Effects Of Note Formatting On Student Learning – Implications For Accessibility And Diverse Minds

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EFFECTS OF NOTE FORMATTING ON STUDENT LEARNING – IMPLICATIONS FOR ACCESSIBILITY AND DIVERSE MINDS

Abstract:

The use of course management systems have resulted in a growing trend among faculty to provide students with course materials to augment lectures. This can include lecture notes, example problems or supplementary reading. In engineering courses, instructor-provided notes are often handwritten -- even in online courses. There is an assumption that handwritten notes are preferred by students and have a pedagogical benefit over typed notes.

Access to course materials for students with disabilities is also improving due to advancements in both technology and awareness. Students with disabilities often receive custom accommodation plans for course work when the original class format does not adequately support their learning. In courses that do not provide access to notes for all students, one key accommodation that students can request is access to course notes. Whether provided to all students or through an accommodation, the format of course notes often makes it difficult for students to access content using assistive technology. Current read-aloud and screen reader technologies can turn typed notes into spoken word; however, they are not able to interface with math or handwritten mediums. This limitation creates a major challenge for students with visual or reading disabilities who are pursuing degrees in mathematics and engineering fields.

The purpose of this paper is to examine the pedagogical effects of note formatting and to understand how this may impact the first steps of adapting a course to a more accessible format. Data is presented from an intervention in a mechanical engineering analysis course that examined the effects of note formatting (typed or handwritten) on students learning, as well as student preferences about the provided note styles. It was determined that note format did not influence student performance on quizzes. A discussion follows to guide the design and development for an inclusive, accessible course.

INTRODUCTION

Diversity in Engineering:

The field of engineering is a balance of creativity and analysis. Engineers are expected to understand abstract concepts and apply them to the physical world. This requires an intricate method of understanding problems and then structuring thought processes to find solutions. As discussed in Felder *et al.*, there is not a singular style of engineer -- some people in the field enjoy practical, detail-oriented tasks while others prefer more creative theoretical projects [1]. The engineering methods used vary between individuals due to the diversity of humanity. No two people are the same, because everyone comes from a different background, with different ways of interacting with the world. Engineers cannot be defined as a singular, uniform character, rather they create a spectrum of diversity throughout the field. This diversity enables the field to balance the creativity and analytical skills which are necessary for successful engineering.

In a similar manner, students come from diverse backgrounds. Each student has different life experiences, creating different ways of interfacing with reality. This in turn creates a personalized style of learning. Many have worked to categorize these learning styles to create a perfected method to teach students [2]. The analysis and study of learning styles has proven to be a helpful starting point when understanding how to interact with students through course content. However, it is safe to assume that there will never be a single comprehensive approach of creating a perfected course model. The flux and evolution of technology, and students, limits the ability to create a constant classroom experience that equally supports all members.

With the understanding of the intrinsic diversity of students, it is important to acknowledge that each individual student has a preferred method of learning. Through the years of education that prepared students to pursue their degrees, each student has devised a personalized approach for how they interact with the course content. Such approaches normally include a combination of reading and listening strategies to interact with course material provided in the classroom and on the learning management system. The different approaches can be seen from the varying study habits of engineering students, as well as the differences in how students interact with their in-class experiences. Students cannot be considered as black boxes. Rather, students have curated their learning habits to support success. This then leads to the concept that each student has a preferred strategy to access their learning experience.

Similarly, course instructors have a preferred method of teaching. Every professor has developed a (conscious or subconscious) style in which they teach. Whether conscious or not, a professor's purpose is to assist the students in their endeavor to learn. A common phenomenon within education is a mismatch between the teaching styles of professors and learning habits of students. This means that information is not able to smoothly be shared between the two parties. One method through which this disparity may be minimized is to create an inclusively designed course experience. Taking into consideration the broad scope of student learning preferences, inclusive design of a class can support the learning of an expanded group of students. Such course development must also consider current technological limitations that may impact accessibility for students with disabilities.

