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iJET International Journal of Emerging Technologies in Learning

iJET | eISSN: 1863-0383 | Vol. 19 No. 5 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijet.v19i05.49183

PAPER

Inclusive Digital Content for the Teaching-Learning of Deaf University Students in Computer Networks

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ABSTRACT

Inclusive education recognizes and values the diversity of students, guaranteeing their development, participation, and learning within the same classroom. However, this form of social and academic inclusion requires extra effort from teachers and educational institutions. This project, aimed at the deaf community, focused on transmitting in their native language, elementary knowledge of computer networks, which is indispensable in this technological age. Specialized teachers selected the content of the topic of study and proposed a methodology for creating new signs with the participation of deaf telecommunications engineering students and professional interpreters, who adequately transmitted the concepts from one language to another. The educational content created in sign language was organized in an electronic book to facilitate access to the deaf student community. The final product was evaluated in four aspects by deaf people and interpreters, obtaining a positive evaluation by most respondents. In conclusion, the importance of developing this type of inclusive pedagogical support tool aimed at university-level students with disabilities is highlighted.

KEYWORDS

engineering education, digital inclusion, sign language, deafness, computer networks, electronic books

1 INTRODUCTION

A person with a disability has long-term physical, mental, intellectual, or sensory impairments that may prevent full participation in society due to the existence of many obstacles [1]. Therefore, social inclusion exists as a process that allows all people to have the same opportunities for real and effective access to a good, a service or an environment, generating the necessary conditions and measures in the facilities and services for their use and exploitation [2]. Inclusion in the field of education is defined as the search for better ways to respond to diversity, identifying and eliminating barriers, through policies and practices that improve the presence, participation and performance of all students; It involves a particular emphasis on those

Moreno, J., Velandia, F., Villamizar, A. (2024). Inclusive Digital Content for the Teaching-Learning of Deaf University Students in Computer Networks. *International Journal of Emerging Technologies in Learning (iJET)*, 19(5), pp. 4–19. https://doi.org/10.3991/ijet.v19i05.49183

Article submitted 2024-02-18. Revision uploaded 2024-04-08. Final acceptance 2024-04-08.

groups of students who may be at risk of marginalization, exclusion or educational underachievement [3]. People who only communicate through the native language of their ethnicity have high risks of being excluded because they cannot read, write, or speak in the languages used in the digital world, therefore, language also becomes a barrier that restricts access and capacity for exploitation and increases dependency [4].

According to the World Bank, 15% of the population, meaning around 1 billion people, have some disability, with a higher proportion in developing countries, which are more likely to suffer adverse socioeconomic outcomes in terms of access to education or health, as well as lower levels of employment and higher poverty rates [5]. In Colombia, it is estimated that around 1.3 million people in 2020 had a disability [6], specifically, for hearing impairment. The National Institute for the Deaf (INSOR), attached to the Ministry of National Education (MEN), reported that there were about 455,718 people with hearing impairment, representing 1.1% of the country's population. In terms of their educational level, there were more deaf students in middle and high school, followed by elementary school, adult education, and kindergarten, which implies providing reasonable adjustments in the educational processes to guarantee access to higher education levels [7]. According to [8], "the numbers in Latin America show that inclusion in higher education is scarce, also, there is insufficient scientific production that provides information about students at this level."

There are state laws that seek to guarantee the right to education for people with disabilities at the higher education levels, encouraging institutions to allocate human and economic resources to conduct research, programs, and strategies for the development of inclusive technologies [1]. The University of Pamplona as an educational institution adopted the policy of social inclusion and universal accessibility for prioritized groups, including people with disabilities, thus committing to contribute to the construction of a fair and egalitarian democratic society, equalizing opportunities concerning others [9].

Often, regulations exist, but they are not suitable; there is a low percentage of deaf people who complete their higher education; looked from another perspective, this is an opportunity to design technological tools to support access, retention, and completion of higher education for this population. Educational institutions face a great challenge, and the role of universities is fundamental; universities have the responsibility of contributing to the professionalization of this population and allowing them access to different productive roles within society. For [10] "In each educational institution at different educational levels, there is a lack of institutional strategies to address inclusive education, as well as the lack of specialized training to care for students with special abilities despite having a minimum number of students per classroom." It is relevant to work on projects aimed at the generation or creation of digital content that can be used for these purposes and from them develop educational tools to support the teaching-learning process, using specific formats and software that can be worked from the network or any device, and through the use of digital content such as text, diagrams, video, fixed and animated image to promote understanding, enhance learning and maintain motivation in deaf students in higher education.

