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INCLUSIVE INTELLIGENT LEARNING MANAGEMENT SYSTEM FRAMEWORK

Application of Data Science in Inclusive Education

David Sotto-Mayor Quaresma Machado

Dissertation

presented as partial requirement for obtaining the Master's Degree Program in Data Science and Advanced Analytics

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
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by

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Dissertation presented as partial requirement for obtaining the Master's degree in Advanced Analytics, with a Specialization in Data Science

Supervisor: Vítor Santos

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

David Sotto-Mayor Machado

Lisbon, October 15th, 2022

DEDICATION

This dissertation and the research that was conducted on the inclusion field is dedicated to all the students with disabilities that keep pursuing their academiic goals and dreams. For all of these lads and lasses the author wishes they can achieve the same happiness in academic success himself was given the opportunity to feel. Through his academic carreer the author expects to take every chance to research digital accessibility that may benefit all students including those with some disability.

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ABSTRACT

Being a disabled student the author faced higher education with a handicap which as experience studying during COVID 19 confinement periods matched the findings in recent research about the importance of digital accessibility through more e-learning intensive academic experiences. Narrative and systematic literature reviews enabled providing context in World Health Organization's International Classification of Functioning, Disability and Health, legal and standards framework and information technology and communication state-of-the art. Assessing Portuguese higher education institutions' web sites alerted to the fact that only outlying institutions implemented near perfect, accessibility-wise, websites.

Therefore a gap was identified in how accessible the Portuguese higher education websites are, the needs of all students, including those with disabilities, and even the accessibility minimum legal requirements for digital products and the services provided by public or publicly funded organizations.

Having identified a problem in society and exploring the scientific base of knowledge for context and state of the art was a first stage in the Design Science Research methodology, to which followed development and validation cycles of an Inclusive Intelligent Learning Management System Framework. The framework blends various Data Science study fields contributions with accessibility guidelines compliant interface design and content upload accessibility compliance assessment. Validation was provided by a focus group whose inputs were considered for the version presented in this dissertation. Not being the purpose of the research to deliver a complete implementation of the framework and lacking consistent data to put all the modules interacting with each other, the most relevant modules were tested with open data as proof of concept.

The rigor cycle of DSR started with the inclusion of the previous thesis on Atlântica University Institute Scientific Repository and is to be completed with the publication of this thesis and the already started PhD's findings in relevant journals and conferences.

KEYWORDS

Digital Accessibility; Intelligent Learning Management System; Data Science; Affective Computing; Recommender System

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LIST OF ABBREVIATIONS AND ACRONYMS

AI Artificial Intelligence

AIS Adaptive Instruction Systems

ANN Artificial Neural Network

API Application Programming Interface

AR Augmented Reality

ASR Automatic Speech Recognition

AWS Amazon Web Services

BCI Brain-Computer Interfaces

BSL Brazilian Sign Language

BVI Blind and Visually Impaired

CedMA Customer Education Management Association

CHI Computer-Human Interface

CNN Convolutional Neural Network

CBMT Corpus-Based Machine Translation

CPDF Cross-Platform Development Frameworks

DGEEC Direção-Geral de Estatísticas da Educação e Ciência

DGES Direção-Geral do Ensino Superior

DL Digital Libraries

DSR Design Science Research

EBMT Example-Based Machine Translation

EDMS Electronic Document Management System

EEG Electroencephalogram

EU European Union

FER Facial Expression Recognition

FIT Framework for Instructional Technology

HE Higher Education

HEI Higher Education Institution

HMT Hybrid Machine Translation

ICF International Classification of Functioning, Disability and Health

ICT Information and Communication Technology

ICIDH International Classification of Impairments, Disabilities, and Handicaps

II Intelligent Interfaces

IoT Internet of Things

IT Information Technologies

ITS Intelligent Tutoring System

K-NN K-Nearest Neighbors

LMS Learning Management System

LO Learning Objects

LSI Learning Style Index

MIT Massachusetts Institute of Technology

ML Machine Learning

MOOCs Massive Open Online Courses

MVLR Multivariate Linear Regression

NMT Neural Machine Translation

NLTK Natural Language Toolkit

OER Open Educational Resource

POU Polytechnic Organic Units

PRISMA Preferred Reporting Items for Systematic reviews and Meta-Analyses

PSL Portuguese Sign Language

RBMT Rule-based Machine Translation

RF Random Forest

RLO Reusable Learning Object

RNN Recurrent Neural Network

SARs Socially Adaptive Robots

SEN Special Education Needs

SEO Search Engine Optimization

SLO Shareable Learning Object

SMT Statistical Machine Translation

SSMI Severe Speech and Motor Impairment

STEM Science, Technology, Engineering and Mathematics

TTS Text-to-Speech

UD Universal Design

UDII User-Driven Intelligent Interfaces

UDL Universal Design for Learning

UX User Experience

VR Virtual Reality

W3C World Wide Web Consortium

WCAG Web Content Accessibility Guidelines

WHO World Health Organization

1. INTRODUCTION

1.1. BACKGROUND / RESEARCH CONTEXT

The relevance of inclusion in higher education can be inferred from the number of articles published on the topic, percentage of population that has some kind of disability and the growing legal framework regulating it worldwide.

In mid-February of 2021 near fifteen thousand scientific articles had been written about inclusion that year as indexed on Google Scholar. Nearly 1.5 million articles were written over the last ten years which proves the interest of the scientific community. Searching more specifically for articles focused on inclusion, education, and disability, 6750 were indexed in the first six weeks of 2021 on Google Scholar, 612 thousand articles over the past ten years.

In education, globally, there is a shift toward more inclusive universities and toward the access of minority groups, as students with disabilities (Lipka et al., 2019). Researchers claim the presence of disabled students in higher education is an established reality, and so the pedagogic methods and materials need to be revised (Cavendish et al., 2020). Yet, recent studies indicate some governments still resist to the inclusion of disabled students mainly due to: i) historical reluctancy to involve in familiarly concerns and decisions; ii) the lack of funds to spend in anything other than basic educational needs; iii) still some resistance to acknowledge the benefits of educating students with disabilities (Yates, 2020).

Worldwide there are concerns regarding the transition to adulthood of young individuals with disabilities, marked by the milestones of graduating from high school, attending higher education and signing a professional full-time contract (Cheatham & Randolph, 2020). In the United States of America, e.g., the last census in 2020 showed that more than 12.2% of total people had some kind of disability, 6.6% for people aged between 18 and 34 (United States Census Bureau, 2020). In Portugal this concern can also be perceived in current governmental policies and most recent legislation although Decree Law 54/2018 still marks the disabled student's legal framework with admittedly integration policies and regulations that are focused on getting the student through the mandatory education cycle, characterized by many adaptations of to the course contents and objectives, as opposed to inclusive measures that reduce the student's handicap and actually prepares them for progression into higher education (Presidência do Concelho de Ministros, 2018a). Still, Portugal's Ministry of Science, Technology and Higher Education places the promotion of accessibility of citizens with disabilities to higher education and knowledge (students, teachers and non-teachers and researchers) as a nuclear objective, setting as an objective for the General Board of Higher Education (DGES) website's inclusion section - *Balcão IncluIES*, the promotion of cooperation and information exchange between different Higher Education Institutions (HEI) regarding support provided to students, professors and researchers (DGES, 2021). And yet, Portuguese General Board of Education and Science Statistics (DGEEC) reports that in the school year of 2021/2022 there were 2779 students with disabilities enrolled on a higher education program in Portugal, which represents an increase of 7.1% over the amount of students enrolled in the previous year (DGEEC, 2022). The same report indicates there was a decrease of 20.1% of school abandonment cases in comparison to the previous year.

In 2021 the adaptations to the learning process that benefited most students that received some adaptation at all (54%) were extra time to conclude their evaluation methods (38%), special evaluation epochs (25%), class attendance regime (6%) and physical spaces adaptations (5%) (DGEEC, 2021a). The adaptation of pedagogic materials consisted mostly of receiving these materials in some digital format (76%), and between those that did not benefit from this policy (46%), most did not need it according to their disability (51%), but still, 21% of the students was unaware this benefit was available, 12% didn't receive it despite having applied for it, and 7% didn't have that adaptation available on their HEI.

As results from different researches the professors have admitted having training and knowledge limitations regarding disability and inclusive education which prevent them from offering students with disabilities the best learning (Helena Martins et al., 2017; Moriña et al., 2020; Smith et al., 2019). Smith stresses that despite the growing positive attitude towards disability, unwillingness to adapt content is still a barrier to disability inclusion in education. Martins corelates this unwillingness to the lack of information and training.

Through the research that preceded this work, the author assessed that 66.67% of the inquired higher education professors never prepared their pedagogic materials considering the possibility of teaching a student with a disability related to sensory functions or learning capacities (Sotto-Mayor Machado, 2021). Over 60% of the inquired professors confess needing specific training before they feel ready to teach a student with a sensory or mental functions disability. This study revealed the accessibility of the pedagogic materials was frequently mistaken for their availability in educational online platforms like Moodle. In that research the author identified the current work as one of the opportunities of future research. Being the author a disabled person himself, it is his desire to put Data Science's capacities to use towards the inclusion of students with disabilities.

1.2. Motivation

The development of digital libraries (DL) in HEIs is an ongoing discussion in the scientific community. Recent research studied from the feasibility of implementing one in the University of Tehran, Iran, where the lack of investment is blocking it, despite the readiness of students to interact with a system of the kind (Varnaseri & Bayati, 2021), to more technical concerns like the critical factors to take into consideration when managing the life cycle of Information Technologies (IT) related contents (Paletta, 2020). On Massachusetts Institute of Technology (MIT), the Openware project promotes the share of pedagogic materials for blended learning methods (online and face to face) (Luna et al., 2021). That study emphasizes the complementarity of both methods while also introducing the flipped learning methodology where students are invited to access digital media, read some materials made available on a platform and participate in some online learning exercise or evaluation moment. The COVID 19 pandemic reinforced the interest and the urgency to research the usage of digital libraries in blended learning contexts (Marbán et al., 2021).

Only recently have the usability of digital libraries been focused, namely by a research that studied the linking of help-seeking situations of blind and visually impaired (BVI) people in digital environments to the usefulness of help features offered (Xie et al., 2020). The study made a theoretical contribution to the field of library and information science by offering a broad understanding of BVI experience while interacting with DL and made a practical contribution by describing some help mechanisms that will boost the information research capacities of a DVI.

Other studies focused on the institutional, legal, and attitudinal barriers to the accessibility of university DLs and its implications for retention of disabled students (Oswal, 2017), heuristics proposals for the evaluation of DL accessibility (Jaeger, 2018).

As for the application of recommender systems the students are used to interact with in streaming services (Wang et al., 2018) or e-commerce (Lee & Hosanagar, 2019), it's implementation is well documented (Singh, 2021), even in the context of DLs (Collins et al., 2018; Porcel Gallego et al., 2017).

The professors are used to promote their pedagogic materials through Learning Management (Moodle, e.g.) to a stricter audience like their own students. On some occasions these materials are made publicly available without author's consent or knowledge (Scribd, 2022).

To the best of this dissertation author's knowledge no studies have yet been published presenting a digital library originally engineered while focusing on the needs of students with different kinds of disabilities. Yet, the trend for digital libraries seems to have been surpassed by the usage of Learning Management Systems even before the COVID-19 pandemic increased the pressure to increase the adoption of e-learning.

Hence the motivation for this research is to return the initiative to share the pedagogic materials with other students and professors to the authors themselves, while making possible the automatically adapted reproduction of these materials to students with different disabilities using the media format and accessibility criteria that best fits their condition. For that purpose the authors needn't be experts in every kind of disability, but simply to comply with European standards for digital accessibility which is a legal requirement in most public or private but public funded higher education institutions. Considering that most private higher education institution receive some sort of public funding such as European or national research grants it is safe to admit most higher education institutions are required to comply with the European Accessibility Act.

1.3. Research Problem

There is a gap between existing knowledge, guidelines, standards and law and the digital accessibility practices applied by most Higher Education Institutions what causes difficulties for students to use the learning platforms and to find accessible content.

1.4. Research Goal

The research goal will be to develop a technological artifact tending a need identified in society and contributing to the base of knowledge, theoretically by taking a step forward in relating the needs implicated by each kind of disability to the adequate digital accessibility criteria and practically by providing a technological artifact that effectively addresses these needs.

The outcome of this research is a conceptual framework for education that allows different types of students to access resources adapted to their disabilities.

Additionally, the framework will also be used to boost the resources available, incrementing the share between the educational community (students & teachers).

To achieve this goal, the following intermediate objectives were defined:

1. Identify the different disabilities profiles and its needs;
2. Identify the recommended criteria for building resources for each profile;
3. Define guidelines for the conversion of the educational resources into adapted resources (for the different target audiences);
4. Develop the framework for an Inclusive Intelligent Learning Management System with a recommender system and the capacity to offer different media output to each user considering his needs;
5. Validate the artifact.

2. METHODOLOGY AND MATERIALS

Hevner's Design Science Research was chosen as the research methodology that better fitted the purpose of this study: the production of an artifact that would promote the inclusion of everyone in higher education, focusing on students with special education needs.

Therefore, a not only the main goal of the research is to produce a technological artifact, but the environment study allowed identifying a social need to address and the exploration of the knowledge base done on the previous chapter facilitates knowing the state of the art and identifying a gap to explore.

