Assistive Technology Applied in an Inclusive MOOC for the Blind

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Abstract: Considering the opportunity provided by Massive and Open Online Courses (MOOCs) to reach wide audiences, a new pedagogical model of the MOOC in Educational Technologies was implemented at Instituto Superior de Engenharia do Porto (ISEP) aiming at maximizing the MOOCs' potential to provide educational offers to both deaf and blind communities. These communities face several and distinctive communication barriers, not allowing them to integrate within the larger intellectual communities as most tools used for information dissemination remain inaccessible to them. This paper's main purpose is to present the innovative pedagogical model devised at ISEP/GILT to better enable the blind/visually impaired individuals to access digital educational content, hence being a contribution for the inclusion of these individuals in educational environments. This inclusive and innovating pedagogical model is a result of the wider research being conducted at ISEP/GILT concerning the development of assistive technology targeted at improving communication with and between the blind and the deaf, consequently fostering their inclusion. Although this paper highlights the pedagogical model proposal targeted at the blind/visually impaired, the model also integrates the deaf. Therefore, we present the complete API (BDC-API) architecture that supports the inclusive pedagogical model. This API translates digital educational content for the blind, grounded on the developed model used to translate written-text into sign language for the deaf.

1 INTRODUCTION

Higher education level of expertise and demands require professionals to constantly revise, update and improve not only their scientific and technical knowledge, but also their pedagogical approaches to comply with both the fundamental principles consigned in the Portuguese Constitution and those specified by the Ministry of Education (ECD, 2010). This implies that teachers need to invest in the continuous improvement of their skills and knowledge, therefore it is fundamental for them to have access to training that may also prepare them to handle special education needs. Nevertheless, the Portuguese education system does not always have appropriate training offers available to respond to special educational needs, particularly concerning blind students (Marques et al., 2017). This is extendable to educational digital content. The postgraduation in Supporting Technologies for Education (TAE), and the postgraduation in Informatics in Education (IE), targeting at Education professionals already in practice or concluding their graduation, were devised having those needs in mind. These educational postgraduation offers are unique for their modular working structure, which enables a flexible enrolment of the participants (Marques and Escudeiro, 2016) (ESTAE, 2012).

However, after realizing the limitations of the firstly devised blended learning model to reach the target audience widely, an inclusive and innovative pedagogical model started to be conceived, having as premise the at distant educational model known as Massive Online Open Course (MOOC) (Marques et al., 2017). The development of that postgraduation offer in a MOOC, relying on internet connectivity, widens the possible participants to unlimited numbers, therefore opening the access to knowledge in any part of the Planet with no time limits – therefore, people anywhere have access to learning by the principles of the so-called distance education and open education (Marques et al., 2017). Once having spotted the lack of digital educational offer in higher education inclusive of

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blind individuals, an inclusive model was created to integrate these postgraduation level MOOCs, which will allow the participation of blind individuals (Escudeiro et al., 2018), two specific and sensorial impairment groups with completely different needs.

This paper focuses on the model devised for widening the education offers to the blind and the visually impaired, therefore contributing to maximize the access to higher education and foster social inclusion of those deprived from using sight to acquire information and to visually interact with the surrounding environment (ACAPO, 2018). The Blind/Deaf Communications API (BDC-API) architecture (Escudeiro et al., 2018) is presented considering the required specification for the target audience in question, as well as the implemented solution that enables the translation of digital educational content specifically for the blind/visually impaired.

With that purpose in mind, this paper starts by detailing the pedagogical model underneath every MOOC structure so that it complies with the requirements of the implied assistive technology specifications. This is followed by the description of both the implemented solution and the BDC-API architecture model. Next, the underlying factors guaranteeing the quality of digital content production (Escudeiro, 2016) using the Quantitative Evaluation Framewor QEF model (Marques et al., 2018) are explored applied to the proposed MOOCs.