In this context, teachers have an articulating role between public policies and pedagogical implementation in the classroom concerning school inclusion. Inclusive teaching is demanding, therefore, the permanent search for appropriate ways to respond to the diversity of students is imperative [11]. Within the ICT teacher competency framework proposed by UNESCO, teachers must be equipped to build a skilled ICT workforce and encourage all members of society, regardless of gender,

language, age, origin, or different abilities; one of the proposed cross-cutting principles is universal design for inclusive learning and education, which "is a process in which curricula (goals, methods, materials, and assessments) are devised to provide flexible and inclusive approaches that can be customized and adapted to individual needs" [12]. "It is believed that ICT can be used as a powerful tool to support inclusion and that information about students' use of ICT can facilitate their integration" [13].

In response to the above, this article proposes a methodology for the creation of digital audiovisual educational content aimed at engineering students with hearing impairment, to support the training processes in higher education. For this purpose, the process used to create content is described as a valuable tool for the training of deaf engineering students, thus improving the dynamics of classes and facilitating the acquisition of new knowledge.

2 METHODS

This research covers the analysis, recording, editing, and presentation of digital content in Colombian Sign Language (CSL) with the participation of deaf engineering students, telecommunications engineering teachers, and sign interpreters; and also implements an instrument to evaluate the effect on the learning of computer networks at a university level. A series of phases were established that led to obtaining the digital resources according to the context of the topics and the target students, and the technological options to ensure accessibility were also considered.

The guide for the production of audiovisual content with reasonable adjustments for the Colombian deaf population of the INSOR is taken as a basis, where they propose the creation of audiovisual products working together with the beneficiaries, therefore, deaf engineering students actively participated in the process. It also defines how it should be an accessible audiovisual piece that articulates and harmonizes different resources that allow access to information such as 1) Audio description, 2) Subtitling, and 3) The incorporation of sign language [14]. Figure 1 shows the phases of the general methodology.

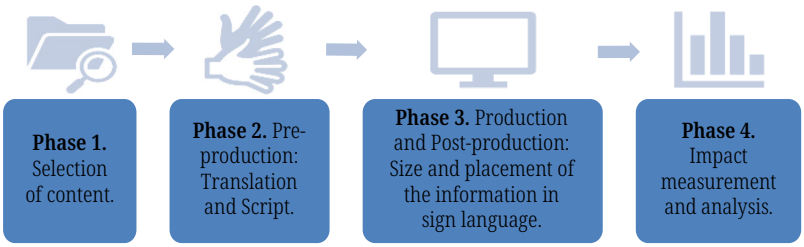

Fig. 1. General methodology

2.1 Content selection

The area chosen for the generation of the digital content was computer networks, specifically the topics related to computer network services and management. Due to the large amount of available material, these were filtered, thus selecting the most appropriate and updated ones. Initially, the programmatic contents of the computer network subjects taught in different universities at the international level available on the Internet were considered, with which books and websites can be related, also

international organizations such as IEEE, ISO, IETF, and ITU-T were considered for norms and standards. Finally, the information was organized by units and topics, thus establishing a structure for the contents.

2.2 Preproduction

The structured information is analyzed from the point of view of a deaf person, along with the support of a teacher in the field of computer networks, to determine which words, ideas, or concepts are not found in LSC, with the participation of a telecommunications engineer with hearing impairment. The online dictionaries of Colombian Sign Language of INSOR and the National Federation of the Deaf of Colombia (FENASCOL) were consulted. The words that were not found in the LSC were created. At this stage, planning and team-building activities were also carried out, including at least one deaf person and an interpreter.

LSC is considered a natural or mother tongue of visual-gestural character, whose channel of expression are the hands, eyes, face, mouth, and body, and its reception channel is visual. This language is created and used by the deaf community to meet their educational needs, as it allows the expression of thoughts, emotions, and feelings that contribute to the intellectual and personal growth of users [15]. A translation process was established to transmit the messages emitted from one source language to another, in this case from Spanish to LSC. The source of information obtained from Phase 1 constitutes a written and summarized Spanish text to be developed as an audiovisual product. It was necessary to create the new signs based on the existing ones, establishing a general vocabulary. Finally, a series of meetings took place with the working group to socialize, adjust the process if necessary, and create the non-existent signs of the most relevant words or concepts.

2.3 Production and post-production

In this phase, the multimedia content is created in a suitable format. The shooting, recording, editing, and other production processes were carried out in the digital content laboratory of the Universidad Francisco de Paula Santander—Colombia. It was necessary to establish and apply a procedure that allowed the participation of the working group, each one fulfilling a different role. Initially, pilot shots were taken to establish the most convenient procedure. Then the post-production began by editing the recorded material using specialized software, making the necessary cuts and format changes.