2.1. Design Science Research (DSR)

The Design Science Research (DSR) has been generating knowledge on how to build innovative solutions to important problems in the form of models, methods, constructs, and instantiations for nearly twenty years now (vom Brocke et al., 2020), a little more, considering the artificial world paradigm was introduced in 96, when Herbert Simon states that the events are consequent to human will, unlike on the natural world where it is accepted and analyzed what is and happens in nature (Simon, 1996).

Alan Hevner, motivated by the lack of research into how information systems are developed, or on the processes of developing information systems, focused on the research process used in the development of information systems and technologies, naming it Design Science Research (Hevner et al., 2004; Hevner & Chatterjee, 2010). For the author, any product or process has an underlying design, but it is important to identify the way in which a rigorously developed design becomes itself research with scientific rigor. It focusses the relevance of identifying an important problem or opportunity in the business or community environment, but also on the rigor that determines the existence of a knowledge base, both descriptive and prescriptive, that provides an understanding of the state of the art regarding possible solutions to this problem. This allows the researcher to be able to prove that he has developed something new and original for the scientific field, putting his design into practice on the ground, but also contributing to increase the knowledge base through rigorous evaluation techniques. Therefore design knowledge links problem and solution spaces by means-end relationships (vom Brocke et al., 2020).

The concept of design can be approached as a noun, in which it represents constructs, models, methods and instantiations, but also as a verb, because it is something that is done, therefore, it creates and also evaluates (Hevner & Chatterjee, 2010). Finally, it can be defined as a problem, both by what originates it, as well as by all technical factors, and by the different human capacities and experiences necessary to achieve the objectives.

- Noun
    - Constructs: Intangible ideas and concepts, but used in the design of the system;
    - Models: A representation of the world in which the system will be used;
    - Methods: Ways of using the product in a real environment;
    - Security: The systems that are effectively built. The tangible output of the project.

- Verb
    - Create;
    - Evaluate.

- Problem
    - Unavoidable requirements and constraints;
    - Complex interactions between components of the problem and the resulting components of the solution;
    - Inherent flexibility to alter artifacts and processes;
    - Dependent on human cognitive abilities (creativity);
    - Dependent on human social capacities (teamwork).

2.2. Implementation of the Research Methodology

The author's experience as a student with special education needs, his interaction with inclusive NGO's and the enquiry of higher education professors in before cited previous research allowed identifying the social need: There lacks an accessible online repository of adapted pedagogic materials. The search for related work in governmental sites led to unavailable or inaccessible platforms and the professors revealed being unable to adapt their own pedagogic materials in case of a creating sensory disabled student enrolls on their classes. This is the authors interaction with the environment from where a need is identified and where the artifact to be produced shall be applied.

The literature review conducted in the previous chapter is the knowledge base from which the author encountered the state of the art, the best practices, norms, and guidelines to implement a solution, but most important how can this research innovate either creating something new or exploring the application of some of the state of the art or trending knowledge to a new context. Upon concluding the research, either with positive findings or finding that the artifact isn't a solution for the problem identified those findings will become a contribute ti the knowledge base, for the author's future research, and for the academic community in general.

The artifact will be a framework addressing the need identified, applying the assessed base of knowledge, designed with the knowledge and skills obtained in the master program that this thesis is expected to conclude.

Figure 1 exhibits the Design Science Research model applied to the nature of this research.

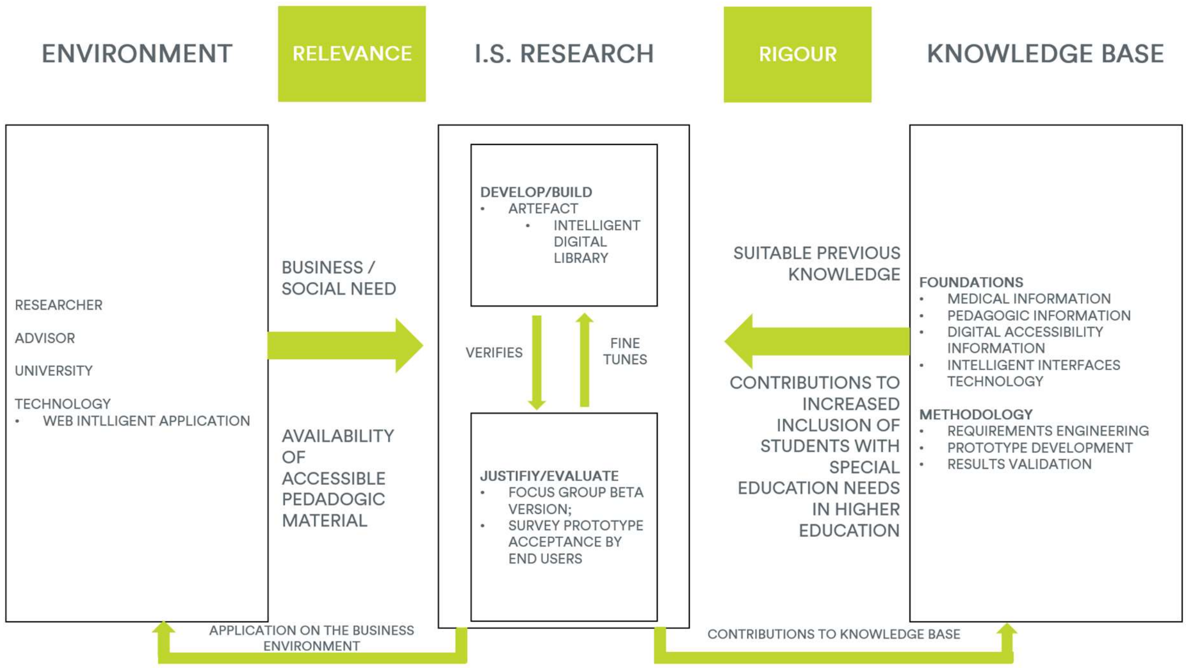

Figure 1 – Applied Design Science Research Framework, adapted from (Hevner et al., 2004)

Hevner lists 7 guidelines for scientific research in information systems. If a given research fails to observe one of these guidelines, then it fails being considered scientific research, being perceived by the scientific community as a consulting issue rather than valid research. These 7 guidelines are:

1. Design as an artifact: The DSR shall produce a viable technological artifact in the form of a construct, model, method or instance;
2. Problem Relevance: The goal of DSR is to develop technology-based solutions to important and relevant business problems;
3. Design evaluation: The usefulness, quality and effectiveness of a design artifact should be rigorously demonstrated by well-executed assessment methods;
4. Knowledge base contributions: Effective research into DSR should provide clear and verifiable contributions in the areas of design artifact, design foundations and/or design methodologies;
5. Thoroughness of research: The DSR is based on the application of rigorous methods both in the construction and evaluation of the design artifact;

6. Design as a research process: The search for an effective artifact requires the use of available means to achieve the desired purposes, satisfying the rules of the problem environment;
7. Research Communication: Design science research should be presented effectively to both the technology-oriented and management-oriented audiences.

Hevner also lists 5 groups of research evaluation methods. These are the methods by which artefacts can be evaluated and justified as the product of scientific research:

1. Observational
    a. Case Study: In-depth study of the artifact in the business environment;
    b. Field Study: Monitor the use of artifacts in various projects;
2. Analytical
    a. Static Analysis: Examine the artifact structure for static qualities (e.g. complexity);
    b. Architecture Analysis: Artifact study adjustment in IS technical architecture;
    c. Optimization: Demonstrate ideal properties inherent to the artifact or provide limits of optimization in artifact behavior;
    d. Dynamic Analysis: Study artifact in use for dynamic qualities (e.g. performance);
3. Experimental
    a. Controlled Experience: Study the artifact in a controlled environment to test its qualities (e.g. usability);
    b. Simulation: Perform artifact with artificial data;
4. Tests
    a. Functional Test (Black Box): Run artifact interfaces to discover flaws and identify defects;
    b. Structural test (White Box): Perform coverage tests of some metrics (e.g. execution paths) in the implementation of the artifact;
5. Descriptive
    a. Informed argument: Use knowledge base information (e.g. relevant research) to build a compelling argument for the usefulness of the artifact;
    b. Scenarios: Build detailed scenarios around the artifact to demonstrate its usefulness;

The researcher must follow the 7 guidelines presented in table 4, only thus qualifying his work as scientific research carried out under this methodology.

Table 1 - Design Science Research Guidelines, adapted from (Hevner et al., 2004)

Guidelines	Description
Relevance of the problem	Not only describe the problem but justify its relevance. Is it a theme for which there is a clear interest of the scientific community? If there is no prior investigation, is it a problem with a significant impact on your environment?
Accuracy of research	Not only should state-of-the-art research be exhaustive in order to describe it as in more detail as possible, but all sources should be properly identified.
Design as a research process	When the objectives to be achieved are identified, methods are designed to ensure this. However, it is important to assess the compatibility of these methods with the problem environment, ensuring their applicability, or identifying feasible changes to the rules and procedures in which the process will be carried out.
Design as an artifact	The research should result in an instance of the artefact developed, enabling it to be tested. It is appropriate at this point to make its description.
Design evaluation	The artifact should be tested and evaluated, reporting the methods used and their results.
Contributions to the knowledge base	How research contributes to the knowledge base, whether by design, the methodologies used, or the results achieved by evaluations.
Research Communication	The communication of the investigation, in form, e.g. of an article, it shall contain information relevant both to potential users of the system and to the scientific community that can replicate the methodologies developed in other contexts, solving other problems.

These seven guidelines are ever present in this research from its conception and planning throughout its execution, validation, and communication.

2.3. MATERIALS

The research doesn't include a full implementation of the framework, nor does it include the collection of data that would reflect its impact on a sample of students. However the author felt necessary to implement some of its functionalities, namely those closer related to the field of Data Science. For that purpose, data was the issue at hand, so public datasets were used, even if diverting from the implementations proposed by the dataset authors, taking different feature engineering options, or testing and choosing the Data Mining, Machine Learning or Deep Learning model that best suited each goal.

2.3.1. Students' results prediction based on learning management system usage

A dataset presented by a group of Malaysian and Oman researchers (Hasan et al., 2021) reflects the results of students (pass or fail) based on biographic data and Moodle and eDify usage. Their "final Dataset" consists of 326 observations and 21 features, including the target categorical feature.

The feature engineering detailed in the article excludes the personal or identity data of the students involved in the study anonymizing them. Still an ApplicantName label remained in the final dataset, even if generic with every record being unique. That feature was dropped on the model implemented in Annex II, along with "Segment" which had a strong Pearson correlation with "Played".

The article doesn't detail a data analysis process after the data-cleaning and pre-processing leading to the published dataset. The authors of the dataset state the purpose of the dataset is for other researchers to study the performance of students while using learning management systems.

Being impossible during this dissertation to prototype and pilot an implementation of the framework Annex I exhibits an implementation of a predictive model of students success based on their Moodle usage data. It does not represent the effects on students with disabilities but prototypes a model that can be tailored to field data to be obtained on future studies and the implementation of this framework.

The model follows the necessary dataset pre-assessment of data, even while the dataset is detailed in the article. Some additional pre-processing and cleaning were performed as mentioned before. It was followed by splitting dependent and independent features, encoding these features, and one-hot encoding categorical data. The dataset was then split into training, testing and validation subsets (60%, 20%, 20%).

This dataset was trained in a logistic regression model with different levels of KFolding and it was proven to reach effective predictions with 20 kfolds. Having proven the predictiveness of students' performance based on their LMS usage it is expected that implementing a similar model in the framework can produce analogous results.

3. LITERATURE REVIEW

3.1. Theoretical Overview

3.1.1. Education and Special Needs

With this section the author aims to describe the special educational needs inherent to the different types of disability. For that purpose, it is considered important to find a worldwide accepted definition of impairment, disability, and handicap, for which the World Health Organization (WHO) is considered, being the world's authority in matters related to health. Following up this distinction the different needs inherent to different disabilities are identified in the educational context.

In Portugal the number of students with Special Education Needs (SEN) registered in schools keeps growing, although in Higher Education (HE) it is still a very small percentage of the population when compared with the total number of students in Higher Education Institutions (HEI) (M. Martins et al., 2018). According to a governmental survey cited in that study, the percentage of students with SEN in Portuguese HEI is about 0,36%. That wouldn't be an issue if disability really affected that few people, but nearly 10% of the population lives with some kind of disability. A dramatic fact is that only about 1% of the high school students with SEN will attempt to continue their studies in a HEI. These authors state that latest initiatives to assure disabled students had physical access to HE classes and digital access to the contents had little impact because different disabilities require different but integrated approaches. They also stress the relevance of the adoption of technology, in particular systems design. These authors realize currently there is a lack of answers and solutions to allow SEN students to attend HE in an inclusive manner. They conclude that as consequences:

- The majority of the students with SEN will not apply to HE;
- A significative number of students with SEN that get accepted into a HEI will drop out shortly after;
- Only a very small percentage of the students with SEN attend HE.

The authors stress the necessity of encouragement actions and measures to enable SEN students to attend, and successfully conclude HE.

Being a SEN student himself, the author of this thesis adds from personal experience that besides the SEN students that reach the age and time in their lives to decide to apply for HE programs there are also the students that start those programs without any disability and suddenly find themselves hospitalized and disabled with no access to any information on how to continue to pursue their life goals. Despite there is a governmental site with most of the necessary information (DGES, 2021) it's inexistent search engine optimization (SEO) configuration makes it useless for a student with freshly acquired SEN unable to find urgent information until he finds, if he ever returns to his HEI, that such site exists. Having no data available to generalize, looking at his experience as a case study, the author can only state that personally, believing there would be some small chance of resuming his studies was the motivation he found to endure treatments and to adapt to become able to do things a little differently than before.

