Guideline-Based Evaluation and Design Opportunities for Mobile Video-based Learning

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ABSTRACT

Learners consume video-based learning content on various mobile devices due to their mobility and accessibility. However, most video-based learning content is originally designed for desktop without consideration of constraints in mobile learning environments. We focus on readability and visibility problems caused by visual design elements such as text and images on varying screen sizes. To reveal design issues of current content, we examined mobile learning adequacy of content with 681 video frames from 108 video lectures. The content analysis revealed a distribution and guideline compliance rate of visual design elements. We also conducted semi-structured interviews with six video production engineers to investigate current practices and challenges in content design for mobile devices. Based on the interview results, we present a prototype that supports a guideline-based design of video learning content. Our findings can inform engineers and design tool makers on the challenges of editing mobile video-based learning content for accessible and adaptive design across devices.

CCS CONCEPTS

• **Human-centered computing → Heuristic evaluations**.

KEYWORDS

Design Guidelines, Content Analysis, Video-based Learning, Mobile Devices

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1 INTRODUCTION

With the increasing ubiquity of mobile devices, learners access video-based learning material at both a time and place convenient for them [16]. The lockdowns and school closures caused by the global pandemic accelerated an increase in learners on video learning platforms such as MOOCs (e.g., edX, Coursera, Udacity, and FutureLearn) due to their openness and easy accessibility [2, 39, 48]. In addition, prior research proves the synergistic characteristics of mobile learning and MOOCs [15, 17].

However, one of the main limitations of mobile learning is the small screen size, which deteriorates the learning experience and decreases the effectiveness of learning with too small font size, content-heavy lecture slides, and complex graphics to digest in a mobile environment. Existing learning frameworks also highlight the importance of such visual design factors in learning. Inappropriate font sizes of learning material impose unnecessary cognitive load [31] and lower judgments of learning (JOLs) [21, 38]. An excessive amount of words is another factor that increases the cognitive load [31, 43, 44] and information overload [4]. Image elements can also increase the cognitive load by splitting learners' attention [30, 31]. However, most of the existing video learning content is originally designed for desktops with a widescreen. Moreover, existing studies on mobile video-based learning lack consideration for video production engineers and designers who are direct stakeholders of lecture video design, being involved in the content design process.

To better understand this challenge, we examined 681 video frames from 108 MOOC video lectures. The lectures are selected from the top MOOC courses list in 2019 released by Class Central [40] and include MOOCs from Coursera, edX, and FutureLearn. To thoroughly understand the common design patterns of current video lectures, we examined the guideline compliance rate for four design elements: font size, the number of words, proportional area (% area) of images, and the number of images for each video frame. The analysis result shows that the current video lectures are not suitable for mobile learning environments with too small font size and dense text, which are not readable and digestible on small screens. 86-98% of the collected video frames had too small font sizes and 60-82% had too dense text, violating the design guidelines. This analysis result reveals the distribution and issues of the current lecture design.

We also conducted formative interviews with six video production engineers to investigate current practices and challenges in content design for mobile devices. The engineers consider how the content they created will be displayed on mobile devices. They mentioned that an increasing number of learners watch a video lecture with various portable devices in different learning environments. For this reason, they try to adapt the content to fit mobile devices by resizing, repositioning, and segmenting the content. The main design factors they consider include font sizes and the amount of information on mobile screens.

However, editing and tailoring video content remains time-consuming [11, 24, 32]. While the video production engineers

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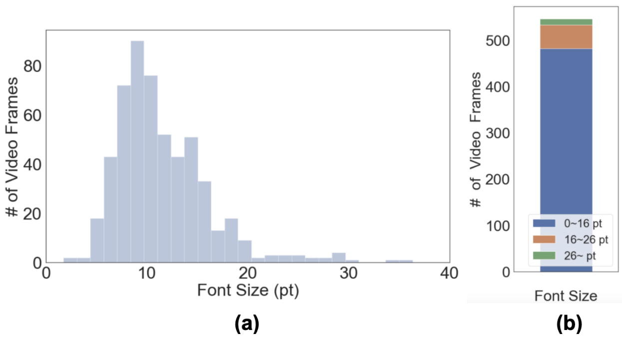

Figure 1: (a) Distribution of font size in current video lecture content. The average font size of 681 video frames is 11.6 pt. (b) Compliance rate with existing design guidelines for font size. 86% of the video frames have font sizes smaller than 16 pt (Google Material Design Guidelines [19]) and 98% of them have font size smaller than 26 pt (presentation design guidelines [12, 23, 36]).