With the multimedia material produced and edited, the next step was to choose the best ICT tool for access to these digital contents so that they are available to the deaf community, it is necessary to choose the most appropriate digital platform that suits the needs of users and the characteristics of such content. This platform must consider the different learning rhythms of students to know which resources are appropriate in the teaching-learning process and be flexible to adapt to the particular environment.

Design for accessibility must take into account a pedagogical and sequential approach to organizing digital content. It seeks to generate an optimal and aesthetically pleasing arrangement on screen. The WCAG 2.0 proposes a series of recommendations for creating content. Following these guidelines ensures more accessible content for a greater number of people with disabilities [16].

2.4 Impact measurement and analysis

In this last phase, functional tests were executed, going through each of the chapters and topics to find and correct possible errors or failures and thus ensure a quality final product. In addition, the impact of digital content on the deaf student community was measured through instruments that allow analyzing the benefit achieved in the development of their academic processes, providing feedback on opinions and suggestions, and making comparisons with traditional methods. A Likert scale was used as an instrument based on the most relevant themes, dimensions, and criteria developed in [17], to evaluate the functionality, usefulness, pedagogical aspects, design, and technical aspects of the proposed digital contents.

3 RESULTS

The results presented below respond to each of the stages of the methodology that were carried out to obtain inclusive digital content as a final product. It begins with the selection of information, the creation and recording of signs and, finally, the presentation of the content in the chosen format.

3.1 Content structure

Thirteen higher education institutions with academic programs dealing with data network management and services were consulted. Based on the bibliography related to these programs, the sources were classified according to the level of information they provide. Fourteen books and nine e-books containing the topics of interest were chosen. Then the organization was carried out and the final structure was established by distributing the information in units and topics as shown in Figure 2.

Meetings were held between deaf people (graduates and students), LSC interpreters, and teachers to review the selected content and determine the existing and missing signs. As a result of these meetings, it was concluded to agree on the selected subject matter, given that it is part of the current demand for knowledge required by the labor market, which allows strengthening the understanding of these topics from their training by receiving it in the first instance in LSC. A total of 138 key terms corresponding to computer networks were identified, of which 69 had no defined sign.

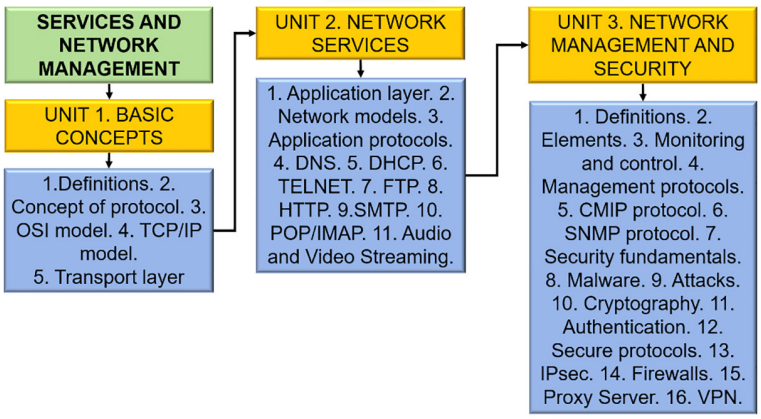

Fig. 2. Units and topics of the selected contents

3.2 Multimedia production

Based on the experience of students and interpreters and the book "Notes for a Grammar of Colombian Sign Language" [18], the movements, gestures, and other elements for the creation of the new signs were structured and then socialized for internal approval by the working group.

To produce the multimedia content in sign language, the Graphic Interchange Format (GIF) was chosen because it is a bitmap graphic file format that supports a smaller number of color ranges and this allowed optimizing the size of the file containing the image, making it an ideal format for the large amount of audiovisual material required. This format is limited to a color depth of 8 bits, which means that, although the quality of the image is lower, the final product is satisfactory. Other formats were also considered, such as text, still images (JPG), and videos (MP4) without audio for the complementary content.

The production of the content in LSC was carried out in a content construction laboratory that has an infrastructure equipped with specialized equipment, software licenses, and trained personnel to create high-quality multimedia material. The laboratory, as shown in Figure 3, is divided into two areas: 1) Recording area with recording cameras, cold and hot lights, backgrounds, and a chroma-key, and 2) Editing area with a desktop computer and its corresponding image and video editing software. However, for the content recording stage, the MP4 format was used, which was then converted into GIF format.