3.1.1.1. Impairment, Disability and Handicap

The concepts of impairment, disability and handicap must be defined before any classification system is adopted and the special needs inherent to different clusters of disabled students.

In 1980, the World Health Organization (WHO) presented the International Classification of Impairments, Disabilities, and Handicaps (ICIDH), distinguishing these three concepts (World Health Organization, 1980).

According to ICIDH an impairment is any loss or abnormality of psychological, physiological, or anatomical structure or function. It is characterized by temporary or permanent loss or abnormal change, including anomaly, defect or loss in a limb, organ, tissue, or other structure of the body, including mental function systems. An impairment represents an external pathology and, usually, reflects disturbances at the organ level.

The same classification defines disability as a restriction or lack of ability to perform an activity of the form or within the range considered normal for a human being, resulting from an impairment. It is characterized by excesses or deficiencies of performance and activity behavior usually expected, and may be temporary or permanent, reversible, or irreversible, and progressive or regressive.

Disabilities can arise as a direct consequence of a disability or as a psychological reaction of the individual to a physical, sensory, or other disability. Disability represents disturbances at the level of the person and concerns activities and behaviors that are generally accepted as essential in daily life.

Finally, the ICIDH defines the handicap of a given individual resulting of an impairment or disability, which limits or prevents the performance of a normal role for the individual, considering age, gender, and sociocultural factors. The handicap is related to the value associated with the situation or experience of an individual when he/she deviates from the norm and is characterized by a difference between the performance or status of the individual and the expectations of the individual or the specific group where he/she is part. The handicap thus represents the socialization of an impairment or disability, and as such reflects the cultural, social, economic, and environmental consequences for the individual.

Disability Classification

This dissertation is compliant with World Health Assembly Resolution WHA54.21 (World Health Organization, 2001b) by which member states are urged to use the International Classification of Functioning, Disability and Health (ICF) in their research, surveillance and report.

To describe these needs, it is important to provide a theoretical framework in advance, setting the definitions of the underlying concepts as accepted by the scientific community.

International Classification of Functioning, Disability and Health

This classification organizes the information in two parts, on a first level, each containing two components that may include one or more domains that reflect one or more constructs (World Health Organization, 2001a):

1. Functionality and Disability
    a. Body:
        i. Functions of organic systems: physiological functions of body systems (including psychological functions). Seeing, e.g.;
        ii. Structures of the body: the anatomical parts of the body, such as organs, limbs, and their components;
    b. Activities and Participation:
        i. Activity is the execution of a task or action by an individual and is limited by the difficulties an individual may have in its execution.
        ii. Participation is the involvement of an individual in a real-life situation, and is limited by problems that an individual may face when involved in these;
2. Contextual Factors:
    a. Environmental Factors: constitute the physical, social and atheist environment in which people live and lead their life;
    b. Personal Factors: the background of an individual's life, comprising individual features that are not part of a health condition or a health state.

As these constructs do not have one-to-one relationships with each other, the ICF is flexible enough to model the functioning or disability of each individual recurring to near infinite combinations of these constructs such that for example an individual may:

- have impairments without having capacity limitations (certain impairments may not imply an handicap);
- have performance problems or capacity limitations without evident impairments;
- have performance problems without impairments or capacity limitations (e.g. stigmatized or discriminated people as result of a previous condition from each they are currently cured);

- have capacity limitations without assistance, and no performance problems in the current environment (e.g. people with mobility to whom society provided assistive technology mitigating or suppressing their handicap);
- experience a degree of influence in a reverse direction (e.g. muscle atrophy due to inactivity or social skills reduction after institutionalization).

To study the special educational needs of students with different disabilities this research will focus on the impact on the *Learning and Applying Knowledge* (learning, applying the knowledge that is learned, thinking, solving problems, and making decisions) and *Major Life Areas – Education* () chapters of the *Activities and Participation* component of the ICF by disabilities affecting each of the eight Body Functions enumerated by this classification:

1. Mental functions: the capacity to retain consciousness, energy and drive, and specific mental functions, such as memory, language, and calculation mental functions. This category is perceived by the higher education professors as one of the functions they mostly need training before teaching a student with one of these disabilities (Sotto-Mayor Machado, 2021);
2. Sensory functions and pain: functions of the senses such as seeing, hearing, tasting, as well as the sensation of pain. This is the group of functions that along with the previous one more concerns the higher education professors, both being perceived as placing bigger challenges to the learning and applying knowledge activity and participation (Sotto-Mayor Machado, 2021);
3. Voice and speech functions: functions of producing sounds and speech;
4. Functions of the cardiovascular, hematological, immunological, and respiratory systems: functions involved in the cardiovascular system (functions of the heart and blood vessels), the hematological and immunological systems (functions of blood production and immunity), and the respiratory system (functions of respiration and exercise tolerance);
5. Functions of the digestive, metabolic and endocrine systems: functions of ingestion, digestion, and elimination, as well as functions involved in metabolism and the endocrine gland;
6. Genitourinary and reproductive functions: functions of urination and the reproductive functions, including sexual and procreative functions;
7. Neuromusculoskeletal and movement-related functions: functions of movement and mobility, including functions of joints, bones, reflexes, and muscles. This is the group of functions that most frequently occur among the students in higher education in Portugal (DGEEC, 2021b; Sotto-Mayor Machado, 2021);
8. Functions of the skin and related structures: functions of skin, nails, and hair.

It will be necessary to explore ICF’s second level of classification as arguably a disability on a different body function may or may not affect the learning and applying knowledge activity and participation, as on the other hand different sensory functions will imply different needs like completely different accessibility criteria.

The complete listing of second level ICF classification of body functions may be consulted in Appendix 8.1. Body Functions.

As for the Activities and Participation component, the Major Life Areas chapter, Education section includes informal, preschool, school, and higher education as well as vocational training or other specified or unspecified education.

Disability, Special Education Needs and Special Education

Today, when disability is studied in the context of education, the trend is to observe it within a social and cultural context (Baglieri et al., 2011). Through this perspective, more than drawing a regression from a classification by type of disability and severity of impairment to predict the chances of success for a student with special educational needs, it is a much broader analysis that goes from the impairment to the handicap, and from the disability to the functionality and activity participation. Which is a tendency already observed in the evolution from WHO's ICIDH classification into ICF.

The cited authors identify two major approaches to the special education: incrementalist and reconceptualist, each different from the other in five dimensions, detailed in table 2, and debate if both polarities are mutually exclusive.

Table 2 - Incrementalistic or Reconceptualistic Approaches to Special Education, adapted from (Baglieri et al., 2011)

Dimension	Approach	Characterization
Conceptualization of disability	Incrementalistic	The medical condition determines a deficit inherent to the individual, which must be cured, accommodated, or simply endured.
	Reconceptualistic	Frames the physiological aspects of the impairment in a social context that gives it meaning.
The role of special education	Incrementalistic	Change the individual enhancing his performance.
	Reconceptualistic	Accept the importance of enhancing individual performance but focus on changing environmental barriers or limitation.
	Incrementalistic	Special education adapts and readies the individual to a postschool world.

Dimension	Approach	Characterization
Expected outcomes of special education	Reconceptualistic	Creates a caring society that accepts human diversity and rejects labeling and stigmatization of individual.
State of knowledge about the practice of special education	Incrementalistic	The field's course is set, and its practices are promising.
	Reconceptualistic	The is still an inadequate and insufficient base of knowledge.
Necessary steps to improve special education	Incrementalistic	The teacher's work is defined by solid scientific research that made available technical application of interventions and strategies specific to each type of disability.
	Reconceptualistic	Demands more self-reflective, ethical decision-making responsibilities from the teachers.

Baglieri describes the distinction of impairment and disability in education in a much similar way to what WHO has been doing since the ICIDH classification.

Finally, Baglieri dismisses any incompatibility between both approaches' followers as they share common ground in the most fundamental values regarding inclusion: the full equality, the pursue of educational arrangements and teaching practices in order to reach the greatest extent of participation and the elimination of segregation and isolation.

As Baglieri the author of this dissertation believes in a reconciled approach where the physiological aspects of each disability will require different accessibility criteria, not to change the individual but to reduce his functional handicap in the educational process. The disability is taken as *ceteris paribus*, assuming it to be irreversible, focusing on fitting the pedagogic materials with accessibility criteria that will reduce an existing functional handicap.

Florian & McLaughlin edited a set of contributions to the discussion over the advantages and pitfalls of disability classifications in the educational systems (Florian & McLaughlin, 2008). This book covers from hot discussions over the fairness and efficiency of allocating resources for the benefit of a minority when these are scarce for the general needs of the educational systems, to the segregation effect of those labeled as disabled, or with special needs, or even the effectiveness of the classification systems being used. On the positive side this book allows the reader to perceive the strength in the positive aspects, such as targeted accessibility criteria or even the specialized training of teachers towards special education needs. Training programs to prepare teachers to deal with and teach students with blindness or deafness exist since the early twentieth century, and as society became more aware that people with disabilities can study, and so, the technology and legal frameworks soon evolved into a more humane and inclusive reality, or, at least, intentions. From late twentieth century, as informatic and communication technologies became more available for a growing part of the population so did the capacities to keep up with the classes increase between those sensory impaired or even with some learning disability.

Moretti, Alves & Maxwell conducted an exhaustive systematic literature review on the usage of ICF in the education field and concluded that although at the time this classification wasn't given many attention in education related publication it showed a great potential to become a reference framework for such studies (Moretti et al., 2012). Overall it already was a reference in other fields mostly being cited regarding the activity, participation, and environmental factors, providing a standardized language.

Finally, a study by Alkahtani also results in a literature review that comprehends definitions of disability, special education, special education needs and types of disabilities and their implications related to educational processes (Alkahtani, 2016). This author tracked the first mentions of SEN to the eighteenth century when scientist studied the education needs of individuals with specific types of disabilities, mostly deafness. These children tended to be segregated or institutionalized but it was the advent of democratic ideals from the American and French revolutions that boosted the cry for their right for an education like any other child. By the nineteenth century special education needs would include people with cognitive impairments. The term itself has been frequently used and commonly associated to the needs to overcome the handicap of people with some physiological, mental, emotional, or social disability.

Today the discussion around the term addresses how dignifying the "special" emphasis is, or not, and while some claim it to be diminishing, others defend that the term is far less aggressive than previous ones like disabled, handicapped or even mentally retarded. The special education comes as an umbrella concept that gathers all the different special education needs.

3.1.2. Accessibility and Inclusion Technologies

The importance of the role of people with disabilities and special needs in society is a trending subject of discussion, even if the needs that must be covered to allow them to fulfill that role haven't been covered over time (Arias-Flores et al., 2021) and much of the work undergoing today still addresses this population and the identification of the needs to cover, or even the ethics behind allowing the technological and scientific progress to produce advances on the digital transformation of the lives of people with or without disabilities (Burukina et al., 2019).

People whose disabilities manifest in adulthood are usually computer literate and intelligent interfaces have an immense inclusive potential over their everyday lives enhancing their communication and participation in society (Betke, 2010).

Still, depending on the disability typology that affects each, reading a screen, viewing an image, listening to a podcast, or perceiving the audio or the visual content of a video, having the required dexterity to control a keyboard or a mouse, or being able to issue voice commands can be a different issue for each one, on a case-by-case basis.

3.1.2.1. Concepts

Intelligent Interfaces

Henry Lieberman has been a frontperson for Intelligent Interfaces (II) which he defines combining the contributes of Artificial Intelligence (AI) and Computer-Human Interfaces (CHI).

The need to add intelligence to every day's interfaces arise from the growing complexity of these, that not only work with other interfaces but are too inflexible themselves and do not change when the user's needs change, or when faced with users with needs that are different between them.

To reach a definition Lieberman splits the concepts into the two words that phrase it (Lieberman, 2003):

- Intelligence: Computers demonstrate intelligence when they present a human-like behavior while solving problems in ways humans would not be able to do mechanically. While human intelligence is supported by affective, thought, and behavioral mechanisms, some of them occurring consciously, other at the sub-conscient level, it would be unrealistic to expect an interface to exhibit human-like intelligence, but still, they do show reasoning and inference, and some have domain-specific knowledge or procedures enabling the performance of useful tasks while learning through interaction with their users and adapting to context;
- Interface: It is the means by which the machine interacts directly with the user through the input and output of communication devices or indirectly affecting the user's environment (e.g., room temperature control).

Therefore, an interface is considered intelligent if or when it can adapt to the needs of different users, learn new concepts and techniques, anticipates the needs of the user, and takes the initiative to make suggestions to the user or even being able to explain the actions it is taking at each moment.

More than a concept definition this will be a guideline throughout this research, as if it directly states how can this research problem be solved.

Considering the different needs from the people using such an interface it will need both natural language and graphic interfaces strengths, ideally making the best use of different input and output mechanisms for different users.

The problem at hand imposes a systematic approach as it cannot be solved by adding more advanced technological features such as increased screen definitions, faster processors, or networks. Nor can it be solved by the AI paradigm alone (Lieberman, 2009).

From the HCI perspective the intelligent interface must provide the clearest experience in the most efficient manner, offer the best support for the user's goal, plans and tasks, present the information in the most effective fashion. Design and implementation will raise problems that will be ultimately semantic, as they address how the human and the machine derive meaning from each other's outputs.

Affective Computing

In 1988 Marvin Minsky raised the question of what is the mind, and how does it work (Minsky, 1988).

He dared to challenge the "unified self" to describe the mind as a system and bureaucratic hierarchy, composed of individual "agents", or active components, which are specialized by functions such as listening or seeing. He would call this system the *Society of the Mind*.

