




PAPER

Adapting Online Education for Deaf and Hard-of-Hearing Adults: Preferences, Perceptions, and Learning Characteristics

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This study explores the online education preferences and learning characteristics of deaf and hard-of-hearing adults based on a survey of 51 participants. Findings show that most participants prefer using smartphones to access online resources, while tablets and PCs are less favored. Respondents engage frequently with social media and news websites but use educational platforms, online banking, and government services less often. Key preferences include the use of visual components—such as sign language videos, graphics, and illustrative examples—highlighting the importance of visual learning. Additionally, clear module structures with pre- and post-lesson exercises are valued for improving comprehension. The study concludes that adaptive, mobile-friendly online courses with short, visually focused modules are essential for effective learning among individuals with hearing impairments.

KEYWORDS

deaf and hard-of-hearing adults, online education, educational preferences, sign language

1 INTRODUCTION

The urgency of addressing the socialization challenges faced by deaf and hard-of-hearing individuals necessitates close attention, contingent on the level of societal cultural development [1]. Research indicates that the transition from education to employment presents significant challenges for deaf people, particularly for those who lack access to higher education [2]. Despite an increase in the number of deaf students attending universities and colleges in Kazakhstan, obstacles continue to impede their access to higher education [3]. Factors such as anxiety, poor study habits, a general lack of interest in college, and negative attitudes toward education have been identified as primary contributors to college dropout among deaf students [4]. Furthermore, deaf adults may experience reduced autonomy and self-confidence if they do not possess the essential skills for independent living, such as managing household tasks [5].

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Kazakhstan's primary educational policy [6] advocates for the inclusion of pupils with exceptional educational needs to facilitate employment opportunities for persons with special needs. Recent institutional reforms in Kazakhstan's special education have directly impacted the education of deaf children. When special education teachers or other specialist professionals are available, deaf pupils are welcome in regular schools. Nevertheless, a more comprehensive understanding of inclusion is needed to improve educational outcomes for deaf students [7]. This approach goes beyond simply placing impaired students in regular classrooms [8]. One of the most important safeguards against the social marginalization of deaf adults is lifelong learning. To develop a cutting-edge and user-friendly online education system that fully meets the educational requirements of the target group and addresses existing gaps in social, educational, and technological domains, we investigate and analyze the learning methods of deaf adults, their cognitive characteristics, and how information—especially educational content—should be presented to them.

2 MATERIALS AND METHODS

2.1 Literature review

Variations in Cognitive Abilities of Hearing and Deaf People. When designing an efficient online learning platform for the deaf, it is essential to consider the target group's learning profile and unique educational needs. Investigating the primary distinctions in mental abilities between hearing and deaf individuals is therefore crucial.

Research indicates that the average IQ of deaf individuals is similar to that of hearing people and tends to increase over time [9]. However, deaf individuals differ from their hearing counterparts in memory, problem-solving abilities, and academic performance [10]. Cognitive differences are also evident in the visual communication skills of deaf persons, particularly in the processing of visual language.

Reports suggest that sensitivity to visual contrast is comparable between deaf and hearing individuals [11]. Key factors influencing language comprehension include linguistic quality and precision, general storage capacity, the level of explicit processing, and the accessibility of long-term memory [12]. In addition, evidence shows that deaf children may struggle with fine motor sequencing, even though their visual cognitive abilities are on par with those of their hearing peers [13].

While hearing loss can hinder the identification of peripheral visual cues, attentional skills remain essential for daily tasks [14]. Notably, hearing loss does not predict attentional deficiencies; deaf individuals often perform similarly—and sometimes even better—than their hearing peers in tasks requiring sustained attention [15]. Nonetheless, significant differences in visual attention, particularly in peripheral attention, have been documented [16]. For example, Mann et al. [17] found that deaf individuals are less disrupted by primary distractions but are more affected by peripheral ones compared to hearing individuals.

Early exposure to sign language appears to benefit the cognitive development and visual perspective abilities of deaf children [18]. However, there is evidence that deaf and hearing individuals differ in tasks involving working memory, partly because sign language requires more spatial coding than spoken language [19]. Given that sign languages are visuospatial and time-consuming to produce, they may adversely impact short-term memory [20].

Deaf individuals often exhibit lower reading proficiency than hearing readers due to their unique method of word recognition [21]. Research suggests that phonological coding, awareness abilities, and overall linguistic proficiency are closely

associated with reading skills in deaf individuals [22]. Moreover, the observed correlation between reading motivation and text comprehension indicates that engaging with challenging texts could enhance their reading abilities [23]. In 2021, research by Earlham College et al. [24] on the reading strategies of deaf adults revealed that most participants employed a keyword technique to comprehend material, which aligns with observations that deaf individuals possess an extensive orthographical lexicon [25]. Furthermore, significant challenges with text production have been noted, likely due to difficulties in differentiating stimuli in working memory and the absence of auditory input [26].