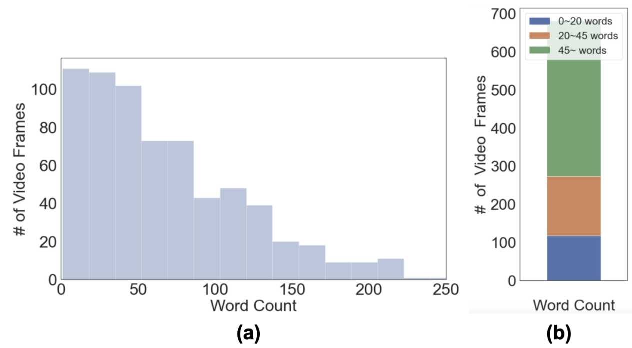

Figure 2: (a) Distribution of number of words in current video lecture content. The video frames contain 73 words on average. (b) Compliance rate with existing design guidelines for number of words. 82% of the sampled video frames have more than 20 words (guidelines from [9]) and 60% of them contain more than 45 words (guidelines from [5]).

consider the mobile version of the video lecture throughout the editing process, designing content that fits the desktop and mobile environments at the same time can be challenging and sometimes requires tedious tasks.

To address this problem, we explored the feasibility of providing guideline-based feedback during the video content design process. We present a prototype of a computer-guided video content design tool that allows engineers to view the analytics and feedback for the content they have created.

In summary, the primary contributions of this research are:

- A content analysis that reveals a landscape of design elements of current video-based learning content and automated inspection for design guideline compliance
- An exploration of challenges and current practices of video content design process for mobile learning environments through interviews with video production engineers
- A prototype system that supports video production engineers with computer-guided video content design

2 VIDEO-BASED LEARNING CONTENT ANALYSIS

To investigate the design practices of existing video and the suitability for mobile devices, we examined 681 video frames from 108 MOOC video lectures, which we selected from top MOOCs released by Class Central [40]. Class Central is a review website for MOOCs and they release a list of the top MOOCs based on user reviews. The selected MOOCs are hosted on Coursera, edX, and FutureLearn and are from 25 universities in 11 countries. We first collected 36 MOOCs offered in English with no talking head production. Talking-head style videos contain no design elements which determine the suitability for mobile devices (e.g., images, text), so we excluded them. Except for the talking-head style, the sampled set covered various common types of video production: presentation, picture-in-picture, voice-over presentation, Khan style tutorial, and a video screencast of the instructor [20, 35]. We then randomly selected three video lectures from each course. The average length of 108 video lectures is 9.07 minutes. After the extraction of video lectures, we sampled 681 video frames from the selected video lectures. They were extracted using an edge-based frame difference, which is used by previous research to measure the level of visual change in video lectures [13, 28, 47]. The number of video frames per video was 5.6 on average (from 1 frame to 31 frames per video lecture). We also used the pytesseract OCR engine [37] for text detection, which is known to show reliable accuracy in existing work [25, 45, 47].

To understand the common design patterns of video lectures, we investigated four design features: font size, the number of words, proportional area (% area) of images, and the number of images per video frame. We selected these features based on literature [3, 18, 41] and interviews with video production engineers. According to the interviews, they consider the size and amount of text and image content as major factors that determine readability on mobile screens.

We investigated the four design features of current lecture content in comparison with the design guidelines in the literature (Table 1). For comparison, we normalized the font size in video lectures since text is displayed in different sizes depending on the screen size and resolution of mobile devices. We used the most common mobile screen size: 5.5-inch diagonal size with 1080 x 1920 screen resolution [1, 6] for normalization.