This Society is described as a corporate-like structure with a hierarchy of agents where the higher levels supervise lower-level agents not necessarily being aware of the specific functions these perform and with agents from different functional areas not having direct contact between them, but still being able to inhibit other's activities. This may seem inefficient at a first reading, but it is the opposite as direct contact between all the agents of the mind would result in a circuit overload or even crash.

Minsky describes the existential doubt as the mind is unable to capture its own essence, whose nature is permanently mutating. So, grasping for one's essence would be as a man catching fish with his bare hands, as once it seems to be within grasp it will slip away.

This self-awareness of man is quite limited so one cannot function and observe oneself functioning at the same time as it would overload the intellectual capacity of the mind.

While this essence of the mind may be undefinable, Minsky dismisses the common dichotomy between the physical and the intellectual planes. So, unveiled the not so mysterious relationship between body and mind, the later ends up being defined as simply what brains do, comparing brains to machines with enormous amounts of parts working under physical laws. Mind may be an intrinsic process that takes a whole lot of experience to be understood, but it would not inhibit Minsky of prophesying the creation of a machine at the image of man.

While braving the path for AI, Minsky at one-point states that “The question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without emotions”

Picard would later claim we have evidence that emotions are an active part of intelligence, especially perception, rational thinking, decision making, planning, creativity, etc. These prove to be so critical in social interactions, to the point where psychologists and educators would have re-defined intelligence to include emotional and social skills (Picard, 2000). Picard states a computer can’t become humanoid without affective abilities.

Still the affective computing cannot be *“emotional”* only, as it would lead a machine to behave unreasonably or infantile at best. So, one cannot talk about affective computing without considering logical reasoning abilities together with affective skills. Making an affective artificial intelligence requires as much emotional intelligence as will a human counterpart.

Ultimately, an affective computer should have the skills to recognize its user's affective expressions, and to respond intelligently if the user indicates frustration, fear, or dislike of something; and to be able to change that user’s emotion.

This affective behavior is desirable on a pedagogical support system enabling the machine to make affectively acceptable suggestions to the user, besides basing them on rational only criteria such as content, context, and accessibility.

There are multiple recent applications of affective computing in interfaces directed to users with mental functions disabilities (Johnson et al., 2020; Rudovic et al., 2018), visual impairments (López-Hernández et al., 2019), or to students in general (Umematsu et al., 2019), and even more specifically to analyze the emotions of people with or without learning disabilities when using virtual learning environments (Ouherrou et al., 2019). These studies will be considered as a knowledge base for this research.

This theoretical overview provides scientific insights on the social need addressed in this research and introduce some research trends that may be relevant to propose a solution for the research problem. Still, the researcher needed a wider knowledge of the state of the art to identify not only what has already been developed and can be of use but also the possibilities raised by the scientific community as possible future research.

One article stood out methodology wise as it presented the implementation model of Hybrid Neural Networks for Facial Expression Recognition (FER) tasks (Jain et al., 2018). Being no news that Artificial Neural Networks are vastly used in the computer vision field, with some predominance of Convolutional Neural Networks. These authors stress that Deep Learning have long surpassed hand-engineered features, so huge datasets of labeled facial expressions now a days allow the accurate identification of five facial expressions: Anger; Sadness; Fear; Happiness and Sadness.

These authors present 6 Convolutional Layers. The first 5 with 8, 16, 32, 64 and 128 filters of size 5x5. Each of these layers is followed by Max-Pool. A last Convolutional Layer has 256 filters of size 3x3 and is followed by Average Pool All convolutional layers have two fully-connected layers and 200 hidden units.

There is, still, much concern in the medical scientific community regarding the facial expression recognition of people with mental disabilities (López-Hernández et al., 2019; McAlpine et al., 1992; Memisevic et al., 2016) as most author state the difficulty to recognize these people's emotions. The medical authors focus on this people real-life struggle to express their emotions and even to understand other's expressions. The thesis author couldn't find any article about the application of Deep Learning to automate facial expression recognition of people with disabilities.

Universal Design

A concept credited to Ronald Lawrence Mace since 1985 (Mace, 1985), himself an architect, product designer and scholar who had a mobility disability.

Speaking of usability three concepts arise (Livramento da Silva et al., 2019): effectiveness (achieving the goals), efficiency (the effort it took to achieve those goals), and satisfaction (how suitable the product felt and the comfort experience while pursuing those goals. These authors cite the following principles of usability: Consistency; Compatibility; Considering user resources; Feedback; Visual clarity; Error prevention and recovery; User control; Clarity of operation; Functionality and information priority; Appropriate technology transfer. The same authors relate Inclusive Design and Universal Design as both depend on functionality (the products must do what hey are expected to), usable (it mustn't frustrate some users or totally exclude others), desirable (aesthetic, status, positive impact), basically viable (a combination of the previous three characteristics).

Mace extended the concept from the architectural domain to computer labs, curriculum, educational software, instruction, libraries, professional organizations, registration options, science labs, student housing and residential life, websites, and other student services (Story et al., 1998). This book enumerated the North Carolina University Center for Universal Design's 7 Principles:

1. Equitable Use: The design is useful and accessible for a vast diversity of individuals, considering abilities, disabilities, ages, racial, and ethnicities;
2. Flexibility in Use: The design suits a diversity of preferences and abilities;
3. Simple and Intuitive Use: It's easey to use and understand the design regardless of the user's experience, knowledge, native or foreign language skills, or even current concentration capacity;
4. Perceptible Information: The design communicates the information effectively to the users independently of present environmental conditions or own user's sensory abilities;

5. Tolerance for Error: The design is resilient to user's unintended misusage of the product minimizing such actions impact and possibly having the option to revert them to a previous state;
6. Low Physical Effort: The design must be usable with minimum effort and maximum comfort efficiently reducing consequent fatigue;
7. Size and Space for Approach and Use: The product must be deployed in a way that the user can approach and use it independently of their body size, posture and mobility.

Universal Design is currently a trending topic in higher education related research (Coffman & Draper, 2022), It's application to teaching computing science and engineering (Sanderson et al., 2022), it's usage since the COVID pandemic (Dickinson & Gronseth, 2020). Over the last five years more than 200 000 publications were made on this topic.

Cross Platform Development and Accessibility

Applications development has evolved from multi-platform binary distribution (apps compiled for different operating systems, whether desktop, laptop or even mobile into the web development paradigm (Corral et al., 2012). According to Corral, this works by using the web browser as an intermediate level of abstraction, allowing the logic layer to be implemented using a scripting language (e.g., JavaScript) and the presentation layer to be implemented using HTML and CSS, making it portable across different web browsers, operating systems, and types of hardware devices. With the advancements in mobile technology, creating and marketing a successful application had become a difficult task. It was important to remember that there were numerous platforms (Android, iOS, Windows Mobile, Blackberry, Harmony OS, etc.) each with a large number of users that could be potential clients for each app. By creating for a single platform, developers were excluding a large number of users. Conducting the entire development process for a single application for each platform, on the other hand, would eventually become redundant, costly, and impractical. Not to mention the desktop versions for Windows, Mac OS, Linux, etc., or even the specific server binary applications.

According to Corral, mobile development had progressed from hardware-specific software to high-level platform operating systems with the introduction of smartphones, each with its own set of benefits and solutions. Each one, however, had its own set of standards, programming languages, SDKs, and distribution channels. If a developer wished to publish his app on more than one platform, he would need to translate the original source code to the appropriate platform, as well as to adjust APIs and low-level implementations so that the new target could support the app in the same way as the original. The application should then be rebuilt in order to receive the right executable code. In 2012, in order to enable real cross-platform development on mobile devices, operating systems were unable to fully utilize the device's capabilities and offline performance needed to be improved. So Corral identified the challenge of developing a software product wrapped as a native program that could be rebuilt multiple times to run on various operating systems. That would allow web applications to function as full-featured applications even when they were not connected to the internet. Broadband would allow developing more complex applications.

In 2020 Rieger would find that accessible cross-platform mobile apps have gotten insufficient attention from researchers and practitioners and proposed identifying unique difficulties, needs, and solution strategies for mobile apps versus traditional web development (Rieger et al., 2020). Despite the fact that organizations such as the W3C and the WAI provide substantial rules in the domain of web accessibility, surveys of websites in many domains demonstrate that the majority of websites follow fewer than half of the top-priority guidelines. Despite finding developers don't follow most of the existing guidelines they end up proposing their own set of principles, guidelines, and requirements for accessible mobile development, and then a Model-Driven Process where techniques are presented as means to fulfill those requirements. One of the author's main conclusions is that even if model-driven approaches are well suited to validate and partially automate the design of accessible mobile apps without adding additional load to developers, future research might focus on how to use that approach to advance the state of the art in accessibility engineering.

Although Rieger presents cross-platform development frameworks (CPDF) like Apache Cordova, Xamarin or React Native he points that these have no major accessibility concerns, leaving up to the developers the task of finding solutions for each platform, Mascetti proves exactly that assessing the availability of screen reader API functions in each CPDF concluding that these fail to provide an interface with different operating systems generally available accessibility features (Mascetti et al., 2021).

In conclusion, CPDF may offer efficient cross-platform development but fail to facilitate the implementation of effectively inclusive applications.

3.1.3. Legal and Standards Framework

In European Union digital accessibility is ruled by the European Accessibility Act (The European Parliament & The Coucil of the European Union, 2019) and implemented by the European Standard EN 301 549 (European Telecommunications Standards Institute (ETSI) et al., 2021) where compliance with the European Web Accessibility norm is leveled by W3C WCAG 2.1 Level AA (W3C, 2018). This is the minimum compliance level to be observed by all public organizations or those who benefit from public funding in the EU.

Directive EU 2016/2012 is transposed to Portuguese Law System by Decree Law 83/2018 (Presidência do Concelho de Ministros, 2018b, p. 2)

ISO/IEC 40500:2012 (International Organization for Standardization, 2019) sets WCAG 2.0 as a worldwide standard.

World Wide Web Consortium (W3C), the authors of the WCAG guidelines recommend using always the latest version available of WCAG, and although these haven't been made mandatory by law the most recent versions available are:

- 2.2 (Working Draft) since May 2021 (W3C, 2021a);
- 3.0 (Working Draft) since December 2021 (W3C, 2021b)

This research will always consider version 3.0.

3.1.4. Digital Learning Resources and Learning Objects

In European Union digital accessibility is ruled by (The European Parliament & The Coucil of the European Union, 2016), the European Accessibility Act (The European Parliament & The Coucil of the European Union, 2019) and implemented by the European Standard EN 301 549 (European Telecommunications Standards Institute (ETSI) et al., 2021) where compliance with the European Web Accessibility norm is leveled by W3C WCAG 2.1 Level AA (W3C, 2018). This is the minimum compliance level to be observed by all public organizations or those who benefit from public funding in the EU.

The term Learning Objects (LO) is credited to Wayne Hodgins when in 1994 he named a Customer Education Management Association (CedMA) workgroup as *"Learning Architectures, APIs, and Learning Objects"*. Per Laverde, content, learning activities, and context elements are all internal and editable components of a digital self-contained and reusable entity with a defined educational goal. To aid their identification, storage, and retrieval, learning objects must have an external structure of information: metadata (Chiappe Laverde et al., 2007).

To provide a larger reach to users, computer-based learning systems have evolved into web-based learning systems during the previous few decades. As a result of this evolution of global access to high-quality learning resources, an entire industry has sprung up around e-learning systems to ensure re-usability, interchangeability, and a method for intellectual property owners to secure their intellectual property (Apoki, Al-Chalabi, et al., 2020). These authors relate the transition from computer-based learning systems to web based learning systems with the uprise of adaptive environments. An adaptive environment, according to the authors, is a platform that combines soft and hard technologies with the goal of improving users' learning experiences through adaptation. Adaptive Hypermedia Settings, Collaborative Learning Environments, and Simulative/Immersive Environments are examples of such environments.

Adaptive Hypermedia Environments (AHEs) aim to offer learning content in a way that is tailored to the user's educational background, interests, and preferences. Simulative/Immersive Environments (through a set of predefined rules) change according to user actions, whereas Collaborative Learning Environments provide a method of group learning where learners improve their knowledge by sharing complementary ideas, whereas Simulative Learning Environments (through a set of predefined rules) provide a method of group learning where learners improve their knowledge by sharing complementary ideas. The bandwidth available today enables the massive consumption of digital learning resources like text, audio, graphical pictures, photos, videos, simulations, animations, learning objects, programmed learning modules, and other digital learning materials. LO started as an object-oriented programming approach to solving the problem of non-reusable open and distance-learning (ODL) content.

A LO isn't just a piece of text, a graphic, or an audio or video clip; it's everything that goes into making a learning object. It is not a subject-specific course curriculum; rather, LOs are grouped into courses. Reusability, modularity, interoperability, portability, and an instructional objective are all significant qualities of ideal LOs by definition. The authors distinguished between a reusable learning object (RLO) and a shareable learning object (SLO). They described an RLO as having educationally sound content, a clear objective, and the ability to be used on a learning platform as its core qualities. An SLO is also an RLO, with adequate metadata to interface with other learning platforms. The adaptation of LOs can be motivated by learner's preferences; status and history; learning medium parameters; pedagogical/domain parameters. The authors review some models of adaptive learning objects that befit this research's objective: an adaptive solution to provide multi-modal access to learning materials for students with much diverse preferences and capacities.

3.2. Systematic Literature Review

3.2.1. Approach

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021) was chosen as rigorous and widely accepted methodology to screen the most updated and relevant literature available about a broad topic unbiased to the author's own ideas on what to search.