In the age of modern technology, electronic learning—often referred to as distance learning—has become an increasingly popular and innovative teaching strategy [27]. It has served as a valuable educational tool for people around the globe. The strength of the Internet, and consequently online learning, lies in its universality [28]. Regardless of an individual's skills or limitations, the Internet is designed to serve everyone. Therefore, it must be accessible to individuals with diverse hearing, vision, mobility, and cognitive abilities.

The Internet's potential to break down social and communication barriers in the physical world has transformed how disability is perceived. This underscores the importance of providing opportunities for individuals with disabilities by ensuring that online services—especially online education—are accessible in a manner that respects and addresses their unique needs. Beyond securing equal human rights, it is essential that people with disabilities, particularly those who are deaf or hard-of-hearing, fully benefit from this technology and its numerous advantages.

However, in developing online educational systems, the unique needs of individuals with disabilities—such as deafness and partial hearing impairment—are often overlooked [29]. Designing user-friendly and accessible interfaces for these users can be challenging [30]. This may be partly because the term “deaf persons” does not imply a uniform set of characteristics and needs; rather, these vary widely among individuals [31].

Variations in the degree and type of deafness, along with the age at which hearing loss occurs, can significantly affect an individual's language, literacy, and overall reading and writing abilities. These differences create challenges in designing online educational interfaces [32] and developing effective instructional prototypes. It is essential for system designers to recognize and address the unique cognitive and communication needs of these users [33]. By incorporating interactive learning environments and diverse representations of learning processes, multimedia ICT tools and online education platforms can better meet these specialized requirements [34].

Deaf individuals primarily use sign language—a unique language that relies on hand movements, gestures, and lip movements rather than sound [35, 36]. Consequently, online education platforms for deaf and hearing-impaired users should present all audio content in a visual format using text, captions, images, and sign language videos. Additionally, it is crucial to design a clear and intuitive graphical user interface that delivers lessons in a way that resonates with these users [37]. However, given that some deaf and hearing-impaired individuals may struggle with extensive written text, minimizing text usage is advisable.

Research indicates that deaf individuals who use sign language process images more rapidly and efficiently than text [38]. Consequently, designers and developers must adhere to established online accessibility standards when creating educational systems for deaf and hard-of-hearing learners. This commitment ensures that the resulting e-learning tools are both effective and engaging for this user group.

Current research suggests that effective online education strategies include the use of illustrative exercises and timely feedback [39], along with concise and comprehensive

micro-modules [40]. E. Brito and G. P. Dias developed a learning management system (LMS) that emphasizes the importance of accommodating diverse individual needs and ensuring that all uploaded content is accessible to students with disabilities [41].

2.2 Contents

In order to assess the current state of cognitive functioning and online education systems for deaf individuals, the first step of the research involved a comprehensive review of the literature. Following this, an online survey was developed. A questionnaire for deaf and hard-of-hearing adults was created (see Appendix A) based on the most recent research on the subject, and it was subsequently uploaded to an electronic survey platform (Google Forms). The survey consisted of thirteen questions divided into four sections:

- Demographic Characteristics
- Information and Communication Technology (ICT) Accessibility
- Learning Approaches
- Specifications of Modules and Online Learning Platforms

The questionnaire comprised five multiple-choice questions, four Likert scale questions, two dichotomous questions, one open-ended question, and one check-box question.

2.3 Technique

This study aimed to explore the learning processes of deaf and hard-of-hearing individuals and to identify the most effective methods for delivering information and instructional materials to optimize learning outcomes. Specifically, the research focused on investigating the ICT access of deaf individuals and understanding their perceptions regarding the module specifications and instructional approaches used by online education platforms.

The study process began with a comprehensive literature review that documented the current state of knowledge regarding deaf and hard-of-hearing students. Building on the insights from this review, an online survey was developed and widely distributed through the Kazakh Society of the Deaf across 17 districts in the country. Data were collected using Google Forms and subsequently analyzed using statistical methods.

2.4 Respondents

The online survey was available for two weeks after being distributed via several Kazakhstan Societies of the Deaf. A total of 51 responses were collected from deaf or hard-of-hearing individuals (refer to Table 1), including 27 males (52.9%) and 24 females (47.1%). The smallest age group consisted of participants aged 55 and above, while the largest group (43.1%) was between 26 and 35 years old. Of the respondents, 32 had varying degrees of hearing loss and were classified as hard of hearing, while the remaining participants were deaf. Additionally, 16 participants (31.4%) were born with hearing loss, and 35 (68.6%) acquired it later in life.

Regarding educational backgrounds, 15 participants attended special schools, and 9 were in correctional classes during secondary school. Only one participant (2%)

completed elementary school, while the majority (52.9%) were graduates of higher education institutions (refer to Table 2). In terms of employment, 36 participants were employed in the public or private sector, seven were unemployed, and three were retired.

