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Evaluating the Low-Stakes Assessment Performance: Student-Perceived Accessibility, Belongingness, and Self-Efficacy in Connection to the Use of Digital Notes in Engineering and Computing Courses

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Evaluating the low-stakes assessment performance, student perceived accessibility, belongingness, and self-efficacy in connection to the use of digital notes in engineering and computing courses

Abstract

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. Digital note-taking has been increasingly implemented and studied in higher education for its potential to further develop universal design for learning (UDL) techniques to benefit all students, especially SWD. This study combines low-stakes assessment results with surveys about accessibility, belongingness, self-efficacy and perceived learning in connection to the use of digital notes. The multi-discipline, multi-site, and multi-timepoint research design includes two junior-level undergraduate probability and statistics courses in the disciplines of Computer Science and Industrial Engineering at the University of Illinois Urbana Champaign (UIUC). The study investigated the effect of digital notes introduced at week 10, produced using ClassTranscribe developed at UIUC. The digital notes allow for transcripts, screenshots, and mathematical equations taken directly from video recordings. The digital notes were provided to the students of the two classes in both .pdf and .epub formats with included links to the video. Additionally, we considered Students With Accessibility Needs (SWAN) if they reported conditions that prevented them from attending class at some point while not having an officially recognized disability by the university.

The students in the classes were surveyed three times: a baseline survey followed by two posttest surveys. The baseline survey was conducted early in the Fall 2022 semester by measuring the students' perceived accessibility of the course using the Web Content Accessibility Guidelines (WCAG)-based POUR model in the context of mathematically-rich engineering courses. The POUR model (perceivable, operable, understandable, and robust subscales) was found previously to be a significant predictor of perceived learning, while disability type was not a significant predictor of perceived learning. After the digital notes were introduced, two posttest surveys were conducted in the 12^{th} and 16^{th} week, respectively, to record changes in students' responses for the POUR scales, perceived learning, belongingness, self-efficacy, and their association with low-stakes assessment including homework assignments and quizzes.

The results from the responses of 285 students (including 22 SWD) for the first survey found that students generally reported positive scores for the courses' accessibility in all four POUR subscales (scores average > 4.40 out of 5). SWAN and students without disabilities (SWOD) differed in perceivable subscales ($p < 0.006$), with SWAN finding course material less perceivable. As the course content's difficulty level increased, SWD differed from SWOD significantly regarding perceivable, understandable and robustness subscales at the second survey with lower scores for SWD (FDR $p < 0.02$). Even though the perceived accessibility scales for the classes decreased in the second survey, the scores for all scales were still relatively high (score average > 4.3 out of 5). We found all four subscales did not change significantly for digital note users while SWOD who didn't use digital notes reported significantly decreased understandable, robust and operable subscales (FDR $p < 0.05$). The change of perceivable subscale was positively correlated to the change of low stakes assessments in SWD ($r = 0.427$, $p < 0.08$). Analysis of the second ($n = 255, 18$ SWD) and third survey ($n = 224, 16$ SWD) also found that digital notes helped increase the belongingness of SWAN ($p < 0.02$) and increase the self-efficacy for SWAN ($p < 0.003$). In addition, SWAN who used digital notes reported higher perceived learning than those who didn't ($p < 0.03$). This study provides empirical evidence of the benefits of UDL based digital notes in promoting the belongingness, self-efficacy and perceived learning of SWAN. It also shows the evidence SWD benefited from digital notes in their low stakes assessments. Results further show the close relationship among belongingness, self-efficacy and perceived learning and yet distinctness of these learning outcome metrics. In addition, the perceived accessibility is confirmed to be uniquely useful for understanding the needs of SWD, and thus deserves more attention to help them succeed.

Introduction

The accessibility of course content plays a critical role in student success. Students with disabilities (SWD) face extra challenges when digital content is inaccessible or difficult to use. This is a significant challenge for many students that instructors are often unaware of; national statistics by the NSF and NCES report [1] 19% of the 4-year undergraduate population have a disability, but according to a Wisconsin research study [2] the majority (75%) of students who self-reported a disability to the study did not report to their instructors or school.

Digital note-taking has been increasingly implemented and studied in higher education for its potential to further develop universal design for learning (UDL) techniques to benefit all students [3]. Accessibility for SWD with such technology is recognized as a best practice [3–6].

Engineering education researchers have previously reported that SWD preferred searchable lecture video with transcriptions for the content delivery compared with students without disabilities (SWOD) [4]. Furthermore, reported student interviews in the past showed all students in a course benefited from multiple modalities of content delivery in online learning [3–5]. However, lecture videos with transcripts and/or a course textbook are not always available, even when students need this content [4]. To meet this need, the authors investigated a digital note-based pedagogy to facilitate content delivery for SWD and SWOD using empirical survey data from students and instructors [6]. The digital notes included full transcripts, screenshots, mathematical equations extracted directly from video recordings, structured content organization, and embedded links to the videos and multiple formats as output.

In this work, we applied the digital notes methodology in two large math-rich engineering / STEM courses to investigate whether such intervention would affect student learning outcomes, especially for SWD or students with similar needs. We not only investigated the low-stakes assessments, students' perceived learning, but also their social learning metrics including belongingness and self-efficacy because belonging and self-efficacy in learning are known important factors that positively influence students academic performance [7], and students' success should not be limited to only performance based measurements. Furthermore, we studied a new instrument (PAIM) based on the POUR model [8] that measured students' perceived accessibility. PAIM was found to be predictive of SWD perceived learning [8].

Background

Perceivable	Users can use their available senses, such as sight, hearing, and touch, to fully process information in their electronic materials.
Operable	Users can interact with and navigate through their electronic materials in a manner they can fully control, without encountering obstacles.
Understandable	Content is readable and understandable, and the functionality of the electronic materials works in predictable ways.
Robust	Electronic materials are compatible with a range of technologies and devices, including assistive technologies.

Table 1: The POUR model

Universal Design for Learning UDL is a pedagogical framework and set of teaching principles to help all students learn well by emphasizing the universal approaches of accommodating multiple modes of student learning, action, and engagement. The three core organizing guidelines 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 [8]. Our study continued to study how to enrich the students' experience and performance with multiple modes of content delivery including adding digital notes directly from lecture videos.

Perceived accessibility In the USA, accessibility requirements of university degrees are defined in the Americans with Disabilities Act (ADA; 1990), and Section 504 of the Rehabilitation Act. The Web Content Accessibility Guidelines (WCAG) produced by the World Wide Web Consortium is a standard adopted by the federal government that helps promote accessibility and define accessibility requirements of digital content. WCAG defines four organizing principles of accessibility; it should be perceivable, operable, understandable and robust (POUR). These are defined in Table 1.

Content that is provided in only a single modality (e.g., audio without captions, visual figures without equivalent textual explanations) will be inaccessible to some students. To assess the accessibility of course materials, researchers created the PAIM survey instrument [8] based on the POUR model. PAIM measures the perceived accessibility by SWD. The perceived accessibility predicts the perceived learning of students significantly [8].

Perceived learning Perceived learning is measured by the CAP scale for surveying student's self-evaluated learning [9]. There is a known limitation of measured perceived learning when contrasting alternative lecture styles; active learning lectures have a lower perceived learning than traditional learning lectures, even though active learning students learn more [10]. However, our use of self-evaluated learning is within the same course design.

Belongingness Belongingness is the experience of positive feelings of being cared about, accepted, respected, valued by and important to the community [11–13]. A strong sense of belonging has been shown to improve academic performance, mental health, self-esteem whereas a low sense of belonging may increase risk of stress, anxiety, depression, rejection, and feelings of loneliness [14]. Study in [7] has shown positive correlation between the students' belongingness with their academic performance. In addition, belongingness is a major factor that contributes positively to an individual's psychological development [13, 15–17].