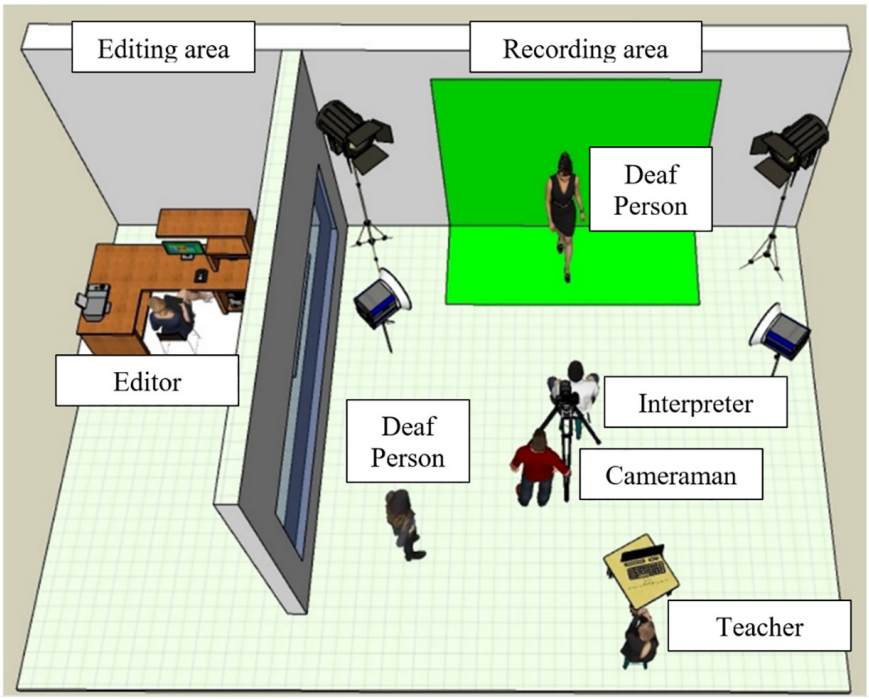

Fig. 3. Digital content laboratory

A procedure for the recording of the digital material was established. Each of the stages corresponding to the process of recording the contents in sign language is presented below. Stages 1, 2, and 3 are performed during the recording process; stage 4 is performed at the end of each recording session.

1. Reading: A teacher of the area should read the contents aloud, clearly, and slowly.
2. Interpreting: An interpreter is in charge of listening to the contents dictated by the area teacher and translating them into LSC.
3. Repetition: The deaf students are in charge of recording the signs in front of the camera.
4. Storage: The person in charge of the camera operation copies and stores the multimedia material.

Another important aspect to consider is the definition of roles and the physical location of the people involved in each step as shown in Figure 4.

The multimedia material obtained during each of the sessions was saved in its original format and marked with its exact date and time. This material was then edited to optimize the duration and size of the files. Also, the structure of the digital content was arranged in units and chapters, requiring that the recorded multimedia material agrees with this scheme.