Table 1. Participant demographic information (n = 51)

	Frequency	Percentage
Age Distribution		
18–25	14	27.5%
26–35	22	43.1%
36–45	7	13.7%
46–55	5	9.8%
55 above	3	5.9%
Sex Distribution		
Men	27	52.9%
Women	24	47.1%
Deafness Type		
Mild hearing loss	32	62.7%
Average hearing loss	4	7.8%
Severe hearing loss	4	7.8%
Complete hearing loss	11	21.6%
Reasons for Deafness		
Congenital	16	31.4%
Acquired	35	68.6%

Table 2. Status of participants’ education and occupation (n = 51)

Category	Frequency	Percentage
Education Type		
Special school	15	29.4%
Correctional classes of secondary school	4	7.8%
Parallel support	5	9.8%
None of the above	27	52.9%
Education Level		
Primary education	2	3.9%
Secondary education	14	27.5%
Technical education	7	13.7%
Higher education	27	52.9%
None of the above	1	2%
Occupational Status		
I am working	30	58.7%
In search of a job	3	5.9%
Student	5	9.8%

(Continued)

Table 2. Status of participants' education and occupation (n = 51) (Continued)

Category	Frequency	Percentage
Self-employed	6	11.8%
Retired	3	5.9%
Housewife	1	2%
Unemployed	3	5.9%

3 USED AI TOOLS

During the preparation of this manuscript, [o3-mini, ChatGPT] was used for English language proofreading. All results obtained with the tool were further reviewed and verified by the authors, who take full responsibility for the content of the paper.

4 RESULTS

We computed Cronbach's alpha coefficients to assess the questionnaire's internal consistency. The questions related to participants' familiarization with ICTs yielded a Cronbach's alpha of 0.866; those addressing attitudes toward the learning approach produced an alpha of 0.966; and the questions concerning the online platform's modules resulted in an alpha of 0.962. These high values support the validity of the questionnaire. Furthermore, we calculated Pearson's correlation coefficients between the questionnaire items to evaluate its structural validity (refer to Tables 3–5). Most of the coefficients were either high or moderate, indicating that the questionnaire is a sound and legitimate instrument for data collection.

Table 3. Pearson correlation coefficients for ICT usage items (n = 51)

Item	PC	Tablet	Smartphone	News & Blogs	Social Networks	Search for Products	Online Shopping	Online Banking	Online Gov. Services	Online Learning	Entertainment
PC	1										
Tablet	0.280*	1									
Smartphone	0.321*	-0.047	1								
News & Blogs	0.283*	0.166	0.393**	1							
Social Networks	0.108	0.151	0.380**	0.444**	1						
Search for Products	0.266	0.284*	0.242	0.338*	0.574**	1					
Online Shopping	0.175	0.260	0.250	0.302*	0.513**	0.808**	1				
Online Banking	0.419**	0.236	0.424**	0.402**	0.368**	0.562**	0.417**	1			
Online Gov. Services	0.267	0.244	0.351*	0.208	0.308*	0.467**	0.443**	0.642**	1		
Online Learning	0.341*	0.313*	0.272	0.474**	0.400**	0.399**	0.414**	0.618**	0.388**	1	
Entertainment	0.429**	0.342*	0.197	0.298*	0.514**	0.546**	0.479**	0.521**	0.419**	0.570**	1

Notes: *Indicates significance at the 0.05 level (2-tailed); **Indicates significance at the 0.01 level (2-tailed).

Table 4. Pearson correlation coefficients for learning strategy items (n = 51)

Item	Tailored/Self-Paced Modules	Organized Clustering	Seamless Progression	Gradual Unfolding	Practice Exercises	Interactive Queries	Evaluation
Tailored/Self-Paced Modules	1						
Organized Clustering	0.806**	1					
Seamless Progression	0.879**	0.817**	1				
Gradual Unfolding	0.748**	0.884**	0.790**	1			
Practice Exercises	0.729**	0.826**	0.736**	0.925**	1		
Interactive Queries	0.779**	0.826**	0.750**	0.747**	0.802**	1	
Evaluation	0.763**	0.806**	0.792**	0.785**	0.821**	0.894**	1

Note: **indicates significance at the 0.01 level (2-tailed).

Table 5. Pearson correlation coefficients for online learning platform module specifications (n = 51)

Item	Concise & Informative Modules	Illustrative Instances	Terminology Clarifications	Visual Aids	Educational Videos	Sign Language Videos	Review Sessions
Concise & Informative Modules	1						
Illustrative Instances	0.818**	1					
Terminology Clarifications	0.746**	0.857**	1				
Visual Aids	0.671**	0.833**	0.934**	1			
Educational Videos	0.633**	0.751**	0.869**	0.882**	1		
Sign Language Videos	0.577**	0.721**	0.796**	0.835**	0.847**	1	
Review Sessions	0.691**	0.770**	0.871**	0.857**	0.810**	0.829**	1

Note: **indicates significance at the 0.01 level (2-tailed).

Based on responses to questions 9 and 10 (refer to Table 6), smartphones emerged as the most useful device for adults who are deaf or hard of hearing (M = 4.37, SD = 0.98). Personal computers, including laptops and desktops, ranked second (M = 3.33, SD = 1.38), while tablets were rated as the least useful (M = 1.76, SD = 1.09). In terms of online services, social media (M = 3.78, SD = 1.03) and news/blogs (M = 3.18, SD = 1.23) were the most frequently used by the participants. In contrast, respondents reported spending less time on online learning (M = 2.73, SD = 1.21), online government services (M = 2.22, SD = 1.10), entertainment (M = 2.92, SD = 1.29), and online banking (M = 2.65, SD = 1.38).

