of the scene are concatenated to produce the transcript.

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