Inclusive Design:

Inclusive design is a method of designing a solution for those who will benefit from or use it. It is commonly compared to universal design, which adheres to the philosophy of design 'one for all' [3] -- whereas inclusive design follows a philosophy of 'one for one' [4]. Universal design focuses on retrofitting a single solution to fit the needs of the most obvious users. However, inclusive design concentrates on ensuring all needs of a single user are met through a single design. It is understood that inclusive design ensures success for all, rather than the most obvious few.

An important facet of inclusive design is the designer's awareness and acknowledgement of people who may not have been considered in the initial design space. Often, these additional sets of people are those who interact with the world in a different manner or with a different strategy then the designer. Sometimes these are people from other cultures, demographics, or ability levels. People with disabilities are important in the discussion of inclusive design. *This is because if their needs become an afterthought in design, the final solution may not be a mere inconvenience, rather a complete restriction to an activity.*

The Importance of Accessibility:

People with disabilities often have limitations in how they interact with the world. This limitation can range from how they move, to the senses they are able to use, to even the method in which they process information. The broad spectrum of ability levels leads to the need for an understanding of how content and information is learned from these varied perspectives. The field of understanding and creating solutions for individuals with disabilities is called Accessibility, often shortened to A11y, substituting the number 11 in for the eleven letters between A and Y. A11y work typically focuses on meeting and exceeding standards set by varied accessibility guidelines, such as those set by the ADA (Americans with Disabilities Act) -- which ensures that people are able to use built spaces -- and the WCAG (Web Content Accessibility Guidelines) -- which outlines important web design requirements.

In education, it is important to take into consideration the needs of individuals with disabilities, not only because it is the right thing to do and legally required, but it is also sometimes written into the bylaws of the educational institution. Many universities and colleges are founded on the cornerstone of ensuring access to education to all [5]. At the time the institutions were founded, the push for access to education typically focused on other demographic dimensions; however, such attention on access can and should now be expanded to consider those with disabilities.

Lessons from an Individual with a Disability:

People with disabilities have the same passions and dreams as those without. This drives the need for education to be suited to any need -- because if there is a passion to learn, there should be nothing in the way. One well-known example of this can be seen in Dr. Stephen Hawking, who became one of the best scientific minds of the century, even with a late stage diagnosis of ALS. Another example can be seen with Dr. Abraham Nemeth.

Abraham Nemeth was a mathematician, who was born with a congenital disease that made him blind from birth [6]. He initially pursued and received degrees in psychology from Brooklyn College and Columbia University in New York; however, he felt rather inquisitive towards math and physics and decided to complete a PhD in mathematics. Dr. Nemeth was hired for a tenure-track professorship at the University of Detroit Mercy, and -- by using creative strategies and study habits -- he broadened the understanding of how individuals can interact with mathematics. Through necessity, Dr. Nemeth developed a braille math code that translated the visual nature of mathematics content into a format that he could feel to understand concepts. This braille system is known as Nemeth Math and is the leading numeric braille system for mathematic content. Dr. Nemeth also worked with his students and colleagues to create a system of math verbalization, which is referred to as Math Speak, and set standards for how mathematic notation can be talked through in a single string of words as compared to the intricate, multi-dimensional layout of equations [7]. These assistive technologies were developed out of necessity, but they are the backbone of the accessibility features that enable others with visual impairments to interact with and learn math.

Assistive Technologies – For Engineering and Mathematics:

Assistive technologies are innovations that allow individuals to interact with their environment in a way that was originally difficult or impossible due to an ability limitation. Common examples of assistive technology are a ramp to a building (as compared to stairs) and subtitles on videos (to support those with hearing limitations). One less obvious assistive innovation is the typewriter, which when developed in 1575 and was known as the *scrittura tattile*, or tactile writing. It was created as a device to provide blind users with a way to write independently [8].