Table 6. Availability of devices and services (Total, n = 51)

Devices	Mean	SD
PC	3.33	1.38
Tablet	1.76	1.09
Smartphone	4.37	0.98

(Continued)

Table 6. Availability of devices and services (Total, n = 51) (Continued)

Services	Mean	SD
News and blogs	3.18	1.23
Social networks	3.78	1.03
Search for products	2.76	1.30
Online shopping	2.88	1.24
Online banking	2.65	1.38
Online government services	2.22	1.10
Online learning	2.73	1.21
Entertainment	2.92	1.29

A one-way analysis of variance (ANOVA) was conducted to explore potential differences among groups regarding participant access to devices and ICT services, as well as their opinions on the instructional mode and specific online platform modules. The analysis revealed no statistically significant differences in preferences for using tablets for online learning ($F(4, 46) = 1.969, p = 0.115, \eta^2 = 0.146$), electronic mail services ($F(4, 46) = 0.817, p = 0.521, \eta^2 = 0.066$), or Internet banking ($F(6, 44) = 1.655, p = 0.155, \eta^2 = 0.184$). Although moderate effect sizes were observed—such as for Internet banking ($\eta^2 = 0.184$)—these differences did not achieve statistical significance.

The analysis indicated that differences in preference for using smartphones for online learning were not statistically significant ($F(1, 49) = 0.765, p = 0.386, \eta^2 = 0.015$). Similarly, the preference for practical exercises in online learning did not reach statistical significance ($F(3, 47) = 2.310, p = 0.088, \eta^2 = 0.128$). Regarding the use of online government services, although the differences were not statistically significant, a moderate effect size was observed ($F(1, 49) = 3.267, p = 0.077, \eta^2 = 0.063$).

Participants were given the opportunity to select the learning strategy they preferred for an online course in question 11 (refer to Table 7). Data analysis revealed that participants highly valued interactive components within the educational modules. For example, exercises following lessons received a high rating ($M = 3.47, SD = 1.50$), as did questions during instruction ($M = 3.53, SD = 1.43$), underscoring the importance of practical engagement and active participation.

Conversely, lower ratings were observed for the organization of module clusters ($M = 3.04, SD = 1.47$) and continuity between modules ($M = 3.02, SD = 1.35$), indicating a need for improved structural coherence and a more logical progression of the curriculum. Additionally, the gradual disclosure of content ($M = 3.14, SD = 1.53$) and the provision of assessments after each lesson ($M = 3.47, SD = 1.48$) were evaluated favorably, highlighting the necessity for clarity and timely feedback.

Collectively, these findings suggest that enhancing the effectiveness of educational programs requires a focus on participant feedback—specifically, strengthening the connections between modules and emphasizing practical learning elements.

Table 7. Descriptive analysis of attitudes towards learning techniques (N = 51)

Learning Technique	N	Mean	SD
Tailored or self-paced learning modules	51	3.12	1.46
Organized clustering of related modules	51	3.04	1.47
Seamless progression throughout the modules	51	3.02	1.35
Gradual unfolding of the module content	51	3.14	1.53
Practice exercises following each session	51	3.47	1.50
Interactive queries during the sessions	51	3.53	1.43
Evaluation following each session	51	3.47	1.48

Table 7 presents the descriptive analysis of participants' attitudes towards various learning techniques for an online course. The data indicate that interactive components—such as interactive queries during sessions ($M = 3.53$) and practice exercises ($M = 3.47$)—were rated more favorably, highlighting the importance of active engagement and immediate feedback. In contrast, the structural aspects of the course, including tailored or self-paced modules, organized clustering, and seamless progression, received slightly lower ratings, suggesting room for improvement in these areas to enhance the overall learning experience.

The analyses indicate that age, hearing loss, and the educational module do not have statistically significant effects on participants' attitudes. Specifically, the age analysis yielded $F(4, 46) = 1.461$, $p = 0.230$, and $\eta^2 = 0.113$, suggesting that age does not meaningfully influence attitudes. Likewise, the examination of hearing loss levels produced $F(3, 47) = 0.678$, $p = 0.570$, $\eta^2 = 0.041$, indicating that varying degrees of hearing loss do not significantly impact attitudes. Finally, the analysis of the educational module resulted in $F(4, 46) = 1.424$, $p = 0.241$, and $\eta^2 = 0.110$, further supporting the notion that this variable may not exert a notable effect on attitudes. Overall, these findings imply that the examined factors are unlikely to significantly influence participants' attitudes, which underscores the need for further research to explore additional variables that may affect educational outcomes.