2 MOOC MODEL

The development of the innovating MOOC pedagogical model detailed in this paper comprehends the postgraduation degrees in Technologies Applied to Education, which are part of the educational offer at ISEP, the School of Engineering of the Porto Polytechnic (Marques and Escudeiro, 2016) (ESTAE, 2012). This innovating postgraduation offer, focusing on the development of skills in the Information and Communication Technologies area (ICT), is divided into two specialization branches: Informatics in Education (IE) and Supporting Technologies for Education. Figure 1 shows the course units alignment in each postgraduation, making it clear the specific areas approached as well as the contents that are common in both offers.

The MOOC pedagogical model introduced in (Marques and Escudeiro, 2016) (Marques *et al*, 2017) and detailed in (ISEP, 2016) was designed to be applied to both postgraduation course units. Each course unit in each postgraduation has been handled as a single homogeneous independent short course based on a structure adapted to online learning, which considers a five-lesson course open for a week. Each course needs to comply with a set of specifications devised for assuring the MOOCs coherence and consistence.

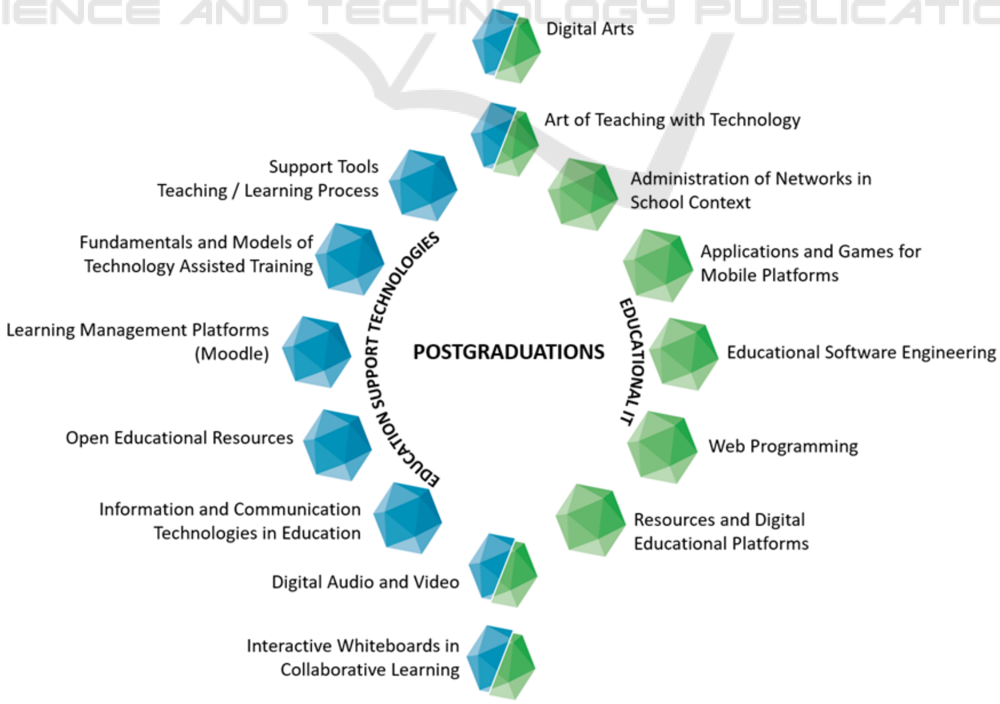

Figure 1: Course Units in the postgraduation offers in Technologies Applied to Education.

The following list concerns those specifications.

Specifications for assuring the MOOC coherence:

- Definition of prerequisites and respective recipients;
- Definition of the learning objectives;
- Definition of the type of contents supporting the lesson, assuring the quality of every material that is made available;
- Introduction to the evaluation strategy – evaluation methods, type of tasks and activities to be carried out –, aligning it with the defined learning outcomes;
- Definition of the interaction model to be adopted (the participant/trainee must have it clear if the course is completely autonomous or if the trainer/teacher is available throughout the process, being thus essential to assure that there is a balance between the trainer's presence, the interaction between the participants and the individual learning process);
- At the beginning of each lesson, an introductory video welcomes the participants, introducing all the trainers involved in the course;
- Definition of a *short view* – course introduction video (2 minute-length).