Such methodology allows screening from a wider range of search results for a set of keywords applied to one or more scientific databases or repositories to a narrower list of items to be reviewed. This screening process consists of automated steps, such as eliminating duplicate results from different sources or filtering items older than a set age, or published on a strict set of languages, or by publication type, or ranking to an increasingly shortened list tapered by human screening of titles, keywords, and abstracts. As opposed to the theoretical overview, the author won't be searching for specific studies but pooling what is available

This review should answer two main Research Questions:

Table 3 – Systematic Literature Review Research Questions

Question #	Question
RQ1	What technologies have been successfully deployed to develop accessible intelligent systems for students with different disabilities?
RQ2	What emerging technologies have become available to develop more accessible intelligent systems?

Scopus, Science Direct, Web of Science, IEEEXplore and Springer were considered as databases for the systematic literature review.

Table 4 exhibits the queries executed in each database and the results obtained in each one.

Table 4 – References Obtained on April 13th 2022

Database	Query	Results
IEEEXplore	"All Metadata":Intelligent System* Accessibility; 2018-2022; Journals or Conferences	198
Science Direct	Title, abstract or author-specified keywords (Intelligent System Accessibility) Year (2018-2022)	76
Scopus	TITLE-ABS-KEY (intelligent AND system* AND accessibility) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))	315
Springer	Intelligent System* Accessibility, Articles (Artificial Intelligence, Computational Intelligence, User Interfaces and Human Computer Interaction) or Conference Papers (Artificial Intelligence, Information Systems Applications, User Interfaces and Human Computer Interaction), Englis, 2018-2022	1504

Database	Query	Results
Web of Science	TS=(Intelligent System* Accessibility) AND PY=(2018-2022) AND LA=(English) AND DT=(Article OR Proceedings Paper) AND WC=("Computer Science, Artificial Intelligence" or "Computer Science, Information Systems" or "Computer Science, Theory Methods" or "Computer Science, Interdisciplinary Applications" or "Computer Science, Software Engineering")	62

Prisma methodology was applied to screen the references retrieved from the databases. Figure 2 depicts the screening flow and the criteria applied in this systematic review.

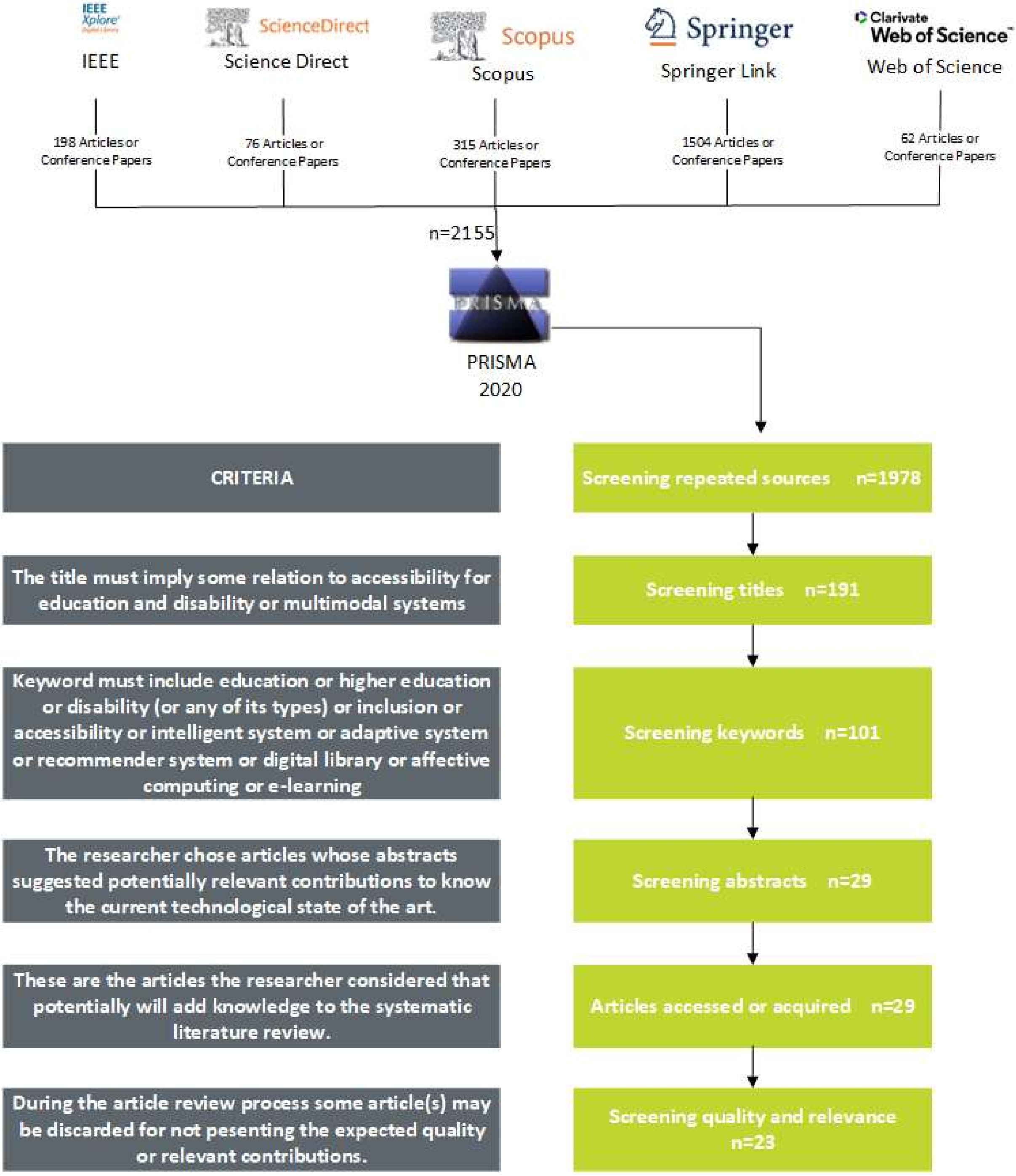

Figure 2 - PRISMA Flow Diagram, adapted from (Page et al., 2021)

3.2.2. Results

The 29 references retrieved (before reading the articles) were studied and clustered in 10 categories presented in Table 5.

Table 5 – Review Studies Theme

Category	Articles
Higher Education Accessibility	2
Web Accessibility	2
Adaptive Systems	6
Affective Computing	1
Universal Design for Learning	1
Assistive Technology for people with Down Syndrome	1
Assistive Technology for People with Functional Disabilities	1
Assistive Technology for People with Hearing Disabilities	3
Assistive Technology for People with Visual Disabilities	2
Assistive Technology for People with other Disabilities	4

3.2.2.1. Higher Education Accessibility

One article, while assessing the accessibility of American Universities identified some issues that can be perceived globally (Chen, 2018):

- Increasing Demand and Expectation: Among the most common requests for accessibility at universities are:
  - Courses: browsing its course catalog, registering, paying, attending classes, being assessed, and obtaining credits;
  - Activities: include participation in student events, residential life, campus activities, and student organizations;
  - Public programs: access to its libraries, public areas, building, and amenities, as well as public lectures and events.

    - Research: Participation in studies and dissemination of findings;
    - Administrative work such as computers, dining, financial, transportation, facilities, HR, security, and administrative assistance to keep the university running.
- Content and tools: Content management systems or learning management systems are used to distribute this digitized content. These publishing platforms relieve users of the need to understand the technical aspects of web page creation, allowing them to focus on the content of their publication. To make matters worse, universities produce a significant amount of Science, Technology, Engineering and Mathematics (STEM) content, which is notoriously difficult to make accessible and necessitates the use of specific Accessibility support pages. Libraries also purchase equivalently inaccessible materials from other universities and academic journals to promote research and teaching. The usage of multimedia, interactive learning modules, and developing technology is another factor that contributes to accessibility concerns. While many of them fail in the market, some gain enough traction to be adopted for use as university activities, and it is only then that universities learn that these tools exclude a segment of the population. Faculty frequently need to employ time-sensitive content that they did not develop, like as articles, media feeds, online video, discussion forums, and social networks, in our interconnected society. These materials keep students interested and involved in their studies. Many of these content makers are not required to deliver accessible content, and even when they are, the delays cause disruptions to the class schedule.
- Knowledge and Skills: Higher Education is not alone in its lack of accessible knowledge. Silicon Valley software firms have determined that for every 5,000 technical employees, they had five accessibility specialists. Universities' primary information technology (IT) organizations draw from the same pool as the industry and have the similar distribution. Universities also have limited staffing flexibility due to:
    - a lack of funds to fully staff positions, so accessibility skills are either ignored or treated as a partial responsibility;
    - lower compensation, resulting in a smaller pool of qualified candidates;
    - lower turnover, resulting in a tendency to stick with outdated knowledge and processes;
- Policy and Practice: Accessibility compliance is relatively recent in comparison to other university functions. In addition, the university must devise a strategy for addressing current inaccessible content and software. Because accessibility affects so many aspects of a university system, including it into existing budgeting, procurement, production, publication, development, auditing, and reporting processes is necessary. Each of these injections needs identifying the suitable processes, persuading the appropriate individuals, obtaining financing, planning, and developing procedures, and training the required personnel.
- Culture: Formalization is a slow process. Changing the culture beneath the surface is considerably more difficult.

The article proposes a review of the business processes in higher education with short term measures (allocating institutional and national accessibility coordinators, creating preemptive accessibility policies, making web accessible complaint points to prevent escalation to NGOs lawsuits being filed, IT procurement) and long-term goals (structural change addressing the people, the environment, and the system, create a central accessibility information repository).

The article concludes there is a Business Process and organizational culture and structure issue to be addressed before any technological revolution.

Martins and others presented the “Smart Ecosystem for Learning and Inclusion” project that would make a generalized inclusion approach considering the entire diversity of disabilities (V. F. Martins et al., 2020). This project is a technical and pedagogical hub with a variety of tools and services to assist teachers in their roles of guidance, mentorship, and creativity, as well as students in their roles of information searching, construction, and learning. The project supports itself heavily on universal accessibility standards. Positioning itself as a learning ecosystem the project includes authoring services, learning and content management system services, and learning analytics services. This project considers the difficulty of providing all users of its ecosystem with the accessibility required for the suggested learning to occur autonomously, while respecting each user's variety and ensuring access to all available information material in its proposal. In order to ensure access, it is vital to consider the assistive technology available and the accessibility resources accessible. The project was based on the Universal Design for Learning notion of accessibility. The UDL approach is based on human diversity-focused design. The ecosystem that is considered in the teaching-learning process respects everyone's unique needs, promoting knowledge acquisition with autonomy, independence, and consistency. The entire process was guided by the importance of accessibility in the digital space, considering recommended technical standards and, in particular, the user experience, context, and conditions of the people who will use the tool, because only then can it be assumed to meet the unique needs of each user and be considered accessible.

From this project the thesis author will retain the multi-role (teacher / student) of the framework as a fresh approach that while thinking of enabling the students doesn’t ignore enabling the educators. A multimodal framework accessible for the entire diversity of disabilities must comply with universal accessibility standards and universal design for learning.

3.2.2.2. Web Accessibility

In the COVID context the usage of video contents on higher education (live and pre-recorded) increased as an alternative to face-to-face classes during confinement period (Acosta et al., 2020). Acosta state that by WHO estimates, 91% of the students worldwide were affected. But the video accessibility issues with Ivy League Universities come far back from at least 2015 when the American

National Association of the Deaf sued Harvard and the Massachusetts Institute of Technology (MIT) for lacking captions or providing caption with insufficient quality and even errors on their Massive Open Online Courses (MOOCs). An assessment of the web accessibility on videos published by the highest ranking universities in the world on YouTube clarifies the criteria for the A, AA or AAA compliance with Web Content Accessibility Guidelines (WCAG) 2.1 guidelines for audiovisual content, as shown on Table 6.

Table 6 – WCAG 2.1 Compliance criteria focused on web video players, Adapted from (Acosta et al., 2020) with criteria text from (*How to Meet WCAG (Quickref Reference)*, 2022)

Rating Level	Criteria

A	• 1.2.1 - Audio-only and Video-only (Prerecorded):
	  o “Prerecorded Audio-only: An alternative for time-based media is provided that presents equivalent information for prerecorded audio-only content”;
	  o “Prerecorded Video-only: Either an alternative for time-based media or an audio track is provided that presents equivalent information for prerecorded video-only content”;
	• 1.2.2 - Captions (Prerecorded): “Captions are provided for all prerecorded audio content in synchronized media, except when the media is a media alternative for text and is clearly labeled as such.”;
	• 1.2.3 - Audio Description or Media Alternative (Prerecorded): “An alternative for time-based media or audio description of the prerecorded video content is provided for synchronized media, except when the media is a media alternative for text and is clearly labeled as such.”
	• 1.4.2 - Audio Control: “If any audio on a Web page plays automatically for more than 3 seconds, either a mechanism is available to pause or stop the audio, or a mechanism is available to control audio volume independently from the overall system volume level.”;
	• 2.1.1 – Keyboard: “All functionality of the content is operable through a keyboard interface without requiring specific timings for individual keystrokes, except where the underlying function requires input that depends on the path of the user's movement and not just the endpoints.”;

Rating Level	Criteria
	• 2.2.2 - Pause, Stop, Hide: There must be a mechanism to pause, stop or hide content that starts automatically, lasts more than five seconds, or features auto-updating information, either being presented in parallel with other content.
AA	• 1.2.4 - Captions (Live): “Captions are provided for all live audio content in synchronized media.”; • 1.2.5 - Audio Description (Prerecorded): “Audio description is provided for all prerecorded video content in synchronized media.”; • 1.4.3 - Contrast (Minimum): “The visual presentation of text and images of text has a contrast ratio of at least 4.5:1”; • 1.4.4 - Resize text: “Except for captions and images of text, text can be resized without assistive technology up to 200 percent without loss of content or functionality.”
AAA	• 1.2.6 - Sign Language (Prerecorded): “Sign language interpretation is provided for all prerecorded audio content in synchronized media”; • 1.2.7 - Extended Audio Description (Prerecorded): “Where pauses in foreground audio are insufficient to allow audio descriptions to convey the sense of the video, extended audio description is provided for all prerecorded video content in synchronized media.”; • 1.2.8 - Media Alternative (Prerecorded): “An alternative for time-based media is provided for all prerecorded synchronized media and for all prerecorded video-only media.”; • 1.2.9 - Audio-only (Live): “An alternative for time-based media that presents equivalent information for live audio-only content is provided.”.