Self-efficacy As the core concept in the Social Cognitive Learning Theory, self-efficacy means an individual's belief in their capabilities to successfully control actions or events in their lives to achieve the desired outcomes [18, 19]. Such beliefs are based on individuals' confidence that they have the cognitive abilities, motivation, and resources to complete the given tasks [17]. Bandura [19] pointed out four contributing factors in building self-efficacy, namely, mastery experiences, social modeling of learning, social persuasion, and states of physiology. In a class designed with low-stakes tests and with the digital notes providing extra opportunities and channels of learning, we expect such an environment to formulate more relaxed social modeling of learning and connect to students mastery experiences as possible ways to boost their overall confidence in learning. Empirical evidence has shown that self-efficacy was significantly related to academic performance and to self-set academic grade goals [7]. Furthermore, we expect an improved self-efficacy score to mean that using digital notes improves on psychological factors of students that go beyond immediate assessment outcomes.

Digital notes based pedagogy Our previous work on digital notes [6] created a new accessible instructional tool that adheres to UDL guidelines. The digital notes consist of a combination of text and visual elements to create digital notes that are automatically generated from lecture videos. The notes are separated into distinct chapters and subchapters that consist of many images, image descriptions, and text.

Digital notes 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 digital note when riding on a bus or working on a homework problem.

Digital notes offer improved accessibility and modes of representation compared to traditional print publications. They offer improved accessibility features including screen reader compatibility, text enlargement, alt-text for images, and image descriptions. The digital notes also enable embedded study tools such as searchability, bookmarks, glossaries, annotations, links, and hyperlinked references. With representation at the forefront of development, digital notes can be generated in many different output formats such as EPUB, PDF, HTML, and LaTeX. This allows students to view, edit, and annotate the lecture content using their preferred medium. To enable increased accessibility, the PDF versions are all generated with accessibility tags for screen reader compatibility and to enable quicker navigation of the digital notes. Each digital note chapter contains a hyperlink that links back to the corresponding video clip the chapter was generated from. This allows students to cross reference between text and spoken versions of the same lecture content with ease. The digital notes can also be generated with a visual table of contents that gives students a preview of chapter content. This enables easier searching of lecture content compared to a traditional lecture video or print textbook.

ClassTranscribe for digital notes The authors, and prior students at the same university, created an intuitive and feature rich interface to create, edit and generate digital notes. The web tool is built into ClassTranscribe, an accessible lecture video platform developed at UIUC and presented at ASEE [20–23].

The editing interface allows users to easily create, merge, and delete chapters/subchapters. Users can edit and tweak transcripts extracted from lecture videos. Users can also add additional text blocks, images, image descriptions, and alt-text. Tags can be added to each content element in order to enable conditional publishing capabilities. Books can be quickly structured by using an automated Quick Split feature or by manually splitting the content into chapters. The former will create a chapter for each slide that is presented in a lecture and attach the corresponding video transcript to each chapter.

Methods

Survey designs

To investigate the effects on learning outcomes with the use of digital notes in engineering and STEM classes, two junior-level undergraduate probability and statistics courses in the disciplines of Computer Science and Industrial Engineering were surveyed at the University of Illinois Urbana Champaign. The student survey was approved by the University of Illinois Urbana Champaign IRB.

After the first survey was collected, digital notes were uploaded to the course sites on the learning management system as an intervention, and then the two posttest surveys were used to collect data on different learning outcomes.

The first survey included demographic questions and the perceived accessibility instrument; the second survey repeated the perceived instrument and added the belongingness and self-efficacy questions; the third survey measured students’ learning by belongingness, self-efficacy, perceived learning and student feedback about the digital notes. As one important aspect of universal design for learning (UDL), multiple means of representation are further enriched by the addition of digital notes.

Perceived accessibility and perceived learning The perceived accessibility subscales were measured using the PAIM instrument based on the WCAG POUR model [8]. In order to shorten the time required for students to finish the survey, we reduced the number of questions in the PAIM list for the POUR four subscales. The questions are listed in Appendix table 1.

Belongingness We drew from, and adapted, three instruments, namely, the 27-item Sense of Belonging Instruments: including the 18-item SOBI-P for psychological state and 9-item SOBI-A for antecedents [24]; and the 30-item Math Sense of Belonging Scale [25]. The SOBI-P measures a sense of belonging in terms of valued involvement and fit in relationships. The SOBI-A examines antecedents to a sense of belonging [26]. The SOBI has demonstrated high internal consistency [26]. The Math Sense of Belonging was consulted on its subject-specific items, such as "I feel that I belong to the math community." or "I feel a connection with the math community." can easily be adapted to items which measure students' sense of belonging in statistics. We then designed the belongingness instrument with 16 questions, listed in Appendix table 18.

Self-efficacy Academic self-efficacy was measured with the 8-item Self-Efficacy of Learning [27], listed in Appendix table 18.

We also designed other open-ending questions about students' learning efficiency, opinions/feedback on the digital notes. The resulting qualitative data helps us triangulate with and interpret the quantitative data. The questions are listed in Appendix table 19. All our surveys together address the following research questions:

1. What is the accessibility level of the two math-rich engineering/stem courses according to the perceived accessibility instrument?
2. How do the perceived accessibility scales change along the time of the courses and differ between the different student groups?
3. How is the perceived accessibility associated with various learning outcome measurements?
4. Does the intervention of digital notes affect any of the learning outcomes such as low stakes assessment, belongingness, self-efficacy and perceived learning? If yes, what are the effects?
5. How different are the above measurements for the various student groups such as SWD, SWAN, and SWOD, and gender?
6. What enhanced features or improvements would students or instructors like to see?
7. What are the big barriers for implementing such UDL based technology?

Development of accessible digital Notes

Digital notes were generated using the instructor version of the ClassTranscribe. The editor allowed the instructors to edit the auto-generated complete transcripts with a rich content editor, separate contents into Chapters and Subsections with editable titles. Images from the lecture videos were double checked to see if they are a fit choice and the instructor is able to screenshot any new image from the lecture video and insert it in place. Instructors then output the digital notes as pdf or EPUB formats and double check their quality with third party readers such as Calibre [28] or Adobe. The tool also automatically creates links to the video to help students immediately connect to the content, in case they need to review the video again.

Course design and schedule of surveys

Two probability and statistics courses from Computer Science and Industrial and Systems Engineering participated in this study. The two classes have 325 and 81 students enrolled, respectively. Both classes introduce probability and statistics notions to engineering students from diverse areas in Computer Science and Industrial and Systems Engineering, but include students from all other engineering disciplines (e.g., students from Electrical and Computer Engineering, Chemical Engineering, Aerospace Engineering, and others). The two courses were selected for our testing of these newly developed digital notes because of their position in the curricula as an introductory point for probability and statistics, but also due to their design.

Specifically, the two courses have a similar assessment setup: they have frequent low-stakes assessments such as regular homework and/or weekly quizzes, with midterm exams and a final exam that have higher weight in grade calculation. The instructors of the courses have employed a series of UDL practices in their course design. These include the availability of multiple modes of content delivery (in the form of lecture slides, textbook, videos with transcripts, as well as digital notes from this project). Table 2 shows the details of the UDL design of the two courses.

	ISE course	CS course
Accessibility	LMS based course site, screen reader, accessibility checker, on-boarding form	LMS based course site, screen reader, accessibility checker, on-boarding form
Assessments	10 Quizzes, 3 midterms, final	10 HWs, 6 Quizzes, 2 midterms, project, final
Asynchronous activities	Worksheet	Graded group discussion
In class activities	Group work in class	Recitation group work, Anonymous poll questions
Multiple content formats	Video with transcripts, digital notes, lecture notes, textbook	Video with transcripts, digital notes, lecture slides, textbook
Q & A	In class and Online forum	In class and Online forum

Table 2: The UDL design of the two courses

Additionally, both classes employed discussion forums, anonymous polls and worksheets for active learning, autograding in quizzes, team-based assignments, the same learning management systems (LMS, Canvas specifically), accessibility features on LMS (such as screen readers and accessibility checker), and the course websites that link all contents and tools on their LMS. They also made available on-boarding forms for students to self-disclose their needs for accommodations.