Elements in a course:

- Theme
- Learning objectives
- Lesson description
- Promotional video
- Complementary material
- Video lesson
- Lesson summary
- Title and subtitle
- Course promotional image (similar in every lesson)
- Trainer's biography

This structure enables learning to take place continuously and actively, enabling appealing, creative and up-to-date content to be well distributed, favouring the accomplishment of tasks according to the acquired knowledge. Complying with that course structure, each lesson is organised as follows:

- Introductory video referring to the lesson's trainers
- Definition of prerequisites and respective recipients;
- Definition of lesson structure;
- Definition of learning objectives (summary);
- Definition of the type of contents supporting the lesson;
- Title and subtitle;
- Lesson conclusions and next lesson theme;
- Last lesson presents the evaluation strategy (evaluation methods, type of tasks and activities to be carried out), aligning it with the defined learning outcomes;
- Presentation of appealing contents, well distributed;
- Launching of 2 questions so that the trainee may effectively apply and demonstrate the skills and knowledge acquired;
- Definition of the interaction model;
- Definition of bibliography to be used.

Promoting social and scientific inclusion in higher education of blind/visually impaired people has been the purpose of developing technical equipment and strategies to extend that MOOC model into the creation of an inclusive and innovating MOOC offer. To reflect this innovating and inclusive concept the logo represented in Figure 2 was designed, symbolizing inclusion in knowledge access and innovation.

Figure 2: Inclusive and innovating MOOC logo (Silva, 2018).

The proposed pedagogical model implies at its founding the involvement of multidisciplinary teams, constituted by professionals with distinct backgrounds, so that an accurate educational environment may be built comprising an accessible, inclusive and innovative pedagogical setting. The subsections that follow detail the implemented pedagogical model, the designed and implemented solution, and the architecture model devised, targeted at blind individuals.

2.1 Implemented Pedagogical Model

To guarantee the postgraduation degrees' homogeneous features, a model comprising a set of recommendations grounded in a pedagogical structured supported by an online adapted technology was devised, which must consider four decisive factors: the structure, length, pedagogical design, content production and validation (Marques and Escudeiro, 2016).

Planning is the fundamental and grounding task, common to all the individuals involved in the development process. Throughout the conception of the pedagogical model, there was especial focus on the team to guarantee the active participation of all individuals in accordance with the objectives previously set and the defined plan. The cohesion and compromise of the team enable a consistent development, which will lead to a product totally adapted to a specific target as presented in Figure 3.

The intervenient share the responsibility of a very relevant task: planning the MOOC pedagogical model. This responsibility is organised as follows:

- The Design Team is responsible for creating the scenario where the lessons are recorded. This team is also responsible for scheduling meetings and recordings time according to the availability of each required intervenient. To support this management, an online planning platform has been used – Trello – where all the relevant information regarding the Post Graduations, meetings' minutes, files and details on each course unit are made available.

As far as the technology is concerned, the responsibilities have been distributed among the several members of the computing team.

- The Computer Team is formed by programmers who are responsible for developing the application that translates text into sound, the Text-to-Speech application. This application explores all the audio potential to enable the communication with the blind and visually impaired so that these may autonomously have access to and make use of the innovative MOOC model.

Besides, the user is required to use accessible technological resources, such as already existing sound/voice software (synthesizers), which once installed in the computer read what appears on the screen (e.g. NVDA) (ACAPO, s.d.). These applications aim at reading the information on the screens, thus identifying the actions to be performed by the users (Santarosa, 2003).