2.1 Font Size

The average font size of 681 video frames is 11.6 pt. The average font size of the body text, excluding the title text, is 11.2 pt. To estimate the compliance rate for design guidelines of current video content, we combined measures of font size that are in different units (e.g., px, sp) to point (pt) for the comparison. Apple's Human Interface Guidelines adopt 17 pt as a default body text size [26] and Google Material Design Guidelines suggest 16 pt as body text size [19], whereas the guidelines for presentation slides encourage using font size above 24 or 26 pt in the body of the slide [12, 23, 36]. Based on mobile design guidelines of Apple and Google, 86% of the video frames have font sizes smaller than 16 pt and 88% of body

Design Element		Design Guidelines in Literature	Current MOOC Videos	Proportion of Inappropriate Design
Text Element	Avg Font Size	above 16-17 pt (mobile)[19, 26] above 24-26 pt (presentation)[12, 23, 36]	11.6 pt (all text) 11.2 pt (body text)	86-98 % (all text) 88-98 % (body text)
	Avg Number of Words	below 20-45 words[5, 9, 42]	73 words	60-82 %
Image Element	Avg Proportional Area of Images	as large as possible especially for complex images[14, 29]	27 % (talking heads not included)	-
	Avg Number of Images	maximum 2 images[14, 29]	0.88 images (talking heads not included)	8 % (talking heads not included)

Table 1: We examined 681 video frames from 108 MOOC video lectures to inform our exploration of current video lecture design. The proportional range of inappropriate design is estimated by a comparison of sampled video lecture design with existing design guidelines. For the list of video lectures analyzed in this paper, refer to the supplementary material.

text has font sizes smaller than 16 pt. Adopting the guidelines for presentation slides, over 98% of the video frames have font size smaller than 26 pt. The distribution of font size and compliance rate for the design guidelines is shown in Figure 1. Regarding the font size guidelines for mobile environment and presentation slides, the analysis result of the current video lectures implies that they might not be readable enough on small screens. Furthermore, the temporal and transitional dynamics of video content can exacerbate the readability problem.

2.2 Number of Words

The video frames contain 73 words on average, which is in accordance with previous work that demonstrates the average number of words per video frame is 69 [46]. The appropriate amount of text in multimedia learning content and presentation slides is suggested by a body of previous work. The redundancy principle and modality principle of multimedia learning theory suggests that learning efficiency increases with less text in multimedia learning content. [27, 34, 41]. More specifically, using no more than 45 words per presentation slide is recommended [5] and more strict guidelines advocate using less than 20 words per slide [9]. Another work advocates that the maximum number of words per slide should be 25 [42]. In our video set, 82% of the sampled video frames have more than 20 words and 60% of them contain more than 45 words, which suggests room for reducing the amount of content in accordance with the suggested guidelines. The distribution of word count and compliance rate for the design guidelines is shown in Figure 2.

2.3 Image

To analyze image elements in video lectures, we excluded 68 video frames with a screencast on code editor or website since we aim to examine the image elements which are added and adjusted deliberately by content engineers or instructors. On the other hand, some of the video lectures display the instructor's talking head in a picture-in-picture mode. Since talking heads are special types of visuals that are different from static images, we excluded the picture-in-picture talking heads from image analysis. The analysis result shows that the video frames contain 0.88 images with 27% of the image area not including the talking heads. The most common layout was the one with half text area and half image area. With regard to the effects of images in learning material, Mayer's Multimedia Learning Theory demonstrates that people learn better from words and pictures than from words alone [10, 33]. On the other hand, existing work on lecture slide design for radiology recommends lecture slides to contain maximum two images in a single slide [14, 29]. In our video set, 8% of video frames contain more than two images per slide. The analysis result for images shows a lower violation rate for the guidelines compared to that of text element from the perspective of legibility.