The 3 surveys were promoted to students using an extra credit scheme with the first 2 surveys as required for receiving any credit. Students were also required to view or download at least 2 lectures' digital notes generated in this study. The usage of these digital notes was later tracked through the content insights available from the cloud service provider Box (box.com).

The first survey was administered early in the Fall 2022 semester (9/13/2022- 10/25/2022) with at least one midterm on probability conducted in between. The digital notes were made available from 10/26 and the second survey was administered from 11/18-12/6 after another midterm on Statistics. Both instructors recognized their students found the midterm on the Statistics portion of the class more difficult. The third survey was administered from 12/8- 12/13 (final exams were in the week of 12/9).

Demographics

We surveyed students from 2 engineering courses for these three surveys. The survey design allowed students with physical, mental, and/or emotional disabilities to self-report as a SWD. Additionally, we identify students as Students with Accessibility Needs (SWAN) if they faced conditions that prevented them from attending class at some point while not having an officially recognized disability by the university. The surveys collected 285, 255, and 224 responses respectively. Among the SWD, there is one student who identified as both physical disabilities and mental disabilities. Students were given the option not to disclose their personal information such as gender. Table 3 shows the demographics in detail.

Survey number	All	SWD	SWAN	SWOD	Physical SWD	Mental SWD	Male	Female	Other	CS Class	ISE Class
I	285	22	90	173	5	18	193	83	9	247	38
II	255	18	101	136	4	15	154	71	30	231	24
III	224	16	76	132	4	13	138	61	25	192	32

Table 3: Demographics of the three surveys

Data Analysis

The survey was first anonymized and cleaned to make sure it only included valid samples from two selected classes at the University of Illinois Urbana Champaign. Then we assigned numeric values to the Likert questions. These questions except the efficacy ones were on a scale from 1 (Never/Strongly disagree) to 5 (Always/Strongly agree). Values of 4,5 indicated positive response, 1,2 indicated negative and 3 indicated a neutral response. Efficacy questions were on a scale from 1 to 3 where 1 indicated some, 2 indicated many, and 3 indicated always. We used the Cronbach alpha to make sure the results are consistent for the three surveys, and the values were 0.97, 0.96 and 0.91 respectively.

For the analysis, we first analyzed the three surveys separately on both individual and subscale level differences. We used the Kruskal Wallis test for the difference between SWD, SWAN and SWOD, and the Mann Whitney Wilcoxon test for group-wise differences and gender differences, which does not require a normal distribution assumption. Due to the large number of p values reported, we also performed a False Discovery Rate (FDR) correction of the p values using the Benjamini-Hochberg procedure [29]. As to the gender difference we analyzed the differences between female and male students first, then we consider nonbinary non-conforming non-disclosed and other (NBCDO) students and analyzed their responses with the female and male groups together.

Data for the low-stakes assessments were derived from ten homework assignments and six quizzes from the CS course as well as ten quizzes from the ISE course. The scores were summarized by assigning ranks to the raw scores using the following cutoffs: 1 for 60% or less correct, 2 above 60% but below 75%, 3 for above 75% but below 88%, and 4 for 88% for above.

Furthermore, we also compared the difference between digital notes users and non-digital notes users. The comparison for the perceived accessibility based on POUR model uses the students' responses that completed both the survey I and II and the other comparison uses the students' responses that completed both the survey II and III. We used the Wilcoxon signed rank paired test to evaluate the difference in the same group and non-paired test for the difference between different groups.

Finally, pairwise Spearman correlations were calculated to detect associations among low-stakes assessment scores, perceived accessibility, belongingness, self-efficacy and perceived learning.

Results

The perceived accessibility of the courses measured in survey I and II

In the first survey, students generally gave positive scores for the courses' accessibility in all four POUR subscales (scores average > 4.4 out of 5) of the perceived accessibility instrument. The positive rates ranged from 88% to 91% and all four subscales received a median score of 5. There was no significance between female and male for any of the subscales. Even with the limited sample size, we still see a significance that NBCDO responded lower than male and female students for all sub-scales, and the details can be found in Appendix Table 23. The Kruskal Wallis test for the difference between SWD, SWAN and SWOD showed there was a significant difference. Compared with SWOD, SWD reported lower understandable subscale without a high significance (FDR $p < 0.072$). The comparison between SWAN and SWOD showed SWAN differed in the perceivable subscale with significance (mean of 4.4 for SWAN vs 4.5 for SWOD, FDR $p < 0.006$). The two groups differed on the following questions: "If I had a question about how features on the course website worked, the course website made it easy to find help", "My electronic instructional materials were easy to see." and "Perceiving the information in my electronic instructional materials was a straightforward process." Table 4 and 20 shows the subscale level basic statistics of perceived accessibility in survey I.

As mentioned previously survey II was conducted after a more difficult midterm and also introduced after the digital note content was available. In the second survey, the perceived accessibility subscales were in general lower than those in survey I and varied more among the students. Table 4 and 5 show the subscale level analysis of perceived accessibility in survey II.

Using the paired comparison with responses from students who filled both survey I and II, we found the average of understandable subscale reduced from 4.4 in survey I to 4.3 (out of 5) in survey II, $p < 0.007$, FDR $p < 0.03$. In addition, the perceivable subscale reduced from 4.5 to 4.4

Question Type	All Students			SWD			SWAN			SWOD			Male			Female		
	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)
Survey(I)																		
Perceivable	4.5	5	88	4.5	5	89	4.4	5	85	4.5	5	90	4.6	5	91	4.4	5	87
Operable	4.5	5	89	4.6	5	90	4.5	5	87	4.5	5	90	4.5	5	91	4.5	5	89
Understandable	4.4	5	88	4.3	5	83	4.4	5	85	4.5	5	90	4.5	5	89	4.4	5	88
Robust	4.6	5	91	4.6	5	87	4.6	5	89	4.6	5	92	4.6	5	92	4.7	5	92
Survey(II)																		
Perceivable	4.4	5	87	4.2	5	81	4.4	5	87	4.4	5	87	4.4	5	87	4.5	5	90
Operable	4.4	5	88	4.2	5	81	4.5	5	90	4.5	5	88	4.5	5	89	4.5	5	89
Understandable	4.3	5	85	4.0	5	75	4.3	5	87	4.4	5	85	4.4	5	87	4.3	5	84
Robust	4.5	5	91	4.4	5	92	4.6	5	93	4.6	5	89	4.5	5	92	4.7	5	94

Table 4: The basic statistics of the Survey I and II perceived accessibility scales

Question Type	SWD-SWAN-SWOD p val (corrected)	SWD-SWOD p val (corrected)	SWD-SWAN p val (corrected)	SWAN-SWOD p val (corrected)	Male-Female p val (corrected)
Perceivable	0.036 (0.045)*	0.011 (0.013)*	0.023 (0.028)*	0.595 (0.707)	0.221 (0.368)
Operable	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*	0.491 (0.707)	0.030 (0.074)
Understand-able	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*	0.240 (0.601)	0.298 (0.372)
Robust	0.284 (0.284)	0.159 (0.159)	0.114 (0.114)	0.707 (0.707)	<0.001 (<0.001)*

Table 5: Survey II POUR differences p-val. * Corrected p-val < 0.05

(out of 5), $p < 0.044$, FDR $p < 0.088$. The average of robust subscale and the average of operable subscale also decreased but without statistical significance. Overall, the perceived accessibility scores were still in general higher than 4.3 out of 5.