- The Researchers Team has studied a way of making it possible for the visually impaired to interact equally in the same platform, namely using specific and accessibility featured equipment, software and content to access the internet, which have been specially designed and built to fulfil this target group's needs. The NVDA, DOSVOX, VIRTUAL VISION and JAWS have been identified as the most relevant applications to be applied in our object of study as resources (Vision, 2016).

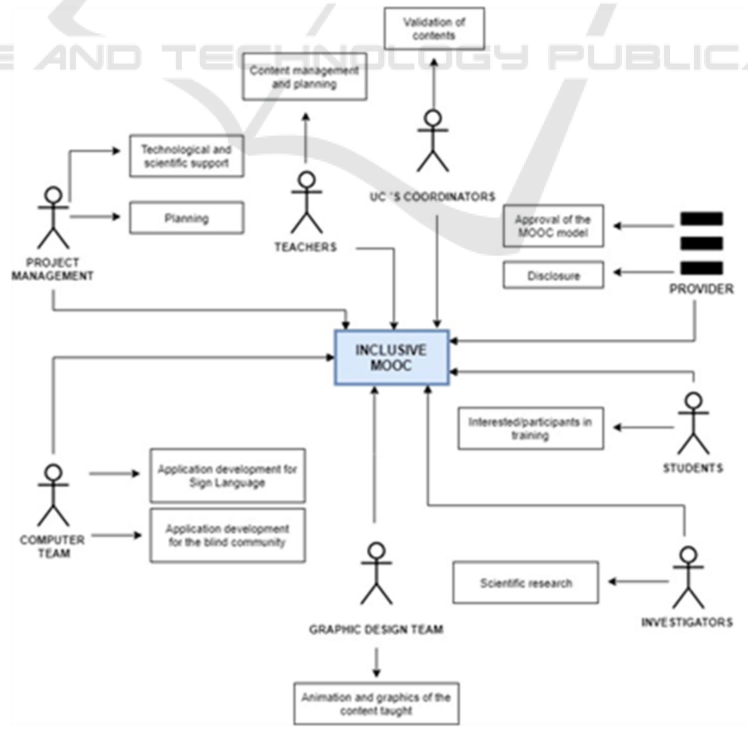

Figure 3: Intervenient elements in the innovative and integrating MOOC.

- The Project Manager (advisor) oversees the project, essentially providing technological and scientific support regarding planning so that the project development may be a success.
- The Course Unit Leaders/teachers plan and develop the contents, in which written texts (direct speech), images, videos, tutorials, among others are included. Afterwards, the structure of the lessons is validated by the coordination team responsible for each course unit, and/or by the responsible teacher (in this case the design team is responsible for correcting and adjusting the audio only to guarantee the sound quality). Supporting the participants/trainees and providing them with accurate and effective feedback is essential throughout the course.
- The Provider (Udemy) will have the responsibility of disseminating the result of this inclusive MOOC pedagogical model. Dissemination will take place within the provider's network of contacts, thus widely promoting the postgraduation degrees.

The participants' interest, motivation and regular interaction is fundamental for them to take the best out of the contents available in the platform (Figure 3).

2.2 Implemented Solution

This section presents the design of the solution as well as its architectural model. The main purpose of this model is to comply with the online learning needs of the blind and visually impaired. Words and sound individually may not be enough to transmit content meaning; hence it is fundamental to be careful about the way text is made available. For blind and visually impaired people the touch is essential to complement the sound so that they may completely receive a message. As far as online learning is concerned, environment sounds are needed to enable the fully potential of the MOOC model to reach this target audience (Diversidade, 2012).

Figure 4 details the structure created for the MOOC model, and its respective development plan. By analysing the schematics, it is possible to understand the connection between each of the project sets. The content experts – the teachers – are responsible for devising and planning the contents (as pointed out in the previous section) as well as for analysing the information produced by the participants. Moreover, they provide feedback and manage the course unit's forum whenever possible. The team responsible for the course units approves/validates the contents and whenever needed requires improvements to the structure of the lessons. Only after this approval are the contents sent to the Design Team to be graphically implemented.