The analysis result indicates that the current video lectures with too small font size and dense text need enhancement to be digestible and readable in mobile environments. The result motivated us to develop a design tool to support the design process of mobile video-based learning content based on the known guidelines.

3 SEMI-STRUCTURED INTERVIEWS

We conducted semi-structured interviews with six video production engineers to investigate engineers' current practices and challenges in mobile video-based learning content design.

3.1 Participants and Recruitment

We recruited six participants (5 male, 1 female) from the U.S. and South Korea via campus mailing lists. All participants have more than 4 years of experience in educational video design (from 4 to 30 years). We selected the interviewees based on the following criteria: the interviewee (1) is responsible for editing visual design elements such as adjusting font size and the amount of information in a video lecture and (2) has experience in using design tools in the working field. Of these, five participants are university staff and have design experience on MOOC content, and one is an independent engineer for editing and publishing video-based learning content. We used a saturation method [7] to determine the number of participants.

3.2 Interview Method

We asked them about the general design process and the main editing techniques they use for video lecture design and editing. We audio-recorded the semi-structured interviews with permission and they lasted about one hour. The full interview questions are included as supplementary material.

3.3 Analysis

The audio-recorded interviews were transcribed using either human or machine transcription. One of the authors then manually corrected transcription errors. We analyzed them using thematic analysis methods [8]. We open-coded the data and identified emergent patterns in a similar way to previous research [22] that investigated the design practices of professional content designers. Here we summarize the results.

3.4 Mobile-First or Desktop-First Design

The engineers said they keep the mobile version of the content in mind throughout the design process. A major concern regarding mobile devices was the small screen size. They modified font size, image size, and the amount of information displayed on the screen to fit the small screen size. One participant sent internal design guidelines to instructors. This participant noted that *"I made this guideline to make my work more efficient. The instructors sometimes do not consider how the content is displayed in mobile environments. Viewers may not watch the lecture on a large desktop screen. They might use smartphones or tablet PCs, so we try to use close-up images, large text with good contrast, and uncluttered slides to be readable in small screens."* (P2). Another participant also mentioned that his team has internal design guidelines for minimum font size in mobile environments. The rest of them, however, did not have specific guidelines for design and they explained that the quality of video design varies depending on engineers' style.

One participant explained that *"We always test our content in mobile environments with small screens such as smartphones. All the design decisions on font size and the number of images are determined by legibility and readability in mobile devices."* (P1). *"We have more users on mobile devices than on the desktop, so we enlarge and segment almost every content."* (P6).

3.5 Main Editing Techniques

We asked the main editing technique to fit mobile devices to inform the design decisions of a content adaptation system. The video production engineers pointed out that the instructors bring the lecture slides which are used in classroom settings equipped with large screens which are not appropriate for learning video most of the time due to lack of consideration for various devices. To fit the provided material to the mobile learning environment, the main techniques they use were resizing, repositioning, and segmenting.

3.5.1 Resizing. They enlarge text and images to make them more visible in various screen sizes. One participant mentioned 20 pt as the minimum font size and they were also using editing software such as Adobe Photoshop and AfterEffects to zoom in complex graphics. The participant noted that *"We make sure that the fonts and graphics are large enough to be seen in small screen size."* (P2).

3.5.2 Reposition. All participants said they reposition text and images by considering the visual flow of the presentation. They move graphics and text to find the proper alignment and composition after resizing content to suit small screens.

3.5.3 Segmenting. The amount of information in a single frame was another important factor they consider while designing content.