Acosta seem to have misinterpreted the 1.4.4. criterion regarding resizable text as they relate it to resizing captions which is explicitly excluded from the criterion.

W3 criteria page (*How to Meet WCAG (Quickref Reference)*, 2022) also describes the techniques by which each criteria can be complied with.

One of their most evident conclusions is the very low accessibility of the videos published by universities worldwide, mainly because they rely on the most commonly used, but still inaccessible platform. It is true that only 20% of the universities on Acosta's sample comply with Level A criteria, which YouTube fully supports. But YouTube only supports half the criteria for level AA (automatic captions) and absolutely none of the criteria for level AAA being the main reason for 0% of the universities complying with this level of WCAG 2.1 criteria.

A group of authors from the World Wide Web Consortium has published an article suggesting applying AI to evaluate Web Accessibility (Abou-Zahra et al., 2018). In context these authors cite examples of AI usage in inclusive devices like smart wheelchairs or blind canes, but they focus on the usage of AI techniques as Machine Learning (ML) and predictive analysis to improve the quality of voice and image recognition.

They present four categories of AI applications for Web Accessibility available today:

1. AI-Based Image Recognition: Microsoft, Google and Facebook among others have been presenting results in describing uploaded photos or images comparing them to catalogued similar pictures already uploaded to their services. As this bank of machine knowledge grows while users upload and catalog their images the grater accuracy these tools can achieve;
2. AI-Based Voice Recognition: Abou-Zahra cites YouTube's automatic captions as an example of this technology. Being an article published before the COVID pandemic these authors hadn't met Microsoft Teams and Zoom's auto captioning of live meetings and their potential not only to make remote and even live classes more accessible for students with hearing impairments but also for someone with less language skills being able to automatically-translate classes or videos for other languages;
3. AI-Based Text Processing: Natural text processing advances made possible auto-summarization allowing students with learning disabilities to extract key points from long texts, to paraphrase for a simpler vocabulary or to link them to glossaries and dictionaries;
4. AI-Based Affective Computing: Microsoft Cognitive Services now offer an Emotions Application Programming Interface (API). Education-wise providing an Intelligent System with Artificial Empathy or Emotional Intelligence cam have a positive impact;

However the technology still faces limitations such as accuracy (still insufficient in image recognition for Abou-Zahra at the time the article was written); accountability (replacing a human sign language interpreter with an AI translator transfers the accountability of correct translation from a translator to an algorithm), sensitivity (raises concerns about privacy, security and even safety of people with disabilities;

Abou-Zahra stressed that despite the advances in AI these still don't discard the need for standards like WCAG. For them, the emerging technologies like Augmented Reality (AR) and Virtual Reality (VR) and their emerging presence on the Web will present bigger challenges for web accessibility as simple text alternatives are not sufficient to describe virtual reality scenes as these will need to describe scenes from the perspective of the viewer. There is likely to be needed the usage of AI techniques to solve this problem. AI can also become used to detect accessibility issues during web development predicting insufficient usability for users with certain disabilities.

3.2.2.3. Adaptive Systems

Apoki proposed an adaptive e-learning system with enough parameterization to offer the student a curriculum tailored to his particular needs (Apoki, Ennouamani, et al., 2020). The model proposed by these authors has the following architecture:

- Learner Model: Stores information about the user, which includes personal information and other features which can be used for personalization;
- Domain Model: Repository of all learning resources, tutorials and assessments, tests or exams;
- Pedagogic Model: Provides an instructional approach by describing what learning content in the system can be altered and how it can be adapted, resulting in the generation of the best learning object and path for a learning scenario using the learner model's user data;
- Adaptive Model: This component keeps track of the learner's interactions with the system;
- Session Monitor: This data is utilized to update the learner model after each learning session, as well as to load the learner's next session. Following the evaluation, log data regarding the learner's activities, progress, and errors can be used to suggest effective paths for other users with comparable characteristics using machine learning techniques.

In the adaptation process the learning cycle begins with a user-system interaction in order to extract user information and preferences. Tests, forms, and questionnaires can be used to gather this information. The acquisition step of the adaptive learning process is the stage in which the information gathered is used to develop the user model. Next specified weights are used to represent the learner model's extracted preferences and attributes. The digital learning resources are then turned into learning objects with semantic annotation in the following step of the adaption process. The transformation of learning resources is required for reuse, system handling, and semantic mapping between user characteristics and learning objects. The process is illustrated in figure

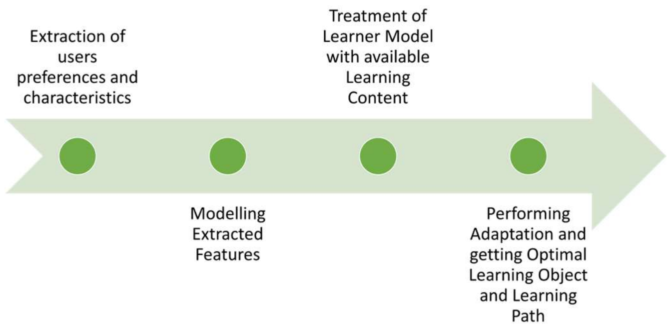

Figure 3 - Adaptation process, adapted from (Apoki, Ennouamani, et al., 2020)

This paper presented and adaptive e-learning system that accommodated users' preferences and abilities.

Another study aimed to identify some of the most promising trends in educational technology, as well as the capabilities supplied by it, and the settings in which these capabilities are used in blended learning implementations in higher education (Castro, 2019). Due to the rapid growth of technology in response to social needs, many issues have developed, and the current digital transformation has put additional stresses on higher education systems. The proposed framework aimed to help with the analysis and assessment of blended learning deployments in higher education by presenting educational technology capabilities as a different and cross-cutting notion. In a multilevel viewpoint study, this notion may aid scholars and practitioners in better understanding the nature of the link between technology, pedagogy, organization, and society in general. From a technological perspective the next generation of learning management systems (LMS), adaptable textbooks and Open Education Resources (OER), learning analytics, adaptive learning technology, digital device ownership and mobile learning, and learning spaces are all examples of digital trends in higher education implementations.

Emond tried to assess if formal human-computer interaction models can be applied to adaptive teaching systems (Emond, 2021). The author states that empirical methods for training system validation have predominated in the field of adaptive instructional systems in general, and intelligent tutoring systems in particular, rather than formal methods for verification. Empirical approaches are the most reliable source of data for determining a product's usability for a specific user demographic sample. Empirical methods, on the other hand, can be expensive to implement and must be used with a nearly complete product or as a method for continuous product evaluation. The validation of software features is the focus of inspection and empirical methodologies. These strategies address the question of whether a product is fit for its intended purpose. On the other hand, formal approaches are concerned with the verification of software features. Formal methods can be used to express design concepts including reachability, visibility, job completion, and reliability, and they can also be used to verify and validate interactive systems.

Emond defines Human-computer interaction as a series of state transitions produced by a combination of user and computer activities. None of these techniques explicitly describe human behavior; they can only be used to uncover system circumstances that are thought to be preconditions to system failures. These models can be described in temporal logic, where verifying a property entail examining all state spaces exhaustively to see if the statement expressing the property is true.

To Emond, adaptation is a crucial concept in many scientific fields, including life and human sciences. The idea originated in computer science as a way to deal with the increasing complexity of computer systems. The incorporation of machine learning components in computer systems, in particular, necessitates a new approach to adaptive testing for rigorous software engineering, particularly on the topic of adaptation-based quality assurance. A control loop is present in every essential building element in human–computer interaction. The closed-loop dynamic behavior or human-computer interaction is not captured by viewing the user interface as a form of stimulus-response contact with the user. The user's behavior will change as his or her skill level rises or as the computer interface evolves. On the surface, many computer programs appear to be adaptable. However, it appears that any conditional statement in a computer program might be deemed adaptive, which seems to expand the term.

Emond concludes that using formal models during system development is one way to improve the reliability of interactive systems. For the past thirty years, formal methods have been used to design and analyze human-computer interaction. Empirical methods for training system validation have predominated in the field of adaptive instructional systems in general, and intelligent tutoring systems in particular, rather than formal methods for verification. The final section detailed the similarities between HCI formal models and AIS standard modules, as well as several areas where HCI formal models can be applied to Adaptive Instructional Systems (AIS) design. Edmond's analysis was primarily conceptual and semi-formal, and more research into concrete use cases was admittedly required.

During Johnston's investigation, he learned that there has been little research into how machine learning algorithms may help with adaptable interface layout, user flow, usability, and usefulness (Johnston et al., 2019). His PhD thesis aimed to address the lack of a framework that enables a dynamic, adaptive, intelligent, and engaging user experience (UX). At least two domains, namely Education and Healthcare, were used to create and test the framework. Another factor to consider was the collecting of data parameters. Data collection could be done by sensors, microphones, or the user's pipeline of interactions and events recorded on cloud platforms like Amazon Web Services (AWS) ML, depending on the device. This would help with security and ML performance. Previous articles imply that User Modeling could be useful for storing parameters and better understanding the user; this is an area that needs more exploration. The framework engaged the user by presenting a demanding environment while also delivering a pleasurable and social interaction with the interface. Each user had a goal, and game features like feedback would drive successful involvement. At the time of publication testing was still planned as future research.

From the US Military perspective the challenge is finding in technology that what makes personalized instruction so effective (Durlach, 2019). This paper describes several AI approaches to AIS and their results and examines if AIS have succeeded in increasing learning outcomes going over why this might be and how to improve AIS effectiveness.

For Durlach, help can be provided in a variety of methods, each of which can be tailored to the learner. Almost all AIS have incorporated the mastery learning technique and provide learners with feedback on their performance when it comes to adopting these guidelines in technology. One important job of feedback is to assist students in comparing their own performance to what constitutes high performance, and to enable them to use this information to close the gap. Another adaptive technique that shows frequently in AIS is the scheduling of practice "trials," which comes from the psychology literature. Learning science has proven that learning experiences that are separated across time are more memorable than those that are crammed together.

The fundamentals of AIS implemented in adaptive learning systems is exemplified by Programmed Logic for Automatic Teaching Operation (PLATO). This guided a student through a set of topics by delivering facts and examples, followed by questions that covered the information. Students may retake the test as many times as they wanted, but they couldn't go on to new material unless they received a passing grade. If necessary, the student could request assistance by tapping a help button. The learner returned to the original question and had to answer it again after finishing each help branch or short-circuiting the assistance sequence by pressing a button. Teachers could develop content and questions directly on the computer, as well as review student information.

The paper presents the concepts of Macro and Micro-adaptations. Macro-adaptation adapts content before the instructional experience begins using pre-task measures or historical data. Mastery and Adaptation-as-Preference. A pretest specifies the starting point of instruction using mastery macro-adaptation, and previously mastered content, as indicated by the pretest, may be skipped. The customizing for both of these macro-adaptations occurs at the start of a learning session or learning topic. They might use a pattern of response errors, reaction latencies, and/or emotional state to spot student issues or misconceptions and intervene in real time. Micro-adaptive treatments can be used to address specific problems or to provide support in the form of hints or encouragement.

Durlach developed the Framework for Instructional Technology (FIT), which outlines numerous methods for employing digital technology to deliver mastery learning, corrective feedback, and assistance. Micro-sequencing and macro-sequencing as two independent components of mastery learning in FIT. When a certain mastery criterion has yet to be reached, micro-sequencing is used to select which learning activity should be performed next to promote mastery. There is no adaptation at the lowest level — all students are treated the same. The information used to activate a system's adaptive behavior becomes more sophisticated with each consecutive level. Adaptive levels of micro-sequencing have to do with how individualized the remedial content is, which is based on the granularity of the student model. The more detailed the student model, the more tailored the remedial content may be. Similarly, the macro-sequencing levels are determined by the student information utilized to establish the next topic's content. The adaptive curriculum allows students to pursue personalized, interdisciplinary learning with the help of an AIS. Feedback and support, in contrast to sequencing, serve to direct attention and aid memory and self-correction for the current learning task. The increasing FIT levels of adaptation for these are determined by how much of the learning context is considered when determining how feedback and support are delivered. Depending on the sort of error made, answer-based hints differ. Because it is dependent on the exact fault the learner committed at a specific point in time, FIT refers to this form of support as locally adaptive. To provide answer-based help, nothing from the student model has to be accessed. Context-aware support, on the other hand, requires information from the student model. Finally, Level IV expands on Level III's naturalistic interactive dialogue. One of the goals of FIT was to give instructional technology buyers a vocabulary to use when describing the features they want in future applications.