Table 8. Descriptive analysis of attitudes toward the specifications of online learning platform modules (N = 51)

Specification	N	Mean	SD
Modules to be concise and informative	51	3.12	1.56
Illustrative instances	51	3.45	1.43
Clarifications for terminology and concepts	51	3.43	1.42
Visual aids	51	3.49	1.30
Educational videos	51	3.57	1.61
Videos presented in sign language	51	3.62	1.38
Review sessions following each unit	51	3.52	1.45

The findings from participant responses (see Table 8) underscore the critical role of various components in enhancing the effectiveness of online learning courses. Educational videos ($M = 3.57$, $SD = 1.61$) and videos presented in sign language

($M = 3.62$, $SD = 1.38$) received the highest ratings, indicating a strong preference for visual formats that facilitate comprehension. Similarly, visual aids ($M = 3.49$, $SD = 1.30$) and illustrative instances ($M = 3.45$, $SD = 1.43$) were well-regarded, highlighting the importance of using visual resources to clarify complex concepts.

Participants also valued clarifications for terminology and concepts ($M = 3.43$, $SD = 1.42$) and review sessions following each unit ($M = 3.52$, $SD = 1.45$), which emphasize the need for clear explanations and timely feedback. Conversely, the specification that modules be concise and informative received the lowest rating ($M = 3.12$, $SD = 1.56$), suggesting that while brevity is appreciated, it may be less prioritized compared to the interactive and visual elements that directly enhance understanding.

Overall, these results highlight the necessity of integrating robust visual and explanatory components within educational modules to maximize accessibility and learning effectiveness for deaf and hard-of-hearing learners.

The analysis revealed that the cause of deafness did not significantly influence participants' attitudes toward the use of videos in sign language ($F(1, 49) = 0.434$, $p = 0.513$, $\eta^2 = 0.009$) or the use of graphics ($F(1, 49) = 1.740$, $p = 0.193$, $\eta^2 = 0.034$). This indicates that, regardless of whether their deafness is congenital or acquired, participants share a similar preference for visual aids in educational settings. Moreover, there were no significant preferences regarding the necessity for brevity in module design ($F(4, 46) = 0.623$, $p = 0.648$, $\eta^2 = 0.051$), suggesting that the length of the modules is not a critical factor across diverse educational backgrounds. Similarly, attitudes toward the inclusion of examples ($F(4, 46) = 0.870$, $p = 0.489$, $\eta^2 = 0.070$) and the provision of descriptions for definitions and terms ($F(4, 46) = 1.192$, $p = 0.327$, $\eta^2 = 0.094$) were also non-significant. Finally, the analysis further indicated no significant differences across each module specification ($F(4, 46) = 0.548$, $p = 0.702$, $\eta^2 = 0.045$). Overall, these results suggest that the examined factors do not play a pivotal role in shaping participants' preferences for visual aids in online educational contexts.

5 DISCUSSION

The current study is an exploratory investigation into the online learning experiences of deaf and hard-of-hearing individuals in the context of modern technology. Its main objective was to understand their attitudes, cognitive traits, and preferred learning methods to develop an online learning environment that meets their specific needs. By integrating findings from a comprehensive literature review with data from an online survey administered to deaf and hard-of-hearing participants, the study provides several key insights.

Notably, the results indicate that these individuals favor smartphones over tablets or PCs for accessing ICTs [42]. When online, they tend to use social media, email, and frequently read blogs and news articles [43], while showing lower engagement with online banking, online learning, online government services, and entertainment platforms.

The analysis indicated that gender did not significantly affect the use of devices and services, including internet access, among deaf and hard-of-hearing individuals. Similarly, there were no statistically significant differences between those born deaf and those who lost their hearing later in life. However, age and professional standing significantly influenced both the choice of online services and the amount of time spent using them. Additionally, participants' educational backgrounds mainly impacted the frequency of email usage.

The target group considers all aspects of the online learning approach important. Participants highlighted that maintaining continuity between modules and including questions and exercises before, during, and after each module are among the most crucial elements. In addition, the use of specialized graphics, illustrative examples, and instructional videos are regarded as key components of the online learning modules. They also place high importance on clear explanations of definitions and terminology, post-module reviews, the inclusion of sign language videos, and concise module design.

The use of visual aids and sign language videos in the online learning modules was significantly affected by the cause of deafness. Additionally, module duration and participants' educational backgrounds influenced their preferences; those with higher education levels preferred shorter modules compared to peers with technical education. Other factors shaping participant preferences include the inclusion of illustrative examples, clear definitions and term explanations, and review sessions at the end of each module.

6 CONCLUSION

The commitment to creating accessible digital environments should be guided by international frameworks, such as the United Nations Convention on the Rights of Persons with Disabilities, which underscores the critical need for equal access to technology for all [44]. This study explored the cognitive profiles, learning requirements, and ICT familiarity of individuals who are deaf or hard of hearing. Field studies indicate that these adults tend to feel more comfortable using smartphones compared to tablets or desktop computers. Consequently, it is essential for the online learning platform to be fully responsive, and the development of a dedicated mobile app should be considered as a supplementary tool.

The literature review reveals that while deaf individuals generally possess strong attentional abilities, their hearing loss makes them more prone to distractions from visual stimuli. To mitigate this, online modules should feature simple navigation that minimizes extraneous visual elements. Additionally, because sign language requires more space than spoken language, it can strain working memory. As a result, learning content should be divided into shorter, more manageable modules rather than longer, text-heavy ones.