Some additional assistive technologies, in the realm of STEM education and practice, are **screen readers**, which are computer programs that interface with the operating system to interact with visual information and 'read' it aloud. They are systems that translate the common visual/spatial user interfacing of computers to an audio or tactile interface. This provides people with visual disabilities access to the computer's power. In order for screen readers to be successful in communicating visual content, images and figures must include pre-typed information about the value they add to the document. This information is called **alternative text** and acts as a caption that is read by the screen reader in place of a visual element. The final important feature of screen readers with respect to math is **MathML** -- which is the language that systematically communicates math to screen readers. In a similar manner to pictures, equations are too difficult and multidimensional for a screen reader to decipher. MathML translates the inputted coded math into the correct notation to communicate math using the connected screen reader.

Several important limitations exist with respect to engineering course content and assistive technologies. To begin, many PDFs have typically not been accessible. The scanned or handwritten nature of material in many PDF documents is not able to interface with screen readers, which require clear, typed text to function to their full potential. Similarly, PDF documents created using LaTex are typically not able to interface with screen readers because the mathematic equations and figures lack the appropriate alternative text. Work has been done to create a plug in that make LaTex documents compatible with screen readers; however, streamlined strategies for creating accessible pdfs from this technical software are still in development [9]. Similarly, some pdf readers do support optical character recognition (OCR) in order to translate scanned documents into searchable (and therefore screen readable) text. However, these features often result in translation errors, which can negatively affect the reader's understanding of the original material. While

Adobe has developed guidelines for the creation of accessible pdf's, most faculty are not familiar with the detailed recommendations provided.

The easiest way to create course content that can interface with screen readers is through Microsoft Word. Microsoft, as a company, has invested in the research and development of assistive technologies. A significant advancement is the "Read Aloud' feature in Microsoft Word, which interacts with text, figures, and equations included in a Word document and speaks them aloud.

Tools such as Microsoft Read Aloud are innovative, not only for individuals with disabilities, but for anyone who wants to interface with content in an audible manner. The impact of an innovation such as this can be seen from the use cases of audio books. Having multiple avenues of information intake is helpful to everyone -- they allow for more creative and individualized approaches to be developed by students to learn new material.

Course Design in Consideration of A11y – Format of Provided Notes:

The complexities of accessibility can feel intimidating when developing a course -- but so can any other aspect of a course. A course will never be created to be perfectly accessible, nor stay perfectly accessible -- rather it will evolve through minor steps of improvement as different aspect of the course are produced and published. The important thing is to create an initial balance between the accessibility needs, the professor's teaching style, and the students' learning habits.

File types provided to students are a significant factor in determining whether a course is accessible or not. As discussed previously, Word documents are the preferred method of delivering content to ensure accessibility. However, an underlying assumption among engineering faculty is that students prefer handwritten notes (such as those distributed in PDFs). Several hypotheses for this assumption come from the idea that handwritten notes bring value to the course. There is some evidence that students who handwrite their own notes retain more of the information, though the impact appears to be on conceptual understanding rather than the recall of facts [10]. Handwritten notes are also assumed to structure content in a manner that encourages student engagement, because the notes appear to be more personalized -- which indicates to the students that the professor added an extra effort as they prepared for the class. Little research has been conducted regarding this dimension of course design.

The following study was designed to determine if the format of faculty-developed course notes (handwritten or typed) influenced student learning or impacted student preference on which notes should be used within an engineering analysis course.

<u>METHODS</u>

The goal of this study was to test the understanding of engineering students' note usages and answer the guiding research question: Is there an advantage to using typed or handwritten notes while studying engineering content?

In this study, the hypothesis of note format advantage was tested within a junior-level Engineering Math class using both qualitative and quantitative measures. The course is a required part of the mechanical engineering program and included 90 students. During the semester, two quizzes were administered that were directly related to lecture material for which course notes were provided in advance of the lecture. The students were split into two random groups, and course notes were assigned through the learning management system. Each group was provided access to a defined set of course notes – handwritten or typed – for each of the two quizzes. To minimize group effects and any possible impact on student learning, the group that received typed notes for the first quiz were assigned handwritten notes on the second, and vice versa. The note assignments can be seen in Table 1.

	Group 1	Group 2
Quiz 1	Handwritten	Typed
Quiz 2	Typed	Handwritten

Table 1: Assignment of note format to experimental groups.