Male students reported significantly lower scores for robustness than females (4.5 Male vs 4.7 Female, FDR $p < 0.001$). They didn't differ significantly in other subscales. Again NBCDO students differ significantly by responding lower than male and female students in all subscales. The details can be found in Appendix Table 23. The Kruskal Wallis test for the difference between SWD, SWAN and SWOD found there was significant difference for three subscales: Understandable, Perceivable and Operable. Compared with SWOD, SWD report lower understandable (4.0 SWD vs 4.4 SWOD, FDR $p < 0.001$), Operable (4.2 SWD vs 4.5 SWOD, FDR $p < 0.001$) and Perceivable subscales (4.2 SWD vs 4.4 SWOD, FDR $p < 0.014$). Interestingly, SWAN did not differ from SWOD significantly any more, their average perceivable subscale was even slightly higher (4.41 SWAN vs 4.4 SWOD).

We then analyzed the change of perceivable accessibility scales by separating student groups to the digital note user and non-user, and compared the two surveys using paired signed rank sum tests to gain insight into how each subgroup were affected. We found all 4 subscales did not change significantly for digital note users while SWOD who didn't use digital notes had significantly decreased understandable, robust and operable subscales (FDR $p < 0.048$), see Table 21 the appendix.

The association between perceived accessibility and the low stakes assessment

We analyzed the correlation between the perceived accessibility subscales with the low stakes assessment. For the perceivable subscale, we calculated the correlation between the difference of the two surveys for each individual student and the difference between their low stakes assessment before and after the digital note intervention. Then we calculated the correlation between the perceivable subscale values and the low stakes assessment at the time point of the second survey. The same analysis was performed for the understandable subscale. We found that the change of perceivable subscale for SWD is correlated with their change in low stakes assessment scores with Spearman correlation coefficient $r = 0.427$ and $p < 0.08$. The other student groups did not have such an association. In addition, we found the understandable subscale values of SWD who used digital notes were correlated with low stakes assessment at the time of survey II with $r = 0.716$, $p < 0.05$. These results are somewhat consistent with the findings when the POUR model-based PAIM instrument was developed [8] while our finding was about the academic assessment scores. These demonstrate the uniqueness of the perceived accessibility instrument in course outcome evaluation. Table 6 and 22 show the details about the correlations between the perceived accessibility and the low stakes assessment.

	All Students			SWD			SWAN			SWOD		
	All	User	Non user	All	User	Non user	All	User	Non user	All	User	Non user
Number of Students	255	128	127	18	8	10	101	48	53	136	72	64
Coefficient	0.028	0.018	0.037	0.427	0.494	0.415	0.059	0.066	0.031	-0.022	-0.036	-0.010
p	0.666	0.844	0.704	0.077	0.213	0.233	0.564	0.644	0.836	0.810	0.769	0.939

Table 6: Correlation between the change in "Perceivable subscale" and the change in low-stakes assessment

The students' low stakes assessment and their difference before and after the digital notes were issued

We analyzed the low stakes assessment scores of the two courses. These scores included 10 HWs and 6 Quizzes in the CS course and 10 Quizzes in the ISE course.

Before the digital notes were published, SWD had lower average of the low stakes assessment scores than SWOD ($p < 0.019$). The SWD who didn't use the digital notes scored lower than SWOD who didn't use digital notes (3.1 SWD non-users vs 3.6 SWOD non-users, $p < 0.016$) while SWD digital notes users didn't differ from their counterpart significantly (3.4 SWD users vs 3.5 SWOD users).

After the digital notes, the SWD non-users scored lower than SWOD non-users (2.9 SWD non-users vs 3.5 SWOD non-users, $p < 0.006$). In addition, the SWD non-users scored lower than SWAN non-users (2.9 SWD non-users vs 3.4 SWAN non-users, $p < 0.01$). No other comparisons between these groups showed statistical significance.

Although the paired signed Wilcoxon tests didn't show significance, the average scores of SWD and those of SWAN who used the digital notes increased after the digital note intervention. On the other hand, the average scores of SWD and those of SWAN non-users decreased after the intervention. The Mann Whitney U test test found SWD users had statistically significant higher average scores than SWD non-users after the intervention (3.6 SWD users vs 2.9 SWD non-users, $p < 0.013$).

Table 7 and 8 show the statistics of the low stakes assessment of all such student groups before and after the digital notes.

	User pre mean	User pre median	User post mean	User post median	Nonuser pre mean	Nonuser pre median	Nonuser post mean	Nonuser post median
All	3.5	3.6	3.5	3.6	3.5	3.6	3.5	3.7
SWD	3.4	3.5	3.6	3.7	3.1	3.3	2.9	3.0
SWAN	3.4	3.6	3.5	3.6	3.5	3.6	3.4	3.6
SWOD	3.5	3.7	3.5	3.6	3.6	3.6	3.5	3.7

Table 7: Low- stakes assessment basic stats of digital note users and nonusers

	SWD SWOD	SWD SWAN	SWOD SWAN	User SWD SWOD	User SWD SWAN	User SWOD SWAN	Non user SWD SWOD	Non user SWD SWAN	Non user SWOD SWAN	User vs Non user	SWD user vs SWD Non user	SWAN user vs SWAN Non user	SWOD user vs Non user
Before	**0.018**	0.110	0.079	0.401	0.625	0.345	**0.016**	0.085	0.113	0.763	0.328	0.828	0.923
After	0.068	0.104	0.785	0.564	0.474	0.755	**0.005**	**0.009**	0.942	0.944	**0.013**	0.742	0.946

Table 8: p-vals for the differences in low-stakes scores between different groups before and after the digital notes

The belongingness of the students in survey II and III and its changes in connection to the digital notes

The belongingness questions (questions are in Appendix table 18 and 19) were asked on the second and third survey. In the second survey, the mean score of belongingness for students in the combined courses was 3.7 out of 5, with a positive rate of 64%. While there was no significant difference between female and male students, NBCDO reported lower belongingness than that of female and male significantly, the details are in appendix Table 25 and 26. The data also showed SWD felt less belonging than SWOD (3.4 SWD vs 3.7 SWOD, FDR $p < 0.001$). SWAN did not differ from SWOD in belongingness and even had a slightly higher average (3.8 SWAN vs 3.7 SWOD).

In the third survey, the mean score of belongingness for all students increased to 3.9 out of 5, with a positive rate of 71%. It showed similar difference from gender perspective. SWD reported higher belongingness but still lower than SWOD significantly (3.5 SWD vs 3.9 SWOD, FDR $p < 0.001$). In contrast, SWAN reported even higher belongingness than SWOD (4.0 SWAN vs 3.9 SWOD, FDR $p < 0.003$).

We then divided the student results into digital notes users and non-users. SWAN digital note users improved their belongingness significantly (changed from 3.9 to 4.0, $p < 0.019$). In contrast, SWAN non-users reported lower belongingness although not significantly changed. Interestingly, SWOD non-users reported higher belongingness in the third survey (changed from 3.6 to 3.9, $p < 0.04$). This could be an effect of other factors such as higher scores in the low stakes assessment or a good percentage of total course score.

The comparison between all digital note users and non-users showed the users have a higher average belongingness than non-users (3.8 users vs 3.7 non-users, FDR $p < 0.005$). Table 9, 10 and 11 show the details of belonging in the second and third surveys and the comparison between the two surveys.

Question Type	All Students			SWD			SWAN			SWOD			Male			Female		
	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)
Survey(II)																		
Belonging	3.7	4	64	3.4	3	49	3.8	4	67	3.7	4	63	3.7	4	64	3.8	4	67
Self-Efficacy *	2.1	2	82	1.9	2	72	2.1	2	83	2.2	2	84	2.2	2	84	2.0	2	78
Survey(III)																		
Belonging	3.9	4	71	3.5	4	57	4.0	4	76	3.9	4	71	3.9	4	72	4.0	4	74
Self-Efficacy *	2.2	2	86	1.8	2	71	2.2	2	87	2.2	2	87	2.2	2	89	2.0	2	80

Table 9: Survey II, III Belonging, Self-Efficacy Basic Stats (* in a scale of 3)

Question Type	SWD-SWAN-SWOD p val (Corrected p val)	SWD-SWOD p val (Corrected p val)	SWD-SWAN p val (Corrected p val)	SWAN-SWOD p val (Corrected p val)	Male-Female p val (Corrected p val)
			Survey(II)		
Belonging	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*	0.034 (0.170)	0.910 (0.910)
Self-Efficacy	<0.001	<0.001	<0.001	<0.005	<0.001
			Survey(III)		
Belonging	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (0.003)*	0.650 (0.860)
Self-Efficacy	<0.001	<0.001	<0.001	0.340	<0.001

Table 10: Survey II, III Belongingness, Self-Efficacy differences p-val. *Corrected p-val < 0.05.