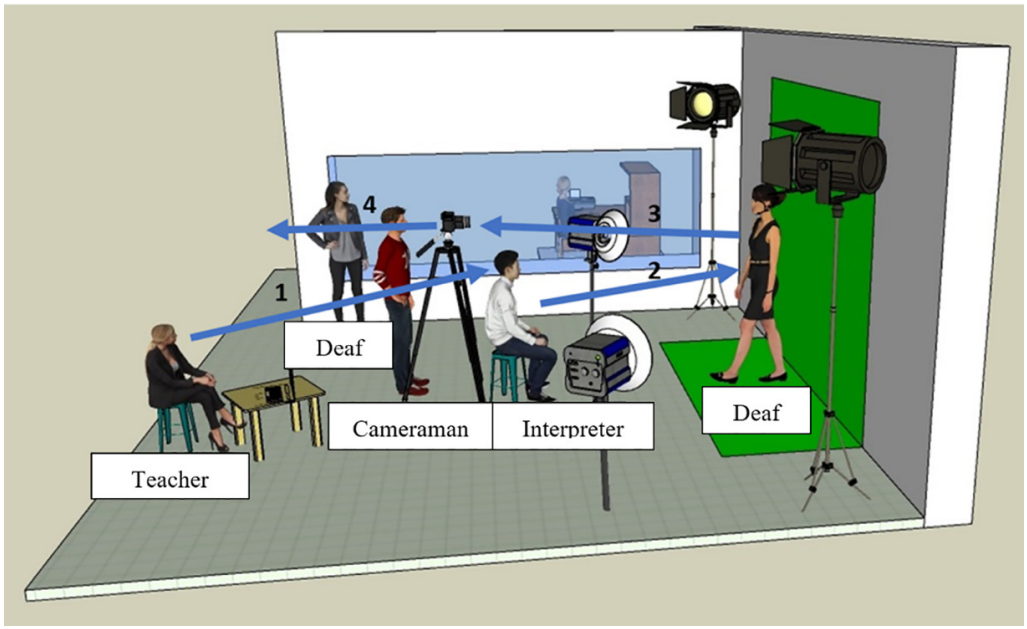

Fig. 4. Recording process

3.3 Multimedia editing

The editing area contains a computer with professional multimedia editing software installed with an updated license to edit and process all the videos taken in the recording area and obtain the final product. The editing consisted of trimming and classifying the videos according to each of the themes performed in LSC. Also, all the audio components that are not necessary for this type of project were eliminated, thus optimizing the size of the final files. Figure 5 shows the editing process and the final product of a recorded signal for the term “router”. Each recorded multimedia file was marked with the corresponding date, unit, chapter, and topic.

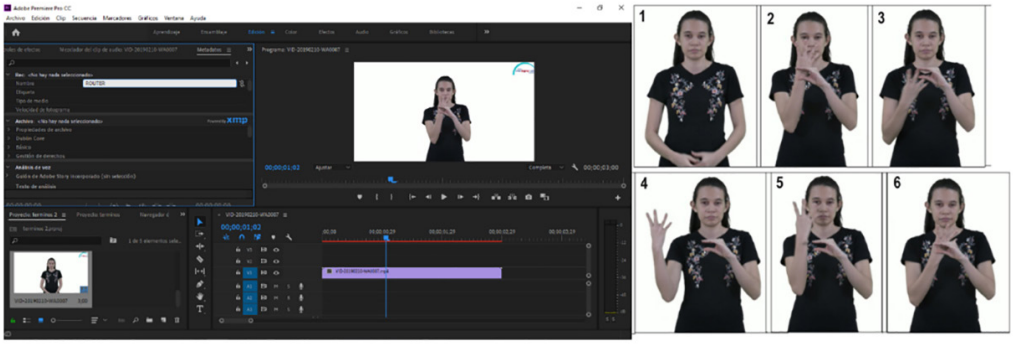

Fig. 5. Editing process of recorded signs

3.4 Presentation and availability of digital content

Table 1 lists the contents that were created, and all the others selected according to their type, quantity, and importance, taking into account that it is for the deaf community.

Table 1. List of recorded and edited contents

Importance	Type	Quantity	Comments
1	Video files	411 short videos in GIF and MP4 format.	The importance of videos is that they allow us to show the subject in LSC.
2	Animations	21 files in GIF format.	They allow to complement the understanding of some topics in a clear way.
3	Fixed images	325 fixed images in JPEG and PNG format.	They complement the ideas or concepts presented.
4	Digital text	328 text pages.	It Shows in text what is transmitted in the videos. Some deaf students find it difficult to understand.

For access to the contents, several tools were considered and, finally, the digital book or e-book format was selected, which offers many advantages that make it appropriate for the presentation of the generated digital content. For the creation of the digital books, the author's software Neobook was chosen, which is a program under Windows that allows the creation of interactive books and any informative document with support for videos, images, and files created with traditional word processors; it is one of the programs used by teachers and is related to the design of didactic resources through the use of ICT [19]. The use of Neobook made it possible to organize the created multimedia content according to the layout on the screen. The individual multimedia files were imported into the software and sorted by unit, topic, and pages.

Initially, a glossary of terms in LSC was created with 63 concepts necessary for the correct understanding of the topics developed in each of the units. Buttons were organized with the letters of the alphabet as the home page and "forward", "back" and "start" buttons as shown in Figure 6.

Subsequently, the topics related to computer network management and services were organized into 3 units and a total of 17 topics. For each topic an .exe application was created, thus obtaining files that were easy to download and took up less space

in memory. For Unit 1, 2 files were obtained, for Unit 2, 8 files and for Unit 3, 7 files. Figure 7 shows the result of the first topic of Unit 1 and the first topic of Unit 2.