After receiving the contents validated by the course units' team, the Graphics Design team manages and schedules the recording sessions. After video recording the lessons, the course units' team validates them, and only after this step is the Design

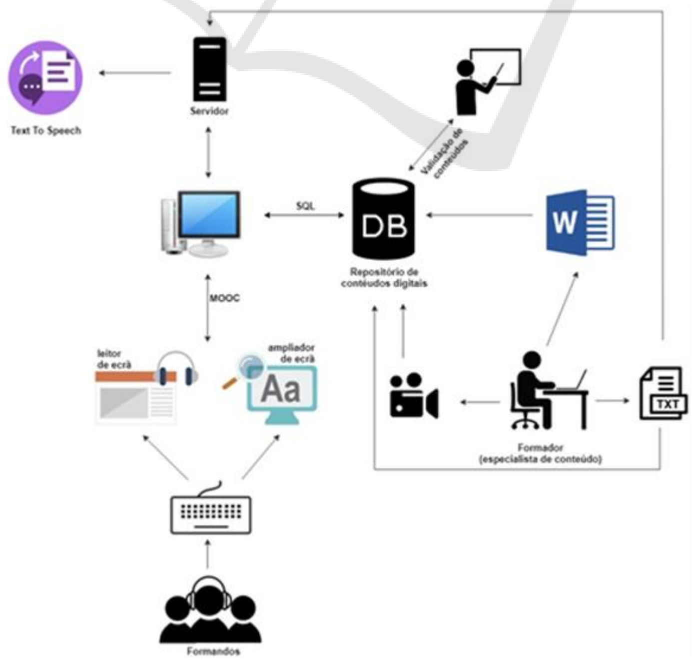

Figure 4: Design of the solution.

Team allowed to edit, handle the sound, animations and graphics appropriate to each course unit.
The following step concerns the Computer Team's job. All the technical work developed within GILT, specially the text-to-speech convertor, has been fundamental to integrate in the MOOC pedagogical model presented in this paper the Text to Speech feature, which enables reaching blind and visually impaired individuals.

Finally, the trainees/participants will have access to quality content specific to the postgraduation of their choice and will be able to attend all the classes regularly, being required to comply with the contents and to solve the related exercises and tasks.

2.3 Architecture Model

This section details the interaction between the diverse components and the types of communication that refer to the project. Table 1 presents the architecture model.

Table 1: Architecture Model.

User		
Interface		
Server	Database	Business logic
Hardware		

As can be observed, the architecture is structured in three layers supported by the hardware component. The interface will enable the user to interact with the system functions. The third layer is divided into three different parts, i.e. the server, the database and the business logic. The web service is responsible for connecting with the server, whose purpose is to enable the connection between several devices. Finally, the database will store the necessary information to reproduce the voice.

Blind people have always faced several difficulties when it comes to communicating, most of the times hindering their inclusion in larger intellectual communities as most of the tools used to make information accessible does not comply with their needs.

However, technology has been improving in such a way that it has been enabling institutions to acquire systems that have made it possible for blind people to be included. Nevertheless, the required equipment is still too expensive, which implies that most institutions cannot afford having the appropriate infrastructures to enable visually and hearing-impaired people to attend their degrees regularly.

Visually impaired people depend on the hearing to communicate. The need for these different communication channels makes it extremely difficult to use the same systems to enable them to communicate, therefore each communication solution must be specifically designed for each community. The defined architecture seeks to minimize the communication barriers blind people usually face, particularly in the education area.

The ACE (Assistive Communication for Education) architecture has led to create the BDC-API (Escudeiro et al., 2018) (Gilt 2016). This has been devised in such a way that new educational tools may be developed even by teachers without any programming knowledge. These educational tools support people with visual and hearing impairment overcome technological barriers and enables them to have access to digital information.