The course notes were created to be identical to each other, except for the formatting. The professor of the course prepared the handwritten notes, following the format he preferred, and the research team prepared the typed notes – ensuring that all visual elements, notation, and figures matched the professor's notes. Figure 1 provides an example portion of the two versions of the course notes.

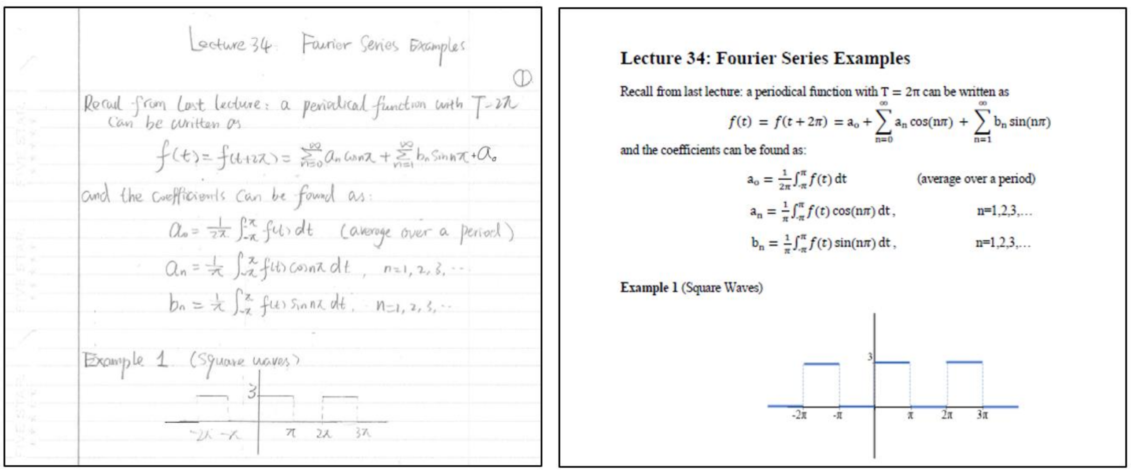

Figure 1: Example of lecture notes, handwritten and typed.

Once the notes were made available to each study group, the students were notified and encouraged to print, or download a digital file, for use during the corresponding lecture. Following each lecture with prepared notes, a short quiz was administered by the professor. After each quiz, a learning assistant collected time stamp data from the learning management system that indicated if and when each student accessed the course notes. Following the completion of the course, the quiz grades, final exam grades, final course grades, and note usage data were collected for each student and anonymized for further data analysis. It should be noted that students were not required to access or use the course notes, which resulted in a smaller sample size than the original course enrollment. In addition, as the quizzes were offered during the class period (and were fairly low stakes assessments), only students who attended class on that particular day actually completed the quiz.

A survey was printed on the back of the second quiz. The survey asked the following 3 questions:

- Did you read the notes? Why or why not?
- Which type of notes did you prefer? Why?
- Which types of notes were easier to read? Why?

The responses to the survey were anonymized and coded for further analysis.

Comparisons of quantitative results between experimental groups were made using a two-tailed, Welch's t-test (unequal group size, unequal variances). The effect of the note format on an individual student's success on the quizzes was assessed using a Wilcoxon's signed rank test. In all cases, the p-value was set to 0.05.

RESULTS

A total of 90 students participated in the course during the study semester. Out of those students, 46 were assigned to Group 1 and 44 where assigned to Group 2. Only 69 students participated in Quiz 1, and 59 participated in Quiz 2. Further data on how many students accessed the notes can be seen in Table 2.

	Original Group	Took Quiz 1	Accessed Notes for Quiz 1	Took Quiz 2	Accessed Notes for Quiz 2	Accessed Both Sets of Notes
Group 1	46	37	28	32	24	14
Group 2	44	32	27	27	19	17
Total	90	69	55	59	43	31

Table 2: Number of students in each study group and their use of pre-quiz notes

The quiz score distributions, for the students who accessed the class notes, can be seen in Figure 2. The average for Quiz 1 was 59% with a standard deviation of 21%, while the average for Quiz 2 was 66% with a standard deviation of 19%.