Furthermore, deaf individuals often face challenges with reading comprehension and text composition, likely due to differences in working memory and the absence of auditory cues. To address this, instructional materials should emphasize key words and limit text, thereby capturing and maintaining learners' attention. This approach aligns with feedback from the target audience, who favored a straightforward, step-by-step presentation of content. Based on these findings, the strategy will involve creating concise learning modules that use minimal text, ultimately facilitating learning and enhancing student motivation.

Research indicates that deaf and hard-of-hearing learners benefit significantly from visual content delivery. This includes the use of pictures, captioned videos, and, importantly, videos in sign language. Since these learners process images and videos much more quickly than text, the most effective instructional approach is to present educational content primarily through sign language videos, supplemented by other visual aids to enhance comprehension.

Deaf adults expressed positive feedback regarding the exercises provided at the end of an online course to assess their learning needs. Consequently, it is

recommended that an automatic assessment system—based on predetermined completion criteria for self-evaluation—be integrated into online learning platforms for deaf learners. This system would offer immediate feedback and ensure that the educational content effectively meets their learning requirements.

The results of the online survey indicate that participants had favorable opinions about the continuity of the online modules. Consequently, it is recommended that the lessons be kept brief in length, aligning with prior conclusions about the necessity of avoiding excessive text and considering individuals' limited working memory capacity. The learning modules should be designed to function independently while still being capable of connecting with one another to form a cohesive learning experience on a specific topic.

Research is currently ongoing, focusing on the creation and use of specialized software that utilizes supercomputers to recognize sign language using machine learning. This technology has the potential to further enhance accessibility and interactivity in online education for the deaf and hard of hearing.

The online poll results indicate that participants appreciated the continuity of the online modules. In light of these findings and earlier conclusions about avoiding lengthy texts—given the limited working memory capacity of the learners—it is recommended that lessons remain brief. Each learning module should be designed to function independently while also being capable of connecting with other modules to form a comprehensive unit on a specific topic.

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8 REFERENCES

- [1] G. Ishrat, K. Nawaz, and S. F. Khan, "Perception of students without disabilities about socialization with hearing impaired peers," *Journal of Development and Social Sciences*, vol. 3, no. 2, pp. 330–349, 2022. [https://doi.org/10.47205/jdss.2022\(3-II\)33](https://doi.org/10.47205/jdss.2022(3-II)33)
- [2] L. Donnellan and E. S. Mathews, "Service providers' perspectives on life skills and deaf and hard of hearing students with and without additional disabilities: Transitioning to independent living," *European Journal of Special Needs Education*, vol. 36, no. 4, pp. 547–561, 2021. <https://doi.org/10.1080/08856257.2020.1776982>
- [3] J. Allan and T. Omarova, "Disability and inclusion in Kazakhstan," *Disability and Society*, vol. 37, no. 7, pp. 1067–1084, 2022. <https://doi.org/10.1080/09687599.2020.1867073>
- [4] M. C. Makatse, "Mitigating school dropout among deaf learners through school support networks: Case study," *UFS*, 2021. [Online]. Available: <http://hdl.handle.net/11660/11402>
- [5] S. Olsson, M. Dag, and C. Kullberg, "Hard of hearing adults' interpersonal interactions and relationships in daily life," *Disabilities*, vol. 1, no. 2, pp. 71–88, 2021. <https://doi.org/10.3390/disabilities1020007>
- [6] K. Ybyrayeva, "The experiences of teachers educating young adults with hearing impairments studying in TVET institutions in Kazakhstan: A collective case study," in *4th ISPC International Scientific Discussion: Problems, Tasks and Prospects*, Brighton, Great Britain, vol. 19, no. 99, 2022, pp. 19–20. <https://doi.org/10.51582/interconf.19-20.02.2022.018>