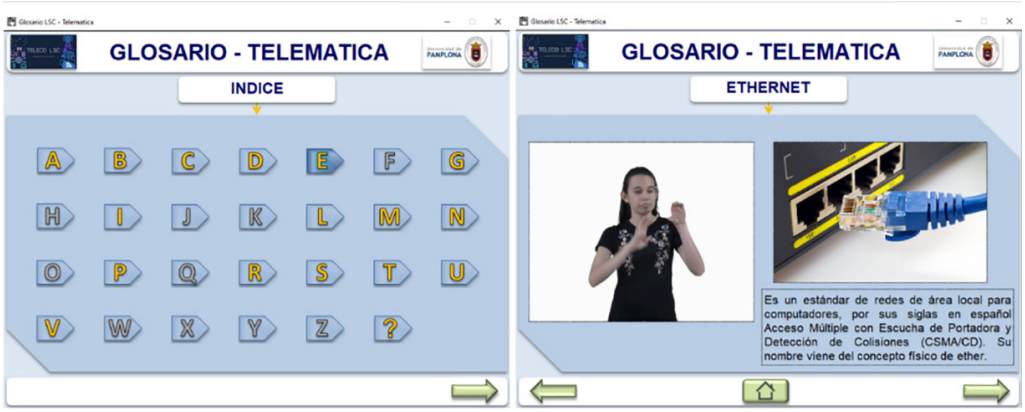

Fig. 6. Glossary view

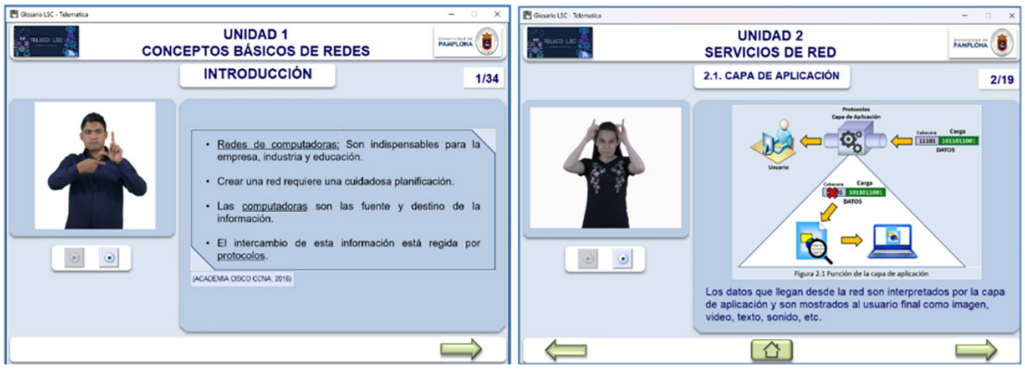

Fig. 7. Example of contents of units 1 and 2

For the correct use and exploitation of the information contained, so that the teaching and learning process is as efficient as possible, it is recommended that the student begins the process or exploration of the e-book, knowing the terms and words presented in the glossary in LSC, preferably the new terms that have been created, and then follow the sequence in the contents of services and management of computer networks proposed.

3.5 Analysis and socialization of the results

Three deaf students were selected from the Telecommunications Engineering program at the University of Pamplona, who are in their 7th, 8th and 9th semesters. The following were considered for the selection of expert personnel: two LSC interpreters with experience in telecommunications sign language, two teachers with expertise in services and network management who have taught classes to deaf students, and a deaf telecommunications engineering graduate. The instrument designed for this is shown in Table 2 and is divided into areas and criteria for its subsequent application to the selected population. The assessment was done with a scale from 1 to 4, where V1 (Strongly disagree), V2 (More disagree than agree), V3 (More agree than disagree), and V4 (Strongly agree). Figure 8 shows the overall results by areas of the instrument applied.

Table 2. The instrument for measuring the impact of the content created

Area	Criteria to Evaluate
1. Assessment of the functional and usability aspects of the multimedia e-book.	**1.** Ease of finding information. **2.** Movement of pages in the book. **3.** Operation of links outside the same. **4.** Experience in navigating in the environment. **5.** Access to e-book media. **6.** Precise indications for use. **7.** Availability for download or access to the e-book. **8.** Multimedia format compatibility. **9.** Fluency and speed of information processing and presentation.
2. Evaluation of the contents and pedagogical aspects of the multimedia e-book.	**1.** Applies to a classroom pedagogical project. **2.** It is suitable for the hearing-impaired population. **3.** The available information is consistent with your area of expertise. **4.** The content is adequate to improve understanding of concepts. **5.** It is an up-to-date, complete and organized resource. **6.** The content in Colombian Sign Language is coherent. **7.** It improves the understanding of the topic when viewed in Sign Language (LSC). **8.** It has a correct structure in LSC. **9.** It is interactive allowing a better understanding of the content. **10.** The multimedia information is related to the subject matter. **11.** There is depth in the content presented in the e-book. **12.** The structure of the multimedia content is appropriate for deaf students. **13.** The information is easy to understand. **14.** Improves the deaf student's levels of knowledge about that topic.
3. Assessment of multimedia e-book design	**1.** Text size is legible. **2.** Videos are clear and of good quality. **3.** Multimedia material is simple and coherent. **4.** The format of the book is accessible and adaptable. **5.** The structure of the e-book is in function of the comprehension of the information. **6.** The navigation within the e-book is well-designed. **7.** The icons and images are per the content presented. **8.** There is a conceptual foundation for the design of the book. **9.** Navigation instructions are clear and precise. **10.** The multimedia material is adequately developed.
4. Assessment of the technical aspects of the multimedia e-book	**1.** Pleasant use of the environment available in the e-book. **2.** Ease of use of the book. **3.** Easy navigation within the book. **4.** Navigation design of the environment. **5.** Book format and movement between pages. **6.** Clear presence of links and multimedia markup. **7.** Text and background colors are appropriate. **8.** Quality of images and multimedia content presented.