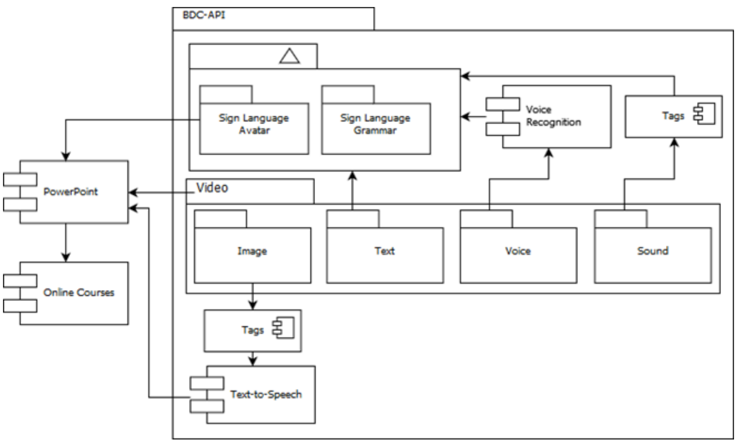

Figure 5: Translation Model (BDC-API).

The BDC-API architecture translates digital educational material for blind and deaf people, thus enabling them to have fully access to this content that they could not have access in another way.
Specifically considering the blind and visually impaired, the BDC-API uses state-of-the-art technology to create a simple and ready-to-use tool for teachers, serious games developers and students. Figure 5 introduces the BDC-API translation modules applied to the educational context (Escudeiro et al., 2018).

The used technologies include the IBM Watson and the Google Speech Web API to recognise voice and translate text-to-speech. The BDC-API was firstly used to create a plug-in for the Microsoft PowerPoint. For this, screen capture was used to enable the 3D Avatar to translate what is written on the screen into sign language in real time. Similarly, the BDC-API uses voice recognition and the Google Web API to enable blind people to communicate and interact with the digital content. The postgraduation MOOCs developed and referred to in this paper (Marques et al., 2017) (Escudeiro et al., 2018) hold a potentially endless learning database, creating a paradigm for the BDC-API which will enable the users to enlarge it according to their needs. This potential has become the main purpose of the BDC-API.

3 EVALUATION METHODOLOGY APPLIED TO THE INCLUSIVE AND INNOVATING MOOC'S PEDAGOGICAL MODEL

The quality of the inclusive and innovating MOOC's pedagogical model development process was controlled through the QEF – the Quantitative Evaluation Framework model (Escudeiro, 2015).
The QEF model evaluates digital educational contents (Escudeiro, 2006) based on the objectives, principles and actions of educational software engineering (Pressman, 2001; Bates, 2000). In the proposed pedagogical model, the evaluation supports the production phases and the development of conceptual models used to produce digital educational contents. Software engineering educational strand will integrate the processes, methods and tools in the development of models for evaluating the educational contents so that their quality improvement is assured.

This evaluation model is generally applied in the development of digital systems content to validate and evaluate the digital content progress during its development cycle at any stage of its production, allowing early detection and correction of eventual failures.

The proposed QEF adopts the SCORM standards as basis and the standard (ISO 9126) as reference, following Scarlet et al. (2000)'s suggestion, proposing a quantitative representation in an orthogonal three-dimensional space.

The quality strand of digital content should be pictured as an area bearing three dimensions (Escudeiro, 2007). Each dimension is composed of a set of factors and, in turn, each factor is defined by a set of requirements also referred to as quality criteria. The purpose is to be aware of the system's performance level at any stage of its development. The dimensions of our quality area correspond to the following: Pedagogical domain, Ergonomic domain, and Technical domain, each of which aggregates a set of factors for which it is important to determine our proposed system's performance degree.

A factor is an element that will represent the performance of the digital content in the system according to a predetermined criterion (Escudeiro, 2015).