- [7] A. H. Fernandez and C. D. B. Camargo, “SEM model to determine the relationship between neurodidactics, inclusive education and sustainability,” *Journal of Turkish Science Education*, vol. 19, no. 3, pp. 740–457, 2022. <https://doi.org/10.36681/tused.2022.147>
- [8] N. Yunani, A. Mustadi, M. Mumpuniarti, I. Ishartiwi, and R. Hidayat, “Differentiated instruction science learning for intellectually disabilities pupils at an inclusive primary school: A case study,” *Journal of Turkish Science Education*, vol. 21, no. 3, pp. 467–483, 2024. <https://doi.org/10.36681/tused.2024.025>
- [9] A. Al-Oweidi and F. Qutishat, “Mental ability of deaf and non-deaf students on the raven’s progressive matrices of mental abilities: A comparative study,” *Journal of Educational and Social Research*, vol. 12, no. 3, 2022. <https://doi.org/10.36941/jesr-2022-0082>
- [10] S. Santos and S. Cordes, “Math abilities in deaf and hard of hearing children: The role of language in developing number concepts,” *Psychological Review*, vol. 129, no. 1, pp. 199–211, 2022. <https://doi.org/10.1037/rev0000303>
- [11] E. Gutierrez-Sigut, M. Vergara-Martínez, and M. Perea, “The impact of visual cues during visual word recognition in deaf readers: An ERP study,” *Cognition*, vol. 218, p. 104938, 2022. <https://doi.org/10.1016/j.cognition.2021.104938>
- [12] S. Nicks *et al.*, “The use of person-centered language in medical research articles focusing on hearing loss or deafness,” *Ear and Hearing*, vol. 43, no. 3, p. 703, 2022. <https://doi.org/10.1097/AUD.0000000000001168>
- [13] F. Larsen and J. Dammeyer, “The relation between sensory loss and communicative and cognitive development in children with congenital deafblindness,” *British Journal of Visual Impairment*, vol. 39, no. 2, pp. 104–116, 2020. <https://doi.org/10.1177/0264619620913901>
- [14] K. R. Lee, E. Groesbeck, O. S. Gwinn, M. A. Webster, and F. Jiang, “Enhanced peripheral face processing in deaf individuals,” *Journal of Perceptual Imaging*, vol. 5, p. jpi0140, 2021. <https://doi.org/10.2352/J.Percept.Imaging.2022.5.000401>
- [15] M. G. Tutlu, M. E. Başgöl, C. Boz, and K. Çinkılıç, “The relationship between hearing and attention in hearing impaired individuals with ADHD comorbidity and the effect of hearing aids on the development of attention: A compilation of research,” *Journal of Turkish Social Sciences Research*, vol. 7, no. 2, pp. 129–136, 2022.
- [16] P. Brazão, F. Ribeiro, A. Castro-Caldas, V. Nunes, and A. Mineiro, “Exogenous orientation of attention in congenitally deaf individuals,” *Psychology and Neuroscience*, vol. 14, no. 2, pp. 173–182, 2021. <https://doi.org/10.1037/pne0000232>
- [17] W. Mann, R. O’Neill, F. Watkins, and R. L. Thompson, “Reading online in deaf and hearing young people: Do differences exist?” *Deafness and Education International*, vol. 25, no. 3, pp. 203–227, 2023. <https://doi.org/10.1080/14643154.2023.2207860>
- [18] T. Reagan, P. E. Matlins, and C. D. Pielick, “Deaf epistemology, sign language and the education of d/deaf children,” *Educational Studies*, vol. 57, no. 1, pp. 37–57, 2021. <https://doi.org/10.1080/00131946.2021.1878178>
- [19] A. Kusters and C. Lucas, “Emergence and evolutions: Introducing sign language sociolinguistics,” *Sign Language Studies*, vol. 22, no. 2, pp. 320–342, 2021. <https://doi.org/10.1353/sls.2021.0023>
- [20] I. Papastratis, C. Chatzikonstantinou, D. Konstantinidis, K. Dimitropoulos, and P. Daras, “Artificial intelligence technologies for sign language,” *Sensors*, vol. 21, no. 17, 2021. <https://doi.org/10.3390/s21175843>
- [21] K. Emmorey and B. Lee, “The neurocognitive basis of skilled reading in prelingually and profoundly deaf adults,” *Language and Linguistics Compass*, vol. 15, no. 2, p. e12407, 2021. <https://doi.org/10.1111/lnc3.12407>
- [22] E. Ormel, M. R. Giezen, H. Knoors, L. Verhoeven, and E. Gutierrez-Sigut, “Predictors of word and text reading fluency of deaf children in bilingual deaf education programmes,” *Languages*, vol. 7, no. 1, p. 51, 2022. <https://doi.org/10.3390/languages7010051>