	User					Non User				
					Belonging					
	pre mean	pre median	post mean	post median	p value	pre mean	pre median	post mean	post median	p value
All	3.8	4	3.9	4	0.502	3.7	4	3.9	4	0.060
SWD	3.8	4	3.7	4	0.715	3.3	3	3.4	4	0.285
SWAN	3.9	4	4.0	4	**0.019**	4.0	4	3.9	4	0.109
SWOD	3.8	4	3.8	4	0.520	3.6	4	3.9	4	**0.039**
					Self-Efficacy					
	pre mean	pre median	post mean	post median	p value	pre mean	pre median	post mean	post median	p value
All	2.0	2	2.1	2	0.096	2.2	2	2.3	2	0.135
SWD	1.9	2	2.0	2	0.854	1.8	2	1.8	2	0.734
SWAN	2.1	2	2.2	2	**0.002**	2.2	2	2.1	2	0.125
SWOD	2.0	2	2.0	2	0.916	2.3	2	2.4	3	**0.021**

Table 11: Belonging, Self-Efficacy user-nonuser differences between survey II and III

The self-efficacy of the students in survey II and III and its changes in connection to the digital notes

The self-efficacy questions (in Appendix table 18 and 19) were asked on the second and third survey.

In the second survey, the mean score of self-efficacy for students in the combined courses is 2.1 out of 3, with a positive rate of 82%. Females reported significant lower self-efficacy than male students (2.0 Female vs 2.1 Male, $p < 0.001$) and NBCDO students slightly higher self-efficacy than that of male and females in terms of positive rate although the sample size of NBCDO is very limited, see details in appendix Table 25 and 26. Notably, SWD reported lower self-efficacy than SWOD (1.9 SWD vs 2.2 SWOD, FDR $p < 0.001$). In addition, SWAN also reported lower self-efficacy than SWOD (2.1 SWAN vs 2.2 SWOD, $p < 0.005$).

In the third survey, the mean score of self-efficacy for students in the combined courses was 2.2 out of 3, with a positive rate of 86%. Female students reported slightly higher self-efficacy than in the second survey (from 1.963 to 2.002) but still significantly lower than males (avg = 2.2) with $p < 0.001$ and NBCDO (avg=2.3) with $p < 0.003$. SWD remained lower in self-efficacy compared with SWOD (1.8 SWD vs 2.2 SWOD, $p < 0.001$). In contrast, SWAN improved their self-efficacy (from 2.1 to 2.2) and they were not different from that of SWOD any more ($p > 0.3$).

With the split of the students further to digital notes users and non-users, we found SWAN digital note users improved their self-efficacy significantly (changed from 2.1 to 2.2, $p < 0.003$). In contrast, SWAN non-users reported lower self-efficacy (2.2 in the second to 2.1 in the third) although not significantly changed. Interestingly, as for belongingness SWOD non-users reported higher self-efficacy in the third survey (changed from 2.3 to 2.4, $p < 0.03$). Table 9, 10 and 11 show the details of student self-efficacy in the second and third surveys.

The association of belongingness and self-efficacy with perceived learning

The perceived learning questions were asked in the third survey (questions in appendix Table 19). The overall average of perceived learning is 3.9 out of 5 with a positive rate of 70%. There were no significant differences between female and male students. Also there were no significant differences between NBCDO students and male and female students. SWD reported lower perceived learning than SWOD (3.3 SWD vs 3.9 SWOD, FDR $p < 0.001$). SWAN reported even higher perceived learning than SWOD (4.0 SWAN vs 3.9) although not significant.

	User mean	User median	Non user mean	Non user median	p value
All	3.9	4	3.8	4	0.984
SWD	3.6	4	3.0	3	0.051
SWAN	4.0	4	3.8	4	**0.025**
SWOD	3.8	4	3.9	4	**0.026**

Table 12: Perceived learning user-nonuser differences in survey III

With the divide of the student data into digital notes users and non-users, we found SWAN digital note users reported higher perceived learning than non-users significantly (4.0 SWAN users vs 3.8 SWAN non-users, $p < 0.026$). In contrast, SWOD users reported lower perceived learning than non-users (3.8 users vs 3.9 non-users, $p < 0.026$). In addition, SWD digital notes users reported higher perceived learning than SWD non-users (3.6 vs 3, $p < 0.052$). Table 12 shows the details of these comparisons.

We then evaluated the pairwise correlation coefficients among belongingness, self-efficacy and perceived learning. The results are shown in Table 13, 14 and 15. We found the belongingness measures and self-efficacy measures were both correlated well with the perceived learning across the student groups except for SWD users with highest coefficient being 0.86 ($p < 0.002$) and 0.64 ($p < 0.001$) respectively. Between belongingness and self-efficacy, the correlation coefficients were also high with $r = 0.787$ for SWD non-users ($p < 0.005$), and reasonably high for SWD ($r = 0.692$, $p < 0.004$).

	All Students			SWD			SWAN			SWOD		
	All	User	Nonusers	All	User	Nonusers	All	User	Nonusers	All	User	Nonusers
Number of Students	224	112	112	16	5	11	76	43	33	132	64	68
Coefficient	**0.728**	**0.724**	**0.723**	**0.586**	0.051	**0.862**	**0.699**	**0.737**	**0.661**	**0.743**	**0.725**	**0.736**
p	**0**	**0**	**0**	**0.017**	0.935	**0.001**	**0**	**0**	**0**	**0**	**0**	**0**

Table 13: The correlation between Belongingness and Perceived Learning in Survey III

	All Students			SWD			SWAN			SWOD		
	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser
Number of Students	224	112	112	16	5	11	76	43	33	132	64	68
Coefficient	**0.370**	**0.428**	**0.317**	**0.692**	0.300	**0.787**	**0.296**	0.136	**0.431**	**0.383**	**0.551**	0.208
p	**0**	**0**	**0.001**	**0.003**	0.624	**0.004**	**0.006**	0.372	**0.006**	**0**	**0**	0.089

Table 14: The correlation between Belongingness and Self Efficacy in Survey III

	All Students			SWD			SWAN			SWOD		
	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser
Number of Students	224	112	112	16	5	11	76	43	33	132	64	68
Coefficient	**0.499**	**0.542**	**0.475**	0.471	-0.205	**0.633**	**0.420**	**0.332**	**0.493**	**0.529**	**0.636**	**0.451**
p	**0**	**0**	**0**	0.066	0.741	**0.037**	**0**	**0.026**	**0.001**	**0**	**0**	**0**

Table 15: The correlation between Self- Efficacy and Perceived Learning in Survey III

Students' usage and satisfaction of digital notes and suggestions

We measured the students' usage of the digital notes regarding the viewing and download through the box.com content insights. The records included both usage of EPUB and pdf formats of the digital notes. Overall, most students used the pdf format of the notes (mean of 1.0 EPUB vs 6.1 pdf). SWD and SWAN did not use more than SWOD students. There was no significant difference in usage between NBCDO, male and female students. We also asked their satisfaction about the digital notes in the third survey. The student responses with a mean of 3.7 out of 5 and the positive rate is 64%. The mean of SWD' satisfaction is higher than SWOD (3.8 vs 3.6) although it was not statistically significant. SWAN also reported with a slightly higher average but not statistically significant (3.8 SWAN vs 3.6 SWOD). Table 16 shows the usage statistics by student groups.