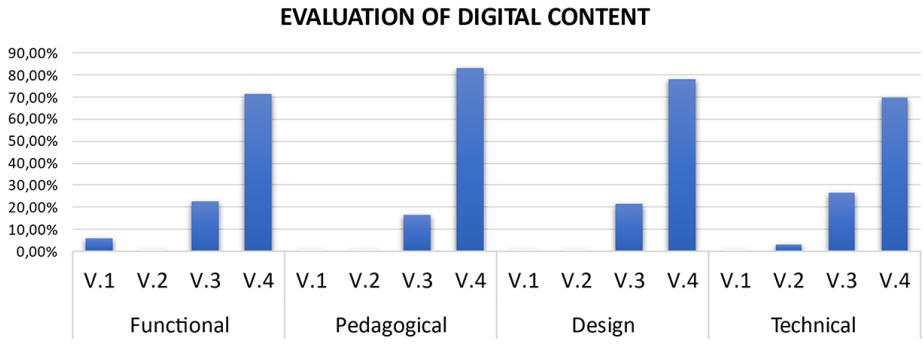

Fig. 8. Overall results of the evaluation of digital content

The results of the evaluation process of the data obtained in the quantitative form are obtained considering the dimensions in which the questionnaire that was applied was structured. Regarding the evaluation of the functional and usefulness aspects of the e-book, the items evaluated positively, V.4—totally agree, with 71.21%, were those related to the ease of finding information and the movement of pages in the book, 22.73% belong to agree more than disagree with the factors of functioning of the links outside the resource. The experience in navigating the environment, the indications of use are precise and the quality of the multimedia components is good. Finally, the items evaluated with a percentage of 6.06% were factors for improvement and at the time of the test, presented difficulty, caused by the availability for downloading or access to the e-book. In addition to the compatibility of multimedia formats, it is stated that it is because more than 80% of the digital content is in video, the target audience being the deaf population, the e-book contains more weight in its digital content.

For the next aspect corresponding to the evaluation of the contents and pedagogical aspects, 83.33% positively evaluated it, stating that the resource can be included as a classroom pedagogical project, is suitable for the deaf population, allows access to multimedia content in sign language through videos, facilitates the transfer of knowledge in their sign language, and allows reviewing, consulting and remembering concepts independently. Aspects for improvement are considered those that obtained a valuation more in agreement than in disagreement with 16.67%. It is related to the inclusion of more interactive content and the realization of adjustments regarding the depth of the topics. It is suggested to include review activities to consolidate the acquired knowledge.

For the evaluation of the design of the e-book, 78.21%, evaluated positively, stating that they totally agree with the size of the text, the clarity, and quality of the videos, the structure of the book in terms of understanding the information in sign language in a direct way, which allows in a certain way the independence of the deaf student from the interpreter and the teacher, facilitating access to information when deemed necessary for study from home, the instructions to navigate are clear and graphic providing a guide for the deaf student or teacher who wishes to implement the book in their pedagogical process. The content available in the book is adapted for deaf students, therefore it is not fully functional for the hearing community in the area. In general, it is a multimedia book adapted to the specific needs and characteristics of the learning process of the deaf population. On the other hand, 21.79% are related to items that will be reinforcement of tasks to include more content that allows to be interactive with the deaf student.

Finally, in the evaluation of the technical aspects of the e-book, the evaluators found as positive 70% of the navigation within the book, stating that it is simple and light movement between pages, offers a pleasant book environment to explore and use, with appropriate text and colors, in addition to the good quality of the images that show a better understanding of the subject in addition to the video and multimedia content in which the information is available for deaf students. Some aspects to improve are the following: evaluated with 26.67% are those related to access. It is recommended to revise the use of the book from different platforms such as mobile devices, allowing to consult it at any time by the student.