Durlach finds it's feasible that putting more effort into incorporating pedagogical content knowledge (how to teach a given area) into AIS intervention strategies will improve the effectiveness of the system. Bug libraries are the few AIS know to have included explicit representation of pedagogical content knowledge.

Durlach conclusions are that AIS is not a uniform category that can be classified as either "effective" or "ineffective." This is because AIS necessitates additional material and backend engineering, as well as the ability for various learners in a class to be at very different points in the curriculum. The choice to employ AIS also raises significant privacy and security concerns about how the learner data gathered will be used. Some have stated that the revelation of those facts to the instructor and maybe the learners themselves is a significant benefit of AIS. If the data can be presented in a way that is useful to instructors and learners, it may be possible for an instructor to change their training or for a learner to regulate their own behavior without requiring the system to use the data effectively for adaptive intervention. Further advances may allow AIS to become more consistently effective on its own.

Rerhaye considers that intelligent tutoring systems that incorporate serious games, intelligent agents in the form of chatbots, and other new applications promise significant benefits for tailored digital learning (Rerhaye et al., 2021). Due to the recent limits imposed by the Corona epidemic, versatile, intelligent learning systems have been developed. Intelligent functionalities stated being developed for learning platforms.

Rerhaye states that to deliver the optimum learning route and learning content to the student, an ILMS should enable features and tools including automation, mapping, scaffolding, mobility, reporting, and knowledge generation. Despite all of these features, Rerhaye considers critical that users have the flexibility to regulate their own learning and turn off AI to gain full access to all materials. The AI backend is in charge of deciphering the user's text input thus learning recommendations and individual content suggestions that fit the learner's needs. To best meet his needs and provide an effective learning experience, personalized learning paths can be automatically developed for each student based on characteristics such as existing skills and prior contact with the LMS, such as test results.

Learning paths, in combination with personalized learning recommendations, can help identify students falling behind and provide hints/learning objects to reduce the risk of failing a course. Learning analytics allows teachers to track students' overall or detailed development and performance in order to identify learning and comprehension gaps.

Regarding the evaluation of LMS, usability and UX should be considered as the foundation of an adaptive, user-centered system. If the usability and user experience standards are not met, it might have a negative impact on the AI functionalities' evaluation.

Rehaye advocates combining qualitative and quantitative evaluation approaches, as well as objective and subjective methods to evaluate LMS, determining the requirement and actual advantage of AI functionalities from a user centered perspective. So, LMS necessitates not just the use of engaging digital learning material, such as machine-readable texts, interactive exercises, animations, and videos, but also the usage of a learning management system tailored to these medium. There are interoperable standards and specifications for the various data formats to improve reusability.

3.2.2.4. Affective Computing

El Hammoumi states that in sophisticated e-learning systems, facial expression recognition is becoming increasingly crucial (El Hammoumi et al., 2018). Supporting students' emotional side while learning tasks, on the other hand, is difficult and requires an understanding of their feelings. For the author, although significant research has been done on facial expression recognition, there have been few practical studies into its application in e-learning systems, and effective solutions to address the involvement of emotions in learning are still lacking. El Hammoumi acknowledges a lot of study in the area of incorporating emotional awareness into e-learning systems. The author found in related work that Intelligent Tutorial Systems with affective feedback capabilities can send appropriate affective or cognitive signals to learners in response to their affective state detection, ensuring their emotional safety and engagement or persistence in the learning experience. His solution consists of a Convolutional Neural Network (CNN) trained on two publicly available databases (CK+ and KDEF). Processing this data requires three steps: Preprocessing (used OpenCV to detect and crop faces), feature extraction (TensorFlow layers in CNN) and Classification (CNN output).

The methodology and reference to the open datasets are key takeaway points from this article.

3.2.2.5. Universal Design for Learning

Toscano presents a systematic literature review on the potential contributions of HCI and Audiovisual Systems to Universal Design for Learning (UDL) (Toscano et al., 2019).

The authors start by defining audiovisual systems as the fusion of any software, hardware, and content components that make up an artifact in order to create solutions for entertainment, health, art, education, and a variety of other topics.

Through the systematic literature review the authors identify a common HCI strategy in which the development of artifacts in specific themes or scenarios is as important as the organization of knowledge, procedures, and standards in theories and methods to aid designers and developers. The item of methods and frameworks, on the other hand, is a more common solution. User centered design was identified as the prominent method to assist in the development of design and software.

The authors conclude that variance in representation and interaction interfaces is a way of ensuring to the public different forms of identification and engagement for the execution of some activity are another illustration of this relationship. Finally, they detected a trend of merging existing established discussions such as intelligent tutoring or smart learning, virtual learning environments, and video lectures can benefit audiovisual system production.

3.2.2.6. Assistive Technology for People with Down Syndrome

An article explored the feasibility and usability of assistive technology for the educational inclusion of people with Down Syndrome (Dratsiou et al., 2020). To contextualize Dratsiou mentions software like SynMax, a mathematics computer application program intended to help these users understand numerical concepts, provide accessible content for instruction or rehabilitation of certain skills. Although that technology may be targeted at children, Stella Software, an online tool tailored to adults with Down Syndrome has the goal of improving their cognitive and mental skills, includes a variety of exercises that incorporate visuals, text, and sound to create a richer learning environment. Dtrasiou stresses that besides the use of any assistive technology, meaningful collaborations and joint ventures between family and school are highlighted as critical factors in improving students' social and behavioral outcomes related to inclusion, with the success of these partnerships reliant on cultivating positive attitudes, sharing common ideas and expectations, and clear communication and trust among all involved stakeholders.

The main principle behind the framework proposed by Dratsiou is that memory can be reinforced if interaction with learning is conducted by involving and activating multiple senses simultaneously, such as visual, auditory, tactile-kinesthetic, and articulatory motor. That is supported by the multisensory principle, while the essential learning construction is achieved through personalization of intervention in accordance with students' performance. The Integrated Healthcare System Long Lasting Memories Care intends to create the groundwork for the creation of an integrated platform with components mostly focused on people with Down Syndrome. The memory game “Memorize-Image it!” as well as other interactive educational games and virtual scenarios were used in this framework.

People with Down Syndrome participated in cognitive training sessions by interacting with this assistive technology, and a multidimensional evaluation was conducted, focusing on both investigating the potential improvement of these people working memory performance and the correlation between educational feasibility and usability of the assistive technology introduced. Before and after their involvement in cognitive training sessions, participants were given Digit Span to test their working memory performance, which is associated to brain functions employed in registering, storing, and retrieving information. Participants improved their working memory performance significantly and the link between characteristics relevant to educational feasibility and usability of the assistive technology suggested was determined using Spearman's correlation analysis.

The findings revealed a substantial positive association between educational feasibility and usability variables, as well as between educational feasibility and usability variables.

The multisensory principle will be considered in any framework that this thesis presents given its impact on long lasting memory for this cluster of users.

3.2.2.7. Assistive Technology for People with Functional Disabilities

Gang outlines the possibilities for improved human cognition through immediate feedback via neurophysical pathways via brain-computer connection (BCI) (Gang et al., 2019). Gang has demonstrated that brain–computer interface technology can help people with functional disability overcome the limitations of currently existing user interfaces. BCI, when used in conjunction with other methods of AR engagement, can provide far more information than these interactions alone. Even now, coupled AR-BCI interfaces could deliver extremely adaptive and personalized services, particularly for those with functional limitations.

Consumer BCI systems come with varying numbers of Electroencephalogram (EEG) channels, forms of EEG connection to the human surface, and extra sensors, and their price is determined by their capabilities.

Gang Identifies some use cases of commercially available BCI:

- BCI for People with Visual Disabilities: The psychological states acquired by this gadget will change when a person is exposed to various external stimulators. In this situation, the online estimation of the automatic conversion of a visual geographic map into tactile form can be aided by the measurement of proper tactile contact via BCI feedback. In the future, this solution should be able to recognize user skills and detect behaviors, patterns, emotions, and intents in real-world situations. In this situation, a combination of technologies, such as machine learning and tactile engagement with BCI, will benefit from instant feedback based on actual neurophysical reactions classified by machine learning methods;

- BCI for Educational Purposes: Experiments reveal that the vibrotactile feedback is well received by the user, thanks to the revolutionary combination of vibrotactile actuators' wide range of frequency and amplitude vibration. The actual goal of this AR-BCI system is for the user to be able to view his or her own physical reactions to the zone of interest. This technique, which is built on a "physical" and "thinkable" object, must entice the user to investigate the zone of interest's invisible thoughts and ambiance;
- BCI for TV-Based Home Care: The SinceTV system, on which the iDTV technology is based, allows for the exchange of generalized data structures of many forms, such as interactive inquiries and responses, as well as values collected from sensors, electrical equipment, and various devices. For distributed applications, it can handle calls, events, and data synchronization. This technology, when combined with neurophysical data collected from users by BCI-devices in inherently interactive mode of operation, can enable elderly people communicate better with one other, families, caretakers, doctors, and social workers.

Gang concludes that in general, brain-computer interface combined with other forms of augmented interaction may provide users with far more information than these interactions alone. These quantitative measures cannot replace present techniques of evaluation and proactive activities in the context of home and health care for individuals with functional disabilities, but they can complement and enhance them. The suggested user-driven intelligent interface, which is based on multimodal augmented reality and brain-computer interaction, could be useful for the applications listed above. It has the potential to improve persons with disabilities' communication and interaction skills, as well as stimulate social innovation.

3.2.2.8. Assistive Technology for People with Hearing Disabilities

A team from INESC-TEC and Universidade de Trás-os-Montes e Alto Douro (UTAD) found the absolute necessity to provide sign language translation for deaf students (M. Martins et al., 2018) and stress the need to recognize Portuguese Sign Language (PSL) as a paralinguistic element that is vital to sustain the speaker's expressiveness, and the receiver's point of view and also the communication context. Sign languages are an entire community native language just as any other language or dialect.

These authors, before the pandemic outbreak saw telepresence robotics as an alternative to presential attendance to classes and defended the captioning and sign language interpretation of all recorded audiovisual content and the need of complementing their solutions as some terminology may not have direct sign language translation. The authors presented a solution where a student watching a class from home would receive audio and video feeds from the classroom and those attending face-to-face would be able to watch the sign language feed. Interestingly this was part of a remote class project that anticipated the pandemic scenario.

The difference from this solution to others is that it resorted to recordings of human sign language interpreters.

Kahlon provides a systematic literature review on the current state of the art on machine translation to sign language, covering 148 studies from 30 highly ranked journals (Kahlon & Singh, 2021). They identified a number of projects around the world, like TESSA, ViSiCAST, TEAM, ZARDOZ, SASL-MT and TGT.

Kahlon and Singh identified the currently available types of translations:

- Rule-based Machine Translation (RBMT): The linguistic information about the source and target languages is used in the RBMT technology. Rule-based systems use morphological, syntactic, and semantic analysis of both the source and target languages to construct output sentences from source language sentences.
- Corpus-based Machine Translations (CBMT): Is created from the multilingual text. Though RBMT systems can provide accurate translations, building the entire RBMT system is a time-consuming effort because language resources must be produced, and new rules must be added to the system on a regular basis. CBMT systems, on the other hand, rely heavily on multilingual information. CBMT systems, often known as data-driven machine translations, can be divided into three groups:
    - Example-Based Machine Translation (EBMT): EBMT is trained using bilingual parallel corpora with sentence pairs from both languages;
    - Statistical Machine Translation (SMT): Is based on Bayes Theorem's first approach to probability distribution. Statistical translation, unlike RBMT, does not involve the development of manual rules, and, unlike EBMT, is not suitable for small corpora and is only effective with large bilingual corpora;
    - Hybrid Machine Translation (HMT): These systems combine many machine translation technologies into a single machine translation system. The failure of single machine translation systems to attain appropriate accuracy has necessitated the development of a hybrid machine translation system;
- Neural Machine Translations (NMT): To forecast the likelihood of a sequence of words, an artificial neural network is used. They use less memory than SMT systems, and they don't have separate language, translation, and reordering models; instead, they have a single integrated model. It does translations using deep learning and representation learning.

The implementation that would be the most adequate to a multimodal digital library would be the 3D Avatar of which Kahlon and Singh name a few examples as implementations of Sign Synthesis.

Garcia proposes an avatar automatic translates to and from LIBRAS, the Brazilian Sign Language (BSL) (Garcia et al., 2021). The described architecture is divided into three levels: the formal model of BSL or Libras description (CORE-SL), the intermediate level of services, and the level of artifacts and applications. Because of the high level of complexity and the need to involve so many different researcher profiles and types of resources in the linguistic axis - such as intelligent avatar translation and signaling – the researchers conducted parallel research to build knowledge so that, once the avatar was available, it could be integrated into the series of bilingual education applications. The architecture currently has some bases and modules, as well as a collection of distinct artifacts.

Similar work can be found in Portugal with avatars translating PSL in the (Cabral & Goncalves, 2020; Escudeiro et al., 2015) although these weren't detected on the queries executed for this systematic literature review but in previous research.