	All		SWD		SWAN		SWOD		Male		Female		NBCDO	
	epub	pdf	epub	pdf	epub	pdf	epub	pdf	epub	pdf	epub	pdf	epub	pdf
Mean	1.0	6.1	0.4	5.1	0.7	5.7	1.3	6.4	1.1	6.0	1.0	6.5	0.7	4.9
Median	0	4	0	4	0	3	0	5	0	4	0	5	0	3.5

Table 16: Digital notes usage stats

The students who used the digital notes gave substantial feedback about their use of digital notes. Overall, they found the notes helpful and appreciated the features such as the searching capability, the embedded links from the notes to the lecture video for topics, the structured organization of the contents by concept or examples. Some students found the digital notes saved them time for reviewing the contents when they didn't need to watch the videos again. They also liked that it was accessible anywhere and anytime. Others found the notes helped clarify key concepts. We also received suggestions as to how to improve the digital notes such as including additional examples that were not covered in the lectures.

Conclusions

In this study we validated the PAIM instrument that measured the perceived accessibility of two math-intensive engineering courses that were designed with UDL principles in mind. We found the perceived accessibility level in general was high with scores higher than 4.3/5 (4.4 in the beginning and 4.3 in the middle of the courses). Such a level of accessibility was higher than that was reported in [8] in its first implementation. Although the perceived accessibility was reported lower when the courses progress to more difficult contents, there was only significant decrease for SWOD students who didn't use digital notes. We found SWD reported significantly lower perceived accessibility than their peers. Such a finding is also corroborated by the observation that SWD are the only group for which there is a relatively significant correlation between the change of perceived accessibility and the change of low stakes assessment scores. In other words, SWD were the group that is sensitive to the change of the "perceivable" subscale in their learning. There was also a significant correlation between the score of the "understandable" subscale with the score of low stakes assessments for SWD.

We found the intervention of digital notes had positive effects on multiple student groups. For example, SWD who used the notes had increased low stakes assessment score while SWD who didn't use had decreased low stakes assessment score. SWAN who used the notes reported higher belongingness and self-efficacy with significance while the SWAN nonusers reported lower average belongingness and self-efficacy scores. SWAN users also reported higher perceived learning while SWAN nonusers reported lower perceived learning. SWOD users did not show differences in these metrics while SWOD non-users were not negatively affected by such intervention, instead SWOD non-users reported higher belongingness and self-efficacy at the end of the course.

SWD reported the lowest low stakes assessment score, belongingness and self-efficacy, which demonstrates their needs in learning in such math-rich courses. SWAN reported lower self-efficacy than SWOD in the middle of the course but reported the same level of self-efficacy as SWOD in the end.

Beyond the association found in previous studies, we found there was a close association between belongingness, self-efficacy and perceived learning for mutliple student groups. We found students belongingness was highly correlated with perceived learning for all student groups except for SWD users (possibly due to the small size). In addition, we found self-efficacy was highly correlated with perceived learning for various subgroups of students except SWD digital note users. Furthermore, we found that belongingness and self-efficacy are significantly correlated for student groups except for SWD users, SWAN users and SWOD nonusers. This aligns with existing findings on the relationship between belongingness and self-efficacy and yet points out the uniqueness of SWD in connection with the digital notes intervention. We also found that female and male students did not report differences in their belongingness while the female students reported lower self-efficacy even though they had the same level of low-stakes assessment scores.

In this study, we provided digital notes with features such as full searchable transcripts, screenshots, mathematical equations extracted directly from video recordings, structured content organization, and embedded links to the videos and multiple formats as output. Students reported they liked these features and suggested features such as extra worked out examples, extra comments, better formatting (i.e., more colors and different spacing) of the texts and structures as in a textbook. Some students would like to have embedded links to other course materials such as those of the recitations. Overall, the majority of the students were satisfied with the digital notes and reported that they found the digital notes were beneficial to their learning.

Discussion

The introduction and utilization of digital notes to multiple classes of statistics students did not decrease students' accessibility to the course. Instead, it significantly boosted students' belongingness, self efficacy and perceived learning. Several factors could have contributed to the improvement. First, the digital notes were completely equivalent to the lectures' content, which is all the content that was required for students to learn, for students who like to have all contents in one place this would be beneficial and an incentive. In addition, the notes were searchable so that students could save time in reviewing for certain desired contents. Furthermore these notes were organized by topics and provided a table of contents that would link to the specific part of the lecture videos, so that students who need to learn with multiple senses and modes could do it synchronously. Lastly, the notes' transcripts were almost completely accurate compared with the automatic transcripts from AI applications, which would promote students' learning as well. Although SWD may include a spectrum of different disability types, this method of pedagogy has the advantage to provide multiple pathways and cater to different disabilities regarding accessibility be it physical or mental/cognitive characteristics. We identified the SWAN student group who lacked access to synchronous lectures, and our study shows SWAN particularly benefited from such notes for they felt more belonged, built up stronger self-efficacy and perceived more learning. The results in our study found that although our courses have already had rather high accessibility, digital notes still made a difference on SWAN and SWD. With further development of new accessibility features or more innovative ways of implementing these notes, students' learning can be better supported.

The sample size is a limiting factor in the power of the statistical tests for SWD in this study due to the fact we designed the study with 2 similarly designed content with the same subject. In addition, SWD may have different needs that are not differentiated due to the sample size. In addition, we don't have responses from the SWD or SWAN non-users for their opinions on the digital notes. The difference in the size of the two courses was also a limiting factor. There were also other unknown factors related to course assessments such as midterm exams, project and the final that could have affected the belongingness, self-efficacy and perceived learning of the students. Furthermore, large STEM courses in math-intense subjects tend to be hard for SWD because the contents are more likely to be inaccessible, i.e., the tables and graphs were found to be undesirable for SWD in previous studies [6].

Future work

Based on feedback and our improved understanding of students' use of digital notes and accessibility needs we will continue to add new features to the user interface to increase its functionality and accessibility. For example we are working on user interface enhancements such as a "split view" in which users can edit the digital note on the left half of the screen and view their changes in real time on the right half (similar to editors such as Overleaf). We intend to add more output formats including Markdown and Microsoft Word (docx) to increase the utility and modes of representation. The next version of the tool will create digital notes with an automatically generated glossary that defines key terms used throughout the chapter (this work is described in a separate paper submitted to ASEE 2023). New use cases of this technology are also possible including personalized class notes and individualized learning.

To assist in future education research it would be possible to integrate into the tool surveys and collect anonymized user usage data from students. For example, links to surveys could be automatically included at the end of each digital note chapter asking students questions about their opinions on the course and the digital notes. Anonymized user usage data could be collected from the web tool to learn when and how students access this content. Automated collection of data would also facilitate future research at a much larger scale. By collecting data on the preferences and needs of students, we can achieve a better understanding of how to assist students, especially students with disabilities.

Our study is the beginning effort of evaluating the effect of a UDL-based approach using digital notes equivalent to live lecture contents. Although it's a single intervention in two UDL based courses with rather high accessibility scores, we see exciting benefits that have emerged specially for the students who either have an officially accommodated disability or who have needs that prevent them from attending live lectures from time to time. We are encouraged to explore more in such UDL based pedagogy and provide the empirical data with the engineering education community to further such innovations.