4 DISCUSSION

The selection of the topics was carried out concretely since they are the main input in the development of the digital content in LSC. Part of the books were

identified and selected, without necessarily making an exhaustive review of each one, considering that the same topics are repeated in different sources. Then the process of creating new signs is established, to strengthen the communication of the deaf and hearing community, both in academic knowledge and in their future work. The steps carried out for the creation of new signs start with the determination of the specialized vocabulary specific to the area of study and consider the morphological processes, the most common being "Iconicity, Conceptual Metaphor, Sequential Composition, Borrowing by initialization and Derivation" [20].

The GIF format used in sign production is widely used in these contexts as in the case of [21] by supporting chat communication between deaf users, integrating a GIF format gallery that represents sentences and words in sign language (SL) format. On the other hand, [22] proposes a model that translates live voice or audio recordings to text and compares it with sign language animations from a predefined GIF format dataset, and finally, [23] supports the inclusion of deaf end-users in social networking applications by providing the ability to browse, search and edit animated videos/GIFs in American Sign Language (ASL).

A process for recording signs was established based on the analysis of sign language recording projects conducted by [24]–[27] to compare the scenario, participants, and methodology with the resources available for recording. Adobe Premiere editing software is used for trimming and reformatting recorded videos and has been used in different works such as that of [28], investigating the accessibility provided to students using educational interpreters, where Adobe Premiere is used to prepare appropriate materials in terms of intelligibility, editing video clips consisting of short utterances from the recordings and in [29] provide a tutorial on more efficient methods for measuring gesture kinematics, using Adobe Premiere to load multiple audiovisual streams and apply the automatic audio synchronization feature.

The presentation of content should be done in a way that text and images are properly organized to help students have a better understanding. Some strategies for good design are to present the content divided into different parts of the screen, to be easily accessible and interactive, easy to handle and navigate, to use icons that are familiar to learners, and to show a consistent relationship with the selection and orientation of text and images [30]. The layout of the sign language interpreting videos within the on-screen area should have greater relevance with these being the main components. Text, images, and animations, among others, are now complementary or supportive elements to the learning process of the deaf student.

The choice of the e-book format provided access to the digital content created. For [31], the "sign-printed bilingual e-books are unique in the way they leverage digital platforms to display video and text and take markedly divergent approaches to integrate the two media". Multimedia material comprises videos, animations, images, and text. Therefore, the digital book format allows for the proper presentation of such content generating a complete and organized final product. Regarding the use of e-books in teaching deaf people, we have as an example the research of [32] that proposes a physical education learning medium to improve the basic movement skills (BMS) of deaf children, using a combination of e-books and QR code materials. On the other hand, in [33], e-books are produced, usually using published picture books as a basis and adding sign language videos.

Authoring tools are the most suitable for the creation of e-books. Neobook is a widely used software in the educational field and enjoys great popularity due to its ease of use and low cost. [34] analyzed the use of Neobook in the teaching-learning process of Computer Science, showing that the use of this educational software would help 82% of students to improve their knowledge. In [35], they state that

Neobook allows teachers to create media that facilitate autonomous learning and increase the understanding of the topics; and in [36], Neobook was selected for its versatility, popularity and accessibility to design an alphabet game to help students understand key academic concepts of economics.

5 CONCLUSIONS

The selection of the content should start with the analysis of the main bibliography of homologous subjects that address the subject of study, to identify the chapters of primary information sources such as books and e-books and thus structure the units and topics that are subject to translation into sign language. The content created is adapted to the curriculum of the subjects in management and computer network services and is timely, clear, and concrete to be delivered to deaf students.

The new signs and videos were created in collaboration with teachers, deaf engineering students, and interpreters. A simple methodology was proposed that allowed us to analyze, create, and record video efficiently for the large volume of contents of the chosen topic, which allowed us to obtain the multimedia material in LSC in a reasonable time.

The e-books created contain all the educational material to support the learning process. Therefore, the illustrations and animations are clear, error-free, visible, and comply with copyright regulations. The e-book format allows the contents to be individualized by units and specific topics and is easily accessible.

The community of deaf engineering students considers the development of these pedagogical support tools in the teaching-learning process as positive, being a significant and real step towards an inclusive education, allowing in this way, a better understanding of specific concepts of the area, due to the availability of information directly in their LSC language. Students' competencies in the area of study are strengthened by facilitating access to this content at any time to resolve doubts and remember or reaffirm concepts, without an interpreter or support teacher present.

6 ACKNOWLEDGMENTS

This article had the support and financing of the University of Pamplona in Colombia and its Internal Call for Projects Bank program that promotes research within the educational community. Likewise, we also thank the GITENT research group for their contributions and support in this process.

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