3.1 Pedagogical Dimension

Learning is the pedagogical domain's fundamental support. Learning is determined by several factors that imply the interrelationship between the individual (subject), usually identified as participant/trainee, and the object, identified as a technological instrument of pedagogical nature. In this context, evaluation is an instrument in the pedagogical practice that allows us to verify which technological procedures are valid in the pursuit of educational objectives (Bloom, 1983, Bloom 1964).

For our quality scenario we have added the following two factors in the pedagogical dimension: the Learning Factor and the Evaluation Factor.
As far as the learning factor is concerned, that is, the process of acquiring knowledge, skills, values and attitudes, enabled by studying, teaching or experience, all digital educational content is expected to be planned and divided into various levels of knowledge, always starting at the lowest level of complexity. In every lesson, the content covered should be clearly connected to each other. What is more, the interaction with the trainee should take place through questions and answers related to the presented content.

Table 2: Pedagogical Dimension.

Dimension	Factor	Requirements
Pedagogical	Learning	- Contents must be hierarchically and sequentially planned. - Contents must be divided into several knowledge stages, always starting in the least complex stage. - Contents, the core of the course unit, must reflect the best scientific or pedagogical evidence available concerning the subjects to be handled, and must be internally coherent, i.e. the considered subjects have to be clearly linked and interconnected. - In each lesson/video class the interaction with the participant/attendee must be considered by including content-related questions directly addressed to the participant/attendee. - A course unit must provide constructive feedback. - A course unit must be prepared for participants with different profiles/disabilities.
	Evaluation	- A course unit must provide problems to be solved in a short period of time. - The activities proposed in the course unit must consider the participants' collaborative work and skills. - The course unit must propose critical reflections about its contents and developed assignments. - The course unit must allow the participants to choose their path while attending it. - The course unit must promote interactions and foster team work. - The Special Education course units (deaf and blind) comprising specific scientific and pedagogical contents must be validated by experts in these fields.

Concerning the evaluation factor, a necessary and permanent didactic task in the course of all the work implied in the teaching and learning process, we consider that the proposed activities should be mainly supported by collaborative work and by the trainees' competence, promoting interaction and group work. Problems of immediate resolution with special impact in Special Education concerning the Blind will be proposed, highlighting the scientific and pedagogical domain of the contents specifically elaborated for visually impaired and blind people (table 2).

3.2 Ergonomics Dimension

The dimension referring to the ergonomics domain handles the scientific knowledge, its conception and the creation of equipment ensuring the full performance of a certain educational system, guaranteeing comfort and security (Wisner, 1987) (Santos and Fialho, 1995), i.e., ensuring the conditions that directly affect a learning scenario in its technical, ergonomics and social features.

In this quality scenario we have added the following factors to the ergonomics dimension: Usability, Video/Audio, and Text.

As far as the Usability factor is concerned, taking into account the specific target audience, complementary contents will be added, being structured to be intuitively and easily accessed. Each lesson will have audio available, which will allow the blind participant/trainee to get feedback in each lesson's discussion forum as well.

The second factor, Video/Audio, refers to the structure and organisation of the lessons: each lesson has to take 8 to 10 minutes, including a brief introduction to the structure. So that the blind may be included in this learning process, we consider that any reference included in the video, referring to images, graphics and animations, will be thoroughly considered in the audio descriptions.

Finally, the Text factor, which will be included according to a set of pre-established criteria inherent to the pedagogical model, considers the following items: clear title of the lesson, objective and appropriate to the contents. Every reference pointed out throughout the lessons have to be included in the lesson's bibliography items. Table 3 details the Ergonomics Dimension.

3.3 Technical Dimension

The dimension concerning the technical domain reflects the digital content quality regarding the functional factors. This dimension includes, among other factors, the following items: adaptability and content management.

Table 3: Ergonomics Dimension.