To begin analysis, the final exam and final grade scores were analyzed to gather a general understanding of the statistical relationship between the two groups. The Welch's t-test (unequal group size, unequal variances) was administered to see if either of the groups had performed statistically better than the other within the course. The t-statistic for the comparison of the final exam grade between the groups was 1.96 with a p=0.054, and the t-statistic for the final grade was 1.44 with a p=0.154. This led to the determination that the study groups were not statistically different in terms of final exam or final course grades. This allowed for the analysis of the quiz data with confidence that the student groups were indeed representative of the same overall population.

When looking at the benefit of lecture note formats, only the scores of the students that viewed the lecture notes prior to the quiz were used in the analysis. The data was analyzed using an unequal variance t-test. The t-statistics for Quiz 1 and Quiz 2 were t=-1.33 and t=-2.03 respectively, which correspond to p-values of p=0.19 and p=0.048. This indicates that there was no significant difference between the groups' performance on Quiz 1. However, there was a slight statistical difference between the scores for Quiz 2, marginally favoring Group 2, who used handwritten notes.

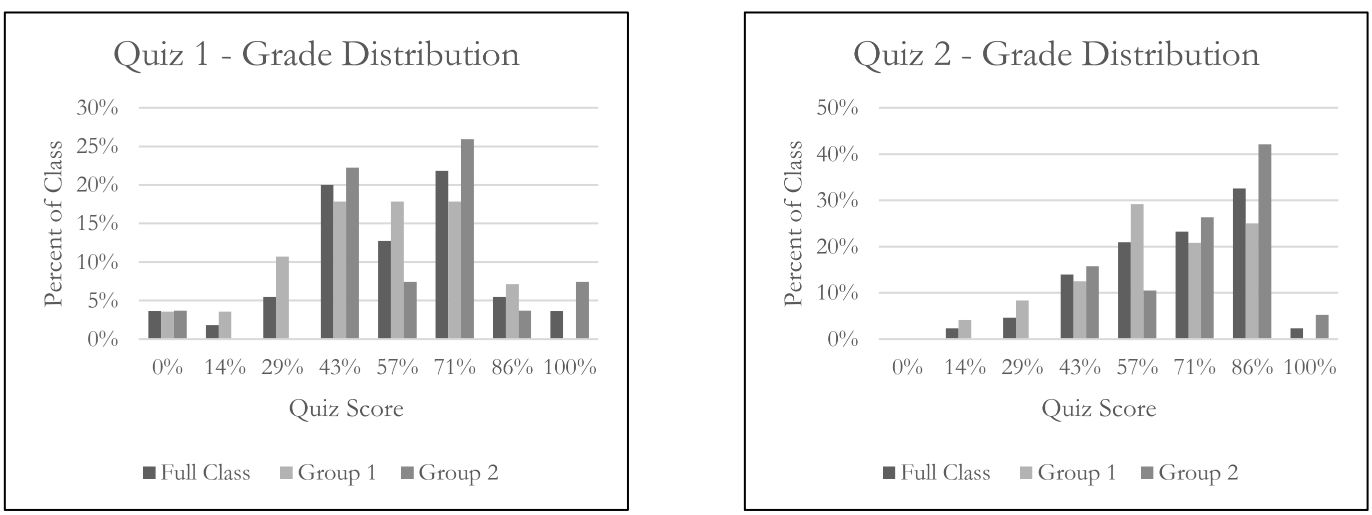

Figure 2: Histograms showing distributions of quiz grade scores.

To ensure that the students who were analyzed in Group 2, were not in general stronger students, each student's quiz scores were normalized by their final exam score, which was assumed to be a good measure of overall student performance. The t-statistics for the normalized quiz grades were $t=-1.44$ and $t=-1.81$ for Quiz 1 and Quiz 2 respectively. These led to p-values of $p=0.156$ and $p=0.07$ for Quiz 1 and Quiz 2, respectively, which indicates no statistically significant difference in student performance based on note format.