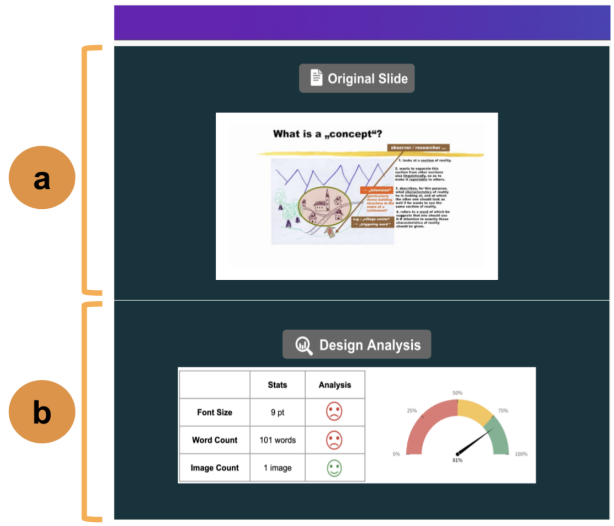

Figure 3: (a) original slide: slide provided by instructors is displayed. (b) design analysis: analysis result of design based on existing guidelines is displayed.

One of our participants explained that *"I always need to segment a provided lecture slide into multiple slides with less information in them and that is a very tedious task."* (P1). Another participant also mentioned that *"Too much content on a slide turns people off. In such a case, we segment a single slide into two or three slides."* (P2). They rarely summarize or reformat the content from a lengthy paragraph to a list of bullet points since they cannot learn and understand every content they edit. They also try to preserve the instructor's original intent without aggressive editing.

3.6 Takeaways from the Interviews

Participants in the semi-structured interviews consider how the content they created will be displayed on mobile devices. For this reason, they adapt the content to fit mobile devices by resizing, repositioning, and segmenting the content. However, designing content that fits the various screen sizes is challenging and sometimes requires tedious tasks.

4 COMPUTER-GUIDED VIDEO CONTENT DESIGN

We designed an initial prototype system to support engineers' design process of mobile video-based learning content. The prototype system allows engineers to view the analytics and feedback for the content they have created. Figure 3 shows the system which provides guideline-based content editing. The system provides analysis results for the slides provided by the instructors (Figure 3(a)) based on the existing design guidelines (Figure 3(b)). It provides statistics for three design features (font size, amount of text, amount of images) and whether the given slide complies with the guidelines or not. It displays smiling faces for the criteria that meet the guidelines and frowning faces for the criteria that do not. The gauge on the right of the statistics table displays the overall appropriateness of the design. The gauge has three parts - good, fair, bad.

5 EVALUATION

We conducted a formative evaluation of the prototype with four video production engineers from South Korea and the U.S. We recruited them via campus mailing lists. All participants have more than 2 years of experience in educational video design (from 2 to 30 years). They are responsible for editing video content such as adjusting font size and the amount of information in a video lecture. We asked for feedback on our prototype system and the interviews lasted about one hour. Here we summarize key findings drawn from the interviews.

Three participants mentioned that the provided design analysis for their content can increase the consistency of design. They noted that different design standards and preferences across engineers result in video content that varies in quality. Some participants mentioned that they want to customize the standards used in the design analysis as needed. *"The design guidelines would be helpful as a consistent indicator, but at the same time, I want to modify the metric considering the characteristics and context of the content."* (P2). One participant noted that the analysis can help them detect a flawed slide. *"Given dozens of lecture slides from an instructor, we sometimes miss out on slides with improper design. The system can function as an alert system."* (P4). These findings reveal design implications for a design tool for video-based learning content across devices.

6 CONCLUSION AND FUTURE WORK

We discuss findings and possible extensions of this work.

In this paper, we examined the mobile learning adequacy of current video-based learning material with 681 video frames from 108 lectures. The content analysis revealed a distribution of visual design elements and guideline compliance rate of the main visual design elements. We also conducted semi-structured interviews with six video production engineers to investigate engineers' current practices and challenges in mobile video-based learning content design. Finally, we present a prototype system for engineers and discuss design implications for the design of an authoring tool for engineers.

In future work, we first plan to conduct a content analysis including extended design factors such as font styles, font colors, visual complexities of graphics. Second, we can develop a design tool for engineers or plug-in software that can be integrated into the existing design tools being used by engineers. Third, we can extend the research to accessibility evaluation protocols and systems for the visually impaired, older adults, or dyslexics since readability and visibility of the content are the main factors of accessibility. We expect that the quality and accessibility of video-based learning content can be improved based on our research.

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