- [23] V. Ocran, "Deaf students reading comprehension, a case study of presbyterian college of education," Thesis, University of Education, Winneba, 2024. [Online]. Available: <http://41.74.91.244:8080/handle/123456789/1536>
- [24] P. Yan and P. V. Paul, "Metacognition and english reading-related outcomes for d/deaf and hard of hearing students: A narrative review," *Human Research in Rehabilitation*, vol. 11, no. 2, pp. 94–112, 2021. <https://doi.org/10.21554/hrr.092106>
- [25] P. J. Holcomb, E. M. Akers, K. J. Midgley, and K. Emmorey, "Orthographic and phonological code activation in deaf and hearing readers," *Journal of Cognition*, vol. 7, no. 1, p. 19, 2024. <https://doi.org/10.5334/joc.326>
- [26] A. L. Mendoza-Cacedo and H. X. Mendoza-Ponce, "Teaching resources in the production of writing of the English language in deaf students," *International Journal of Linguistics, Literature and Culture*, vol. 10, no. 4, pp. 73–81, 2024. <https://doi.org/10.21744/ijllc.v10n4.2441>
- [27] M. E. Ahmed and S. Hasegawa, "Development of new distance learning platform to create and deliver learning content for deaf students," *Education Sciences*, vol. 12, no. 11, p. 826, 2022. <https://doi.org/10.3390/educsci12110826>
- [28] M. E. Skyer, "Power in deaf pedagogy and curriculum design: Multimodality in the digital environments of deaf education (DE2)," *Arts and Culture Studies Review*, vol. 53, no. 3, pp. 345–381, 2022. <https://doi.org/10.4467/20843860PK.22.025.16614>
- [29] P. Escudeiro, B. Galasso, D. Teixeira, M. C. Gouveia, and N. Escudeiro, "Inclusive MOOC – educational content for deaf people, a Portuguese proof of concept," *Cypriot Journal of Educational Sciences*, vol. 17, no. 4, pp. 1285–1303, 2022. <https://doi.org/10.18844/cjes.v17i4.7151>
- [30] T. Kato, A. Shitara, N. Kato, and Y. Shiraishi, "Sign language conversational user interfaces using luminous notification and eye gaze for the deaf and hard of hearing," in *ACHI 2021: The Fourteenth International Conference on Advances in Computer-Human Interactions*, 2021.
- [31] E. Klimentová and V. Dočekal, "Specific needs of families of deaf parents and hearing children," *Central European Journal of Educational Research*, vol. 2, no. 3, pp. 39–45, 2024. [Online]. Available: <https://hdl.handle.net/2437/318101>
- [32] D. A. A. Alothman, "Language and literacy of deaf children," *Psychology and Education*, vol. 58, no. 1, pp. 799–819, 2021. <https://doi.org/10.17762/pae.v58i1.832>
- [33] Q. Fu, J. Fu, S. Zhang, X. Li, J. Guo, and S. Guo, "Design of intelligent human-computer interaction system for hard of hearing and non-disabled people," *IEEE Sensors Journal*, vol. 21, no. 20, pp. 23471–23479, 2021. <https://doi.org/10.1109/JSEN.2021.3107949>
- [34] M. de los Á. Domínguez-González, C. Hervás-Gómez, and P. Román-Graván, "Technologies as a support resource for people with disabilities: A systematic review," *Journal of Turkish Science Education*, vol. 20, no. 4, pp. 619–631, 2023. <https://doi.org/10.36681/tused.2023.035>
- [35] A. Kusters, "International sign and american sign language as different types of global deaf lingua francas," *Sign Language Studies*, vol. 21, no. 4, pp. 391–426, 2021. <https://doi.org/10.1353/sls.2021.0005>
- [36] H. R. Bosker and D. Peeters, "Beat gestures influence which speech sounds you hear," *Proceedings of the Royal Society B: Biological Sciences*, vol. 288, no. 1943, p. 20202419, 2021. <https://doi.org/10.1098/rspb.2020.2419>
- [37] A. Boamah, "The deaf and graphic design education: Figuring the challenges of the sign language interpreter," *American Journal of Art and Design*, vol. 6, no. 4, pp. 120–126, 2021. <https://doi.org/10.11648/j.ajad.20210604.12>
- [38] C. Suardi, A. N. Handayani, R. A. Asmara, A. P. Wibawa, L. N. Hayati, and H. Azis, "Design of sign language recognition using E-CNN," in *2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT)*, Surabaya, Indonesia, 2021, pp. 166–170. <https://doi.org/10.1109/EIConCIT50028.2021.9431877>

- [39] T. Luangrungruang and U. Kokaew, "E-learning model to identify the learning styles of hearing-impaired students," *Sustainability*, vol. 14, no. 20, 2022. <https://doi.org/10.3390/su142013280>
- [40] T. Kumaragurubaran, S. Senthil Pandi, M. Tharun, and M. V. Devi, "Unlocking sign language communication: A deep learning paradigm for overcoming accessibility challenges," in *2024 International Conference on Communication, Computing and Internet of Things (IC3IoT)*, 2024, pp. 1–6. <https://doi.org/10.1109/IC3IoT60841.2024.10550356>
- [41] E. Brito and G. P. Dias, "LMS accessibility for students with disabilities: The experts' opinions," in *2020 15th Iberian Conference on Information Systems and Technologies (CISTI)*, 2020, pp. 1–5. <https://doi.org/10.23919/CISTI49556.2020.9141046>
- [42] M. F. van Wier, E. Urry, B. I. Lissenberg-Witte, and S. E. Kramer, "A comparison of the use of smart devices, apps, and social media between adults with and without hearing impairment: Cross-sectional web-based study," *Journal of Medical Internet Research*, vol. 23, no. 12, p. e27599, 2021. <https://doi.org/10.2196/27599>
- [43] T. Ahlin and A. Hiddinga, "Technological socialities: The impact of information and communication technologies on belonging among deaf and hard-of-hearing people," *Sociology Compass*, vol. 17, no. 5, p. e13068, 2023. <https://doi.org/10.1111/soc4.13068>
- [44] G. Chibaya, P. Govender, and D. Naidoo, "United Nations Convention on the Rights of Person with Disabilities (UNCRPD) implementation: Perspectives of persons with disabilities in Namibia," *Occupational Therapy International*, vol. 2021, no. 1, p. 6693141, 2021. <https://doi.org/10.1155/2021/6693141>

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