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A survey questions tables appendix

Question Type	Question
Demographics	What is your gender identity? I have a disability or disorder that makes it harder for me to succeed in this course Choose one or more race/ethnic group that you consider yourself to be Students with physical disabilities are those who reported that they had one or more of the following conditions: blindness or visual impairment that cannot be corrected by wearing glasses; hearing impairment (e.g., deaf or hard of hearing); orthopedic or mobility impairment; physical impairment or problem. Do you identify as a person with a physical disability? Students with mental or emotional disabilities are those who reported that they had one or more of the following conditions: speech or language impairment; learning, mental, emotional, or psychiatric condition (e.g., serious learning disability, depression, ADD, or ADHD); or other mental or emotional health impairment or problem. Do you identify as a person with a mental/emotional disability?
Perceivable	I could fully perceive the information in my electronic instructional materials using my available senses (e.g., seeing, hearing, touch, etc.) My available senses (e.g., seeing, hearing, touch, etc.) were sufficient to perceive the information in my electronic instructional materials. My electronic instructional materials were easy to see. It was easy for me to perceive information from images or other graphics. Videos were accompanied by accurate captions or transcripts. The information in my electronic instructional materials was presented in a variety of different ways. My instructional materials were easy to hear. My instructional materials were compatible with my available senses (e.g., seeing, hearing, touch etc.). Perceiving the information in my electronic instructional materials was a straightforward process. The information presented in videos was easy to perceive.
Operable	I felt successful at getting my electronic instructional materials to work. I could fully operate the user interface for my electronic instructional materials. (The user interface is how you interact with electronic materials via typing, clicking, touching, etc.) I could get my electronic instructional materials to work without needing to ask another person for help. My electronic instructional materials were easy to navigate. It was easy to find materials I needed on the course website. I could successfully operate my electronic instructional materials using the computer accessories I most prefer to use (e.g., mouse, keyboard, touchscreen). I could operate my electronic instructional materials without having to request accommodations. Operating the user interface for my instructional materials was easy for me. (The user interface is how you interact with electronic materials via typing, clicking, touching, etc.) Navigating my instructional materials was a pleasant experience.
Understandable	The information in my electronic instructional materials was understandable. The textual content in my electronic instructional materials was easy to follow. My electronic instructional materials were formatted in a consistent way. If I had a question about how features on the course website worked, the course website made it easy to find help. My electronic instructional materials used clear and simple language. My electronic instructional materials worked in a predictable manner. Directions in my electronic instructional materials were easy to understand.
Robust	My electronic instructional materials were compatible with the assistive technologies I use. It was easy to access my electronic instructional materials using my assistive technology. Getting my assistive technology to work with my electronic instructional materials was a simple process. My electronic instructional materials worked well with my assistive technologies. Using my electronic instructional materials with my assistive technology was a pleasant experience.
Open ended	How much time do you spend on learning materials per week?

Table 17: Survey I Questions

Question Type	Question
Demographics	Are there times when you are unable to attend scheduled course activities due to a health issue (e.g., chronic migraine, chronic digestive issue, period pain) that is not classified as a disability.
Perceivable	I could fully perceive the information in my electronic instructional materials using my available senses (e.g., seeing, hearing, touch, etc.) My available senses (e.g., seeing, hearing, touch, etc.) were sufficient to perceive the information in my electronic instructional materials. My electronic instructional materials were easy to see. It was easy for me to perceive information from images or other graphics. Videos were accompanied by accurate captions or transcripts. The information in my electronic instructional materials was presented in a variety of different ways. My instructional materials were easy to hear. My instructional materials were compatible with my available senses (e.g., seeing, hearing, touch etc.). Perceiving the information in my electronic instructional materials was a straightforward process. The information presented in videos was easy to perceive.
Operable	I felt successful at getting my electronic instructional materials to work. I could fully operate the user interface for my electronic instructional materials. (The user interface is how you interact with electronic materials via typing, clicking, touching, etc.) I could get my electronic instructional materials to work without needing to ask another person for help. My electronic instructional materials were easy to navigate. It was easy to find materials I needed on the course website. I could successfully operate my electronic instructional materials using the computer accessories I most prefer to use (e.g., mouse, keyboard, touchscreen). I could operate my electronic instructional materials without having to request accommodations. Operating the user interface for my instructional materials was easy for me. (The user interface is how you interact with electronic materials via typing, clicking, touching, etc.) Navigating my instructional materials was a pleasant experience.
Understandable	The information in my electronic instructional materials was understandable. The textual content in my electronic instructional materials was easy to follow. My electronic instructional materials were formatted in a consistent way. If I had a question about how features on the course website worked, the course website made it easy to find help. My electronic instructional materials used clear and simple language. My electronic instructional materials worked in a predictable manner. Directions in my electronic instructional materials were easy to understand.
Robust	My electronic instructional materials were compatible with the assistive technologies I use. It was easy to access my electronic instructional materials using my assistive technology. Getting my assistive technology to work with my electronic instructional materials was a simple process. My electronic instructional materials worked well with my assistive technologies. Using my electronic instructional materials with my assistive technology was a pleasant experience.
Belonging	I feel that I belong to the course community I consider myself a member of the engineering or computing world. I feel like an outsider. I feel accepted. I feel respected. I feel valued. I feel appreciated. I feel like I fit in. I feel significant. I try to say as little as possible. I enjoy being an active participant. I wish I were invisible. I trust the testing materials to be unbiased. I have trust that I do not have to constantly prove myself. I trust my instructors to be committed to helping me learn. Even when I do poorly, I trust my instructors to have faith in my potential.
Self-Efficacy	Soon after the end of a lesson, I am able to remember ______ of the key concepts. I am able to organize my activities so that I can meet ______ course requirements. I am able to explain to my fellow students, in a way they can understand ______ of the key concepts covered in a course. After sitting an exam, I am able to remember ______ of the key concepts covered in the course. Sometimes/About half the time - I _______ know how to get up to date on a topic if my knowledge of it is dated. I can understand ______ of the concepts covered in my course. I can _______ interpret news reports related to a topic I am studying When I find something new about a topic that I am studying, I am _______ able to connect it with other things that I know about the topic.
Open ended	How much time do you spend on learning materials per week? What benefits do you see using digital notes, apart from the extra credit you receive? What complaints do you have for digital notes in helping you learn new materials? (or frame as how satisfied are you?) What errors in the digital notes have you noticed after using it for the past weeks? How do you describe your experience of using digital notes as a whole? And how do you describe your experience of using certain features of digital notes? What parts/sections of the digital notes were the most effective in helping you learn? And how were they helpful? Have you developed new ways of learning with digital notes? If so, can you describe what that type of learning is and in what way is it different from your previous learning methods? Do you feel digital notes promote, hinder, or do not do much to your interaction with instructors or fellow students? Can you explain how that works for you?

Table 18: Survey II Questions

Question Type	Question
Belonging	I feel that I belong to the course community
	I consider myself a member of the engineering or computing world.
	I feel like an outsider.
	I feel respected.
	I feel valued.
	I feel appreciated.
	I feel like I fit in.
	I feel significant.
	I try to say as little as possible.
	I enjoy being an active participant.
	I wish I were invisible.
	I trust the testing materials to be unbiased.
	I have trust that I do not have to constantly prove myself.
	I trust my instructors to be committed to helping me learn.
	Even when I do poorly, I trust my instructors to have faith in my potential.
Self-Efficacy	Soon after the end of a lesson, I am able to remember ______ of the key concepts.
	I am able to organize my activities so that I can meet ______ course requirements.
	I am able to explain to my fellow students, in a way they can understand ______ of the key concepts covered in a course.
	After sitting an exam, I am able to remember ______ of the key concepts covered in the course.
	Sometimes/About half the time - I _______ know how to get up to date on a topic if my knowledge of it is dated.
	I can understand ______ of the concepts covered in my course.
	I can _______ interpret news reports related to a topic I am studying
	When I find something new about a topic that I am studying, I am _______ able to connect it with other things that I know about the topic.
Perceived Learning Goals	I can organize course material into a logical structure.
	I can produce a course study guide for future students.
	I have changed my attitudes about the course subject matter as a result of this course.
	I can intelligently critique the texts used in this course.
	I feel more self-reliant as a result of the content learned in this course.
	I feel that I am a more sophisticated thinker as a result of this course.
Efficiency	To achieve the same learning goal,I spend less time learning the same material with digital notes than with the other methods in the same course module.
	I spend more time, but the time is spent on more learning activities that did not exist prior to digital notes in the course module.
Satisfaction	I feel that it is compatible with other parts of the course.
	I feel that it provides an additional channel of learning.
	I feel the trouble of learning to use it overweighs its benefit.
	I feel that it is redundant since other parts of the coursemodule have similar functions.
	I feel that it creates a different way of learning.
	I feel that with digital notes, I am less confident about mastering the course content.
	Overall, I am _________ with the digital notes in this course.
Open ended	How do you describe your experience of using digital notes as a whole? And how do you describe your experience of using certain features of digital notes?