Dimension	Factor	Requirements
Ergonomics	Usability	- The participant must be able to start and conclude each lesson when he/she wi it. -The course unit must provide help through complementary material. -The lesson's complementary material must be of easy and intuitive access. -The course units must consider a uniform help pattern. -The course unit must have various audios available, compliable with participant's needs (including the blind participants). -The course unit must allow the participant to configure the audio. -The deaf must have access to the digital content by means of an auton bidirectional translator which translates the Portuguese written language intc Portuguese Sign Language. -The system must have an avatar to foster the interaction with the deaf participa -A help button must be available for the deaf/hearing impaired. -A help button must be made available for the blind/visually impaired. -The lesson must use color combination appropriately (accessibility). -The lesson must make use of visual resources such as images and icons, in ord help transmitting the content better. -The lesson must consider human perception, i.e, must be prepared for the div participants' physical abilities/capabilities (deaf/blind). -The course must enable the participant to receive feedback in a forum.
	Video/Audio	-The course is supported in digital video classes. -Video classes must have 8 to 10 minutes-length, corresponding to each lesson. -Each course unit must have a brief introduction to the lessons. -In the video edition, the use of images, graphics and animations must be specific prepared for the blind/visually impaired by a detailed audio description. -The audio is recorded in Portuguese. -The whole text is presented in linear and concise form. -The text included is written in Portuguese.
	Text	-The lesson title must be clear, objective and appropriate to the content. -The content must be written following the Portuguese spelling agreement. -Whenever references are used, these have to be included in the bibliography.

Table 4: Technical Dimension.

Dimension	Factor	Requirements
Technical	Content Technical	- Contents are created by a team of certified experts in the field of knowledge. - There is a previous and appropriate content planning to assure the courses homogeneous features. - Contents must be validated by the course unit's responsible teacher. - Contents addressing the blind/visually impaired must be validated by experts in the field. - Contents addressing the deaf/hearing impaired must be validated by experts in the field. - Contents must be certified by the appropriately certified entities.
	Adaptability	- The course is adapted to be attended by the deaf/hearing impaired by integrating the 3D avatar. - The course is adapted to be attended by the blind/visually impaired by audio analysis and processing.

The adaptability factor represents the MOOC capability of being adapted to different environments without the need for additional actions (the blind or visually impaired participants/trainees access content via audio).

The content management factor enables finding solutions to significantly simplify the creation, management, publishing, distribution and archive of digital contents, as detailed in table 4.

The ergonomics and pedagogical domains, regarding the human/machine relation are closely

linked, thus being possible to develop an evaluation system comprising these fundamental features in applying evaluation parameters to digital content.
When measuring the quality of a digital content it is necessary to evaluate the relative importance of each of the three dimensions – pedagogical, ergonomics and technical – in and for the environment where the content is going to be explored. The selected factors for each dimension, in the context of the present study-object, have been selected within the possible factors used to characterize these dimensions. The importance of selecting these factors and the inter-relation between them are crucial for the development, production and maintenance of digital contents in the system of the considered study-object.

4 CONCLUSIONS

This paper main objective was to detail the inclusive and innovating MOOC, focusing on the new pedagogical model developed to enable the blind/visually impaired individuals to access online digital higher education training content easily. Devising this inclusive and innovating MOOC model implies developing an application capable of converting text into sound, supported by the already developed model targeted at the deaf. It has been described that these models are combined, coexisting in the BDC-API, which simplifies access, content integration and adaptability while fostering inclusion. Contributing to enlarge the access to knowledge of visually impaired/blind individuals by devising a friendly-to-use system that may be fed and maintained by people with no programming knowledge and/or skills is the aim of the inclusive MOOC solution and architecture described in this paper.

Involving a multidisciplinary team of professionals, ranging from computer engineers to design, content producers and cooperative management, the inclusive MOOC has complied with every factor considered in the QEF dimensions. There is still room for improvement and further study, the following step is to get direct feedback from a considerable number of blind/visually impaired individuals after direct use of this inclusive MOOC model.

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