A Wilcoxon's Signed Rank Test was administered by comparing the scores within an individual to determine if one mode of notes consistently had a more positive impact on the student's quiz scores. Only scores from students that accessed the notes file prior to the both quizzes were used. For the sample size of 31, the z-value was found to be 0.24, which indicates that there was no significant difference between the format of the notes when it came to an individual student's performance.

For the qualitative data, 53 students returned the survey (of 59 who took Quiz 2). The main variable of interest was which format of notes the students preferred. After interpreting students' responses, it was concluded that 17 students preferred handwritten notes, and 12 students preferred typed. Other answers included: no response (13), no opinion (2), Both (2), Online (3), Printed (1) and Personal (3). The variation of responses was due to the open-ended nature of the survey question. Further student responses will be discussed in the following sections.

DISCUSSION

Students who preferred typed notes typically indicated that it was due to the fact that they were 'easier to read' and 'easier to annotate'. Many students, independent of format preference, mentioned that typed notes were clearer than handwritten notes -- which decreased the students' uncertainty with respect to various equations and notation details. Students who preferred handwritten notes mentioned enjoying the connection between the notes and how the professor lectured by writing on the board or with the document camera. These students mentioned that it made them feel more connected and engaged in class. Finally, some students who preferred the handwritten notes discussed the fact that this note format made it easier to emphasize various important aspects of the notes.

Due to the results of the Wilcoxon's Signed Rank Test, it can be concluded that – while students may have had a personal preference -- there was no observable, quantitative advantage to using typed or handwritten notes in this study. However, the qualitative data showed a slight preference towards handwritten notes. The exact reason for this difference between preference and impact was not explored thoroughly in this study. However, one reason for this conclusion may be indicated through one student's comment of preferring handwritten notes because "there is no particular reason, it is just easier for me to understand". Extrapolating from this comment, it is likely that the note style that students prefer to use in class is likely to simply be a personal preference -- a preference that could originate from study habits, experience, or convenience.

Due to the population enrolled in the course, this study involved students without an accommodation for visual or reading disabilities. The question that was being investigated was whether preparing class notes for improved accessibility – by making them ready for a screen reader – would affect student learning in the course in general.

When a professor is creating a class with accessibility in mind, it is important to be aware of technologies available to ensure success for students with disabilities. Universities and colleges typically have resource centers that work with students with disabilities and professors to ensure appropriate accommodations are created and utilized. These offices will have information on what technology is available at the institution. For in-person classes, many innovations are typically available for use. For example, an assistant can be used to scribe, SmartPens can be used to record audio of the lecture, and after class tutoring can be conducted to ensure successful learning for students with disabilities. For online classes, assistive technologies are more limited. When creating content for an online course, one must be aware of the accessibility measures that may be needed for students to complete the course. *Typed notes are a good way to ensure accessibility is considered, and this study demonstrates that they do not negatively impact student learning.* However, if handwritten notes are preferred by the professor, more conscious efforts -- such as utilizing math speak principals in video lectures -- will be necessary.

Accessibility is evolving. New technology is being created, different methods are being developed, and further understanding is being gained. The focus of this work was not to make a perfectly accessible course. It was to provide faculty with information that could be used to create a course that would be readily transitioned into a fully accessible format if and when it was needed. A professor of a course is the designer of how the course's material is structured and conveyed. It is their responsibility to be inclusive and conscious of the choices they make to ensure the final result promotes success for all students.

CONCLUSION

The goal of this study was to understand whether there was a measurable advantage to the format of notes used to prepare for a quiz, and none was found. Student success on assessments was not linked to the style of professor provided notes. There was some variation among students with respect to individual preference about the note format; however, this was not a clear enough common preference to conclude that one style should be used over the other.

Both formats of notes have pros and cons. Typed notes allow for clear content and accessible material; however, such notes typically require a large effort to make them coherent. Handwritten notes are perceived to be slightly more preferred by students and are simple to create; however, they are inaccessible to screen readers. If accessibility is to be considered for the current semester or in the future, typed notes will provide the opportunity for students with visual or reading disabilities to utilize screen readers in order to independently access the material. If professors opt for handwritten notes, they should be prepared to investigate other systems to support students with diverse needs.

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