Table 19: Survey III Questions

B analysis results tables appendix

Question Type	SWD-SWAN-SWOD p value (corrected)	SWD-SWOD p value (corrected)	SWD-SWAN p value (corrected)	SWAN-SWOD p value (corrected)	Male-Female p value (corrected)
Perceivable	0.005 (0.019)*	0.190 (0.380)	0.584 (0.779)	0.001 (0.005)*	0.080 (0.161)
Operable	0.072 (0.096)	0.547 (0.729)	0.097 (0.277)	0.040 (0.081)	0.550 (0.724)
Understand-able	0.046 (0.091)	0.018 (0.072)	0.138 (0.277)	0.205 (0.273)	0.724 (0.724)
Robust	0.908 (0.908)	0.856 (0.856)	0.959 (0.959)	0.669 (0.669)	0.072 (0.161)

Table 20: Survey I POUR differences p-val. * Corrected p-val < 0.05

	User					Non User				
					Perceivable					
	pre mean	pre median	post mean	post median	p value (corrected)	pre mean	pre median	post mean	post median	p value (corrected)
All	4.5	5	4.4	5	0.280 (0.560)	4.4	5	4.3	5	0.084 (0.112)
SWD	4.5	5	4.4	5	0.396 (0.528)	4.4	5	4.1	4	0.232 (0.465)
SWAN	4.4	5	4.4	5	0.935 (0.935)	4.4	5	4.4	5	0.563 (0.978)
SWOD	4.5	5	4.5	5	0.341 (0.683)	4.5	5	4.3	5	0.159 (0.159)
					Operable					
	pre mean	pre median	post mean	post median	p value (corrected)	pre mean	pre median	post mean	post median	p value (corrected)
All	4.5	5	4.5	5	0.647 (0.863)	4.5	5	4.4	5	0.049 (0.099)
SWD	4.6	5	4.4	5	0.345 (0.528)	4.4	5	4.0	4	0.084 (0.336)
SWAN	4.5	5	4.5	5	0.405 (0.809)	4.4	5	4.5	5	0.978 (0.978)
SWOD	4.5	5	4.6	5	0.727 (0.888)	4.5	5	4.3	5	0.033 **(0.048)***
					Understandable					
	pre mean	pre median	post mean	post median	p value (corrected)	pre mean	pre median	post mean	post median	p value (corrected)
All	4.5	5	4.4	5	0.032 (0.127)	4.4	5	4.3	4	0.115 (0.115)
SWD	4.3	5	4.1	4	0.249 (0.528)	4.0	4	3.9	4	0.557 (0.557)
SWAN	4.5	5	4.4	5	0.119 (0.476)	4.3	5	4.4	5	0.789 (0.978)
SWOD	4.5	5	4.4	5	0.239 (0.683)	4.5	5	4.3	5	0.024 **(0.048)***
					Robust					
	pre mean	pre median	post mean	post median	p value (corrected)	pre mean	pre median	post mean	post median	p value (corrected)
All	4.6	5	4.6	5	0.988 (0.988)	4.6	5	4.5	5	0.042 (0.099)
SWD	4.7	5	4.7	5	0.655 (0.655)	4.5	5	4.2	5	0.396 (0.528)
SWAN	4.6	5	4.7	5	0.808 (0.935)	4.6	5	4.5	5	0.598 (0.978)
SWOD	4.7	5	4.6	5	0.888 (0.888)	4.6	5	4.4	5	0.036 **(0.048)***

Table 21: POUR user-nonuser differences. * Corrected values < 0.05.

	All Students			SWD			SWAN			SWOD		
	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser	All	User	Nonuser
Number of Students	255	128	127	18	8	10	101	48	53	136	72	64
Coefficient	0.005	0.111	-0.089	0.219	**0.716**	-0.156	-0.017	0.056	-0.045	-0.015	0.097	-0.145
p	0.940	0.218	0.361	0.382	**0.046**	0.666	0.871	0.696	0.760	0.864	0.423	0.287

Table 22: The correlation between the subscale “Understandable” and low-stakes assessment after the digital notes

Question Type	Male			Female			NBCDO					
	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	Male-Female-NBCDO p val (corrected)	Male-NBCDO p val (corrected)	Female-NBCDO p val (corrected)
						Survey(I)						
Perceivable	4.6	5	91	4.4	5	87	3.6	4	52	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Operable	4.5	5	91	4.5	5	89	3.6	3	47	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Understandable	4.5	5	89	4.4	5	88	4.1	4	65	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Robust	4.6	5	92	4.7	5	92	4.2	5	67	0.001 (0.001)*	0.002 (0.002)*	<0.001 (<0.001)*
						Survey(II)						
Perceivable	4.4	5	87	4.5	5	90	3.9	4	67	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Operable	4.5	5	89	4.5	5	89	4.0	4	70	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Understandable	4.4	5	87	4.3	5	84	3.9	4	63	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Robust	4.5	5	92	4.7	5	94	4.1	4	67	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*

Table 23: The NBCDO statistics of the Survey I and II perceived accessibility scales

	User(6)					Non User(3)				
	pre mean	pre median	post mean	post median	p value	pre mean	pre median	post mean	post median	p value
Perceivable	4.1	4	3.7	4	0.285	3.3	4	4.1	4	0.465
Operable	4.0	4	3.8	4	0.593	3.4	3	4.2	5	0.465
Understandable	4.0	4	3.7	4	0.285	4.1	4	4.1	4	0.715
Robust	4.3	4.5	4	4	0.317	4.2	5	4.2	4	0.713

Table 24: NBCDO POUR user-nonuser differences

Question Type	Male			Female			NBCDO					
	μ	Med	Pos (%)	μ	Med	Pos (%)	μ	Med	Pos (%)	Male-Female-NBCDO p val (corrected)	Male-NBCDO p val (corrected)	Female-NBCDO p val (corrected)
Survey(II)												
Belonging	3.7	4	64	3.8	4	67	3.3	3	35	<0.001 (<0.001)*	<0.001 (<0.001)*	<0.001 (<0.001)*
Self-Efficacy	2.2	2	84	2.0	2	78	2.3	2	93	<0.001*	0.023*	<0.001*
Survey(III)												
Belonging	3.9	4	72	4.0	4	74	3.7	4	54	0.001 (0.003)*	0.001 (0.002)*	<0.001 (0.001)*
Self-Efficacy	2.2	2	89	2.0	2	80	2.3	2	89	<0.001*	0.658	<0.003*

Table 25: The NBCDO statistics of the Survey II and III Belongingness and self-efficacy scales

	User(6)					Non User(3)				
	pre mean	pre median	post mean	post median	p value	pre mean	pre median	post mean	post median	p value
Belonging	3.1	3	3.6	3	0.109	3.6	4	3.8	4	1
Efficacy	2.1	2	2.1	2	1	2.5	3	2.5	2.5	0.655

Table 26: NBCDO belongingness and self-efficacy user-nonuser differences

Question Type	Understandable/ Perceivable	Operable/ Perceivable	Understandable/ Operable	Operable/ Robust
Coefficient(p val)	0.97(<0.001*)	0.92(<0.001*)	0.88(0.002*)	0.72(0.029*)

Table 27: Significant correlations within low-stakes assessment score and POUR for NBCDO after using digital notes