3.2.2.9. Assistive Technology for People with Visual Disabilities

Jariwala has released a prototype that includes a system for visually impaired high-school students to learn and practice mathematical problems, as well as a mathematical expression parser and evaluator to assist them in practicing mathematical questions (Jariwala et al., 2021). Mathematics in high school lays the groundwork for pupils to study and succeed in the social and professional realms. Recent technological breakthroughs have offered pupils with a variety of virtual tools to help them enhance their arithmetic skills. As a result of this disadvantage, children with vision impairment and students without disabilities have a considerable knowledge gap. Visually impaired pupils are five or more grade levels behind their sighted peers in 15% of cases. Jariwala researched how high school pupils learn and practice mathematical problems. First, provide students with an easy-to-learn interaction mechanism for unambiguous communication with the program, and incorporate a highly interactive text-to-speech library that gives the student speech control. This method allows for communication with the system, but responses are limited to closed-ended inquiries. For the system to function properly, the developer must manually provide the questions and answers. The study recommends that students use Natural Language Toolkit (NLTK) to execute fundamental text operations on a dataset in order to find answers to their questions. The prototype parses and evaluates mathematical equations using the mXparser expression parser. The suggested library's main disadvantage is that it does not support the Python programming language and only provides step-by-step answers to a limited number of mathematical ideas. Jariwala explains how to develop and incorporate an expression parser into a system to help students practice mathematical questions. The foregoing considerations highlight the need to improve the current prototype of an interactive application for visually impaired pupils to master high school mathematics concepts.

Jariwala states that there have been significant changes in how information is delivered to students with vision impairments as a result of technological advancements, with screen readers being the most common approach. Before accessing useful information, visually impaired people frequently had to wade through a lot of unnecessary content. Although a digital duplicate of a text helps visually impaired pupils learn, making a digital copy of complex mathematical calculations, as noted in, is more difficult. Process-Driven Math is another effective strategy that was established to assist blind students in succeeding in college mathematics. By masking complex numbers and symbols behind mathematical vocabulary layers, Process-Driven Math frees up students' working memory while solving equations.

Jariwala's application architecture consists of:

- An Intelligent Agent: Researchers can use NLP to organize and structure datasets in order to accomplish tasks such as automatic summarization, translation, and speech recognition. Questions and answers concerning learning more about the system, acquiring mathematical concepts, and asking for help are included in the dataset;
- Math Expression Parser and Evaluator: These authors created an expression parser and evaluator that allows students to explore mathematical concepts while also asking for guidance. Js is an open-source library that parses mathematical equation strings, creates an expression tree, and returns the root node of the tree. Expressions can be analyzed, manipulated, and evaluated using an expression tree. If pupils want hints, the platform only delivers information in speech format.

Jariwala's goal with the construction of their prototype and subsequent enhancements is to encourage self-directed learning tools, particularly for mathematics for visually impaired high school pupils. Only English is supported as a primary language in the current edition.

Mikulowski presents a tool with the similar goal applied to the concept of flipped classroom, with a 4-Layers of augmented reality architecture (Mikułowski & Brzostek-Pawłowska, 2020):

- First AR Layer: General Recognition of Mathematical Objects in the Document - The first general information layer contains text elements that are conveyed through synthetic speech and informs about encountering objects such as graphics, mathematical formulas, quizzes, questions, answers, pairing fields, and links to teacher comments. The first layer UI is a set of keyboard shortcuts that make it easy to locate previously identified elements in a document, including a Braille display interface.
- Second AR Layer: More Information About Math Objects - When a student encounters a mathematical item and recognizes its type, he or she can investigate it further. The AR elements of the Multi-sensual Augmented Reality second layer make this possible. This layer comprises semantically accessible formula text in Polish or English via speech synthesizer, graphic titles and descriptions, and content of matching fields, such as questions or replies that can be text, a formula, or a graphic. The student can use the Braille display to read this

information at the same time. The second layer's user interface consists of a collection of keyboard keys for obtaining information about each math item in the text. Additionally, this layer is equipped with mathematical converters for tactile reading of formulas.

- Third AR Layer: Thorough Exploration of the Math Object - The third AR layer was created to explore mathematics, function graphs, and geometric drawings in greater depth. Visual elements are explained by automatically generated text or manually contributed explanations of visual elements; comments of the entire graph and its elements; texts of the formula elements; continuous sounds with constant and variable monotonicity describing graph elements; short technical sounds termed audio-icons. The UI comprises four keyboard shortcuts, numeric keyboard keys, many on-screen touch motions, a haptic touch of a braille display, synthetic speech, and bolded lines noteworthy graphic components.
- Fourth AR Layer: Recorded Teacher Comments: Optionally, the fourth layer includes material recorded by the teacher as hints, tips, or comments in the form of static video (just sound) integrated in the content as a link to a YouTube resource. Standard keyboard shortcuts for opening links in a browser are supported by this layer. It is up to the teacher to submit comments, and it is up to the student to use this kind of teacher's advice. Students in their cognitive reality can increase their mathematics skills thanks to this mix of AR reality offering the proper instruments.

The tool received positive feedback from students and Math teachers in Netherland and Poland.

Cross referencing this project’s fourth layer with (Acosta et al., 2020) it is possible to notice how Acosta classifies YouTube as inaccessible according to WCAG 2.1 guidelines but Mikulowski and Brzostek-Pawłowska incorporate it in a solution for the visually impaired obtaining positive feedback. Still, in this project, YouTube is used as a layer of a multi sensual framework, and the guidelines that failed on Acosta’s assessment were mostly related to hearing disabilities which confirms that one can’t evaluate web accessibility globally but relating it to each individual’s abilities.

3.2.2.10. Assistive Technology for People with other Disabilities

Mishev presents a study on the application of innovative software to aid people with different disabilities such as visual and hearing, or dyslexia (Mishev et al., 2022). There is a plethora of accessibility solutions and technologies available today for people with various types and levels of disability. Regarding education there are cost and time-effective technologies that enable students to access standard curricula. However, just because assistive technology is available, does not mean that it improves learning or is appropriate for every impaired student.

Mishev as other previously cited authors points to Text-to-Speech (TTS) technology as an example of assistive technology useful for those with some handicap on reading capacity. His team developed a

Macedonian voice synthesizer as that language was still unavailable in a human like voice. They also produced a Macedonian sign language interpretation service.

Regarding fonts recommended for people with dyslexia Mishev cites studies where some of those available fonts didn’t produce the expected results. A commonly accepted guideline is the usage of sans serif enlarged and spaced fonts, regardless of a specific typeface,

All these modules were combined into a multimodal platform, establishing a multimodality principle to follow on this thesis. As one solution won’t suit everyone a solution must be found for each one.

Schultz studied the possibility of applying automatic speech recognition on UI for people with neurodegenerative diseases and despite unsatisfactory results he recognizes potential in this methodology if enough data is collected to train machine learning models to recognize impaired speech (Schultz et al., 2021).

So far the cited authors offer audio alternatives for users with visual impairment and visual aids to people with hearing impairments. Shohieb introduced the possibility of users having both conditions simultaneously (Shohieb et al., 2020), coming to a solution where the web page material is converted into a tactile presentation technique that can be printed on swollen paper with a special embosser printer or touched with a display device. This technology received an average of 85 percent user satisfaction in deafblind user tests. This new adaptable technology, which has been tested with users, has the potential to alleviate at least some of these folks' daily issues while also assisting them with web accessibility and lifelong learning content.

Sinha and Dasgupta approach the case when the user has speech and severe motor impairments (Sinha & Dasgupta, 2021). Despite the proliferation of studies in adaptive systems and accessibility guidelines the authors found a gap in the study of the needs and solutions for people with Severe Speech and Motor Impairment (SSMI) (cerebral palsy, e.g.). These individuals lack fine motor control, resulting in complete or partial failure of body parts responsible for speech and limb movement. WebSanyog is a browser enhanced with automated and manual scanning techniques that allow a person with a motor disorder to access the browser's graphical user interface (GUI) as an alternate way to access and navigate through Web pages, instead of using keyboard and mouse. Furthermore, the browser includes an intelligent content scanning engine that allows users to access Web content with less time and effort. Besides the desktop version portability was achieved by an Android version.

Studies were found addressing assistive technologies for people with Down Syndrome, Autism, and other learning disorders but none related to their inclusion on higher education. Yet this can be considered a consequence of the queries executed, because recent references can be found regarding the participation in Higher Education of Autistic people (Bakker et al., 2019; Nuske et al., 2019; Sarrett, 2018) and since the author started researching inclusion in Higher Education that the case study of young Rafael Calderón-Almendros, the first Down Syndrome student to graduate on a Conservatory

Higher Education Program after struggling with stereotyping, discrimination and abandonment is kept as a reference (Calderón-Almendros & Habegger-Lardoeyt, 2019).

4. PORTUGUESE HIGHER EDUCATION SYSTEM WEB ACCESSIBILITY ASSESSMENT

4.1. Assessment Methodology

To measure the digital accessibility of Portuguese HEI it was considered analyzing and rating their institutional websites. Similarly rating their learning platforms would be desirable, yet these are not publicly available without authentication.

Therefore, an experimental study was conducted assessing the websites using the accessMonitor 2.1 tool (Administrative Modernization Agency, 2022). As legislators and enforcers of these accessibility criteria it is curious to be the second thesis the author verifies that the Portuguese Agency for Administrative Modernization complies with the accessibility and usability statement requirement on their accessibility related site[1] and yet they keep missing it on their institutional site[2] against what is required by Law Decree 83/2018, therefore proving that the same governmental entity that says that all public institutions must follow the procedure identified in the first site, keeps failing to do it on their main site.

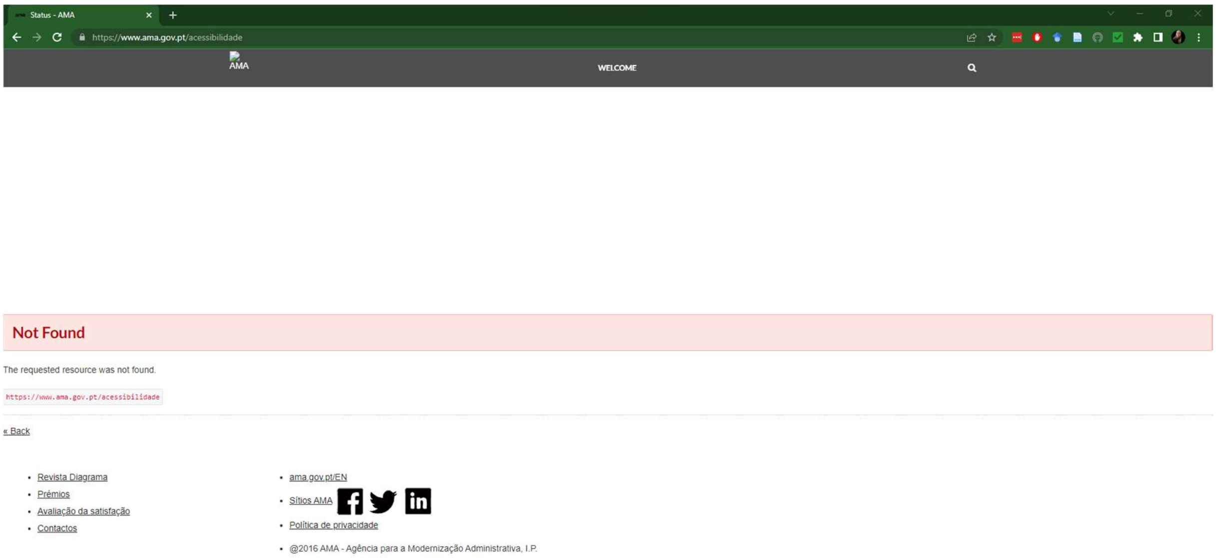

Figure 4 - Evidence of failure to comply with own ruling by ama.gov.pt

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[1] https://www.acessibilidade.gov.pt/acessibilidade/
[2] https://www.ama.gov.pt/acessibilidade/

When defining the sample size, it was decided to assess all publicly available Portuguese HEI websites, yet some considerations were made during data collection, namely:

The Portuguese Higher Education System comprises a university and polytechnic subsystems and polytechnic organic units (POU) that are attached to universities or not.

Even if the POU that are attached to universities have their own subdomains, their websites are extensions of their university website, using the same technology and layout as their host. As such, a university with many organic units would bias the results if all organic units would be treated as single entities thus repeating the same results. So, 85 HEI were obtained from DGES website (DGES, 2022).

This sample includes all public (civil and military/police) and private universities, polytechnic institutions and polytechnic organic units not attached to universities.

Dimensions wise, as websites are often more aesthetic intensive on the homepage, three pages were rated on each website: the homepage, the 1st cycle programs, and the applications page. Not available results occurred on rare cases where the page was inexistent, or the tool was unable to rate it. The three pages scores were averaged so the missing values wouldn't affect the result.

Each website was also assessed for the existence of an accessibility statement reachable by <domain>/acessibilidade (https://www.utad.pt/acessibilidade, e.g.).

A weight of 75% was issued to the average web accessibility score (0 to 10) of the pages assessed and 25% to the normalized categorical value of the existence of the accessibility statement on public HEI (0 for inexistent or 10 for existent). Despite private HEI without any public funding are not mandated by law to comply with Decree Law 83/2018 (Presidência do Concelho de Ministros, 2018b) it is hard to know which have public funding, as most have some national or community research fundings and being a measure that lets students with disabilities easily find that information on a standardized URL all scores were calculated as for public or private with public funding HEI.

4.2. Assessment Results

Results[3] have shown that no private HEI complies with Decree Law 83/2018 independently of receiving public fundings. 7/35 (19.44%) of the public HEI comply with the Decree Law.

The assessment score distribution has a mean of 4.34 and a standard deviation of 1.31 with a minimum of 1.7 and a maximum of 9.125. 25% of the observations have a score of up to 3.525, the median is of

[3] Available in https://github.com/david-sottomayor/TELHESD

4.025 and 75% of the websites scored under 5.05. Figure 5 presents the score distribution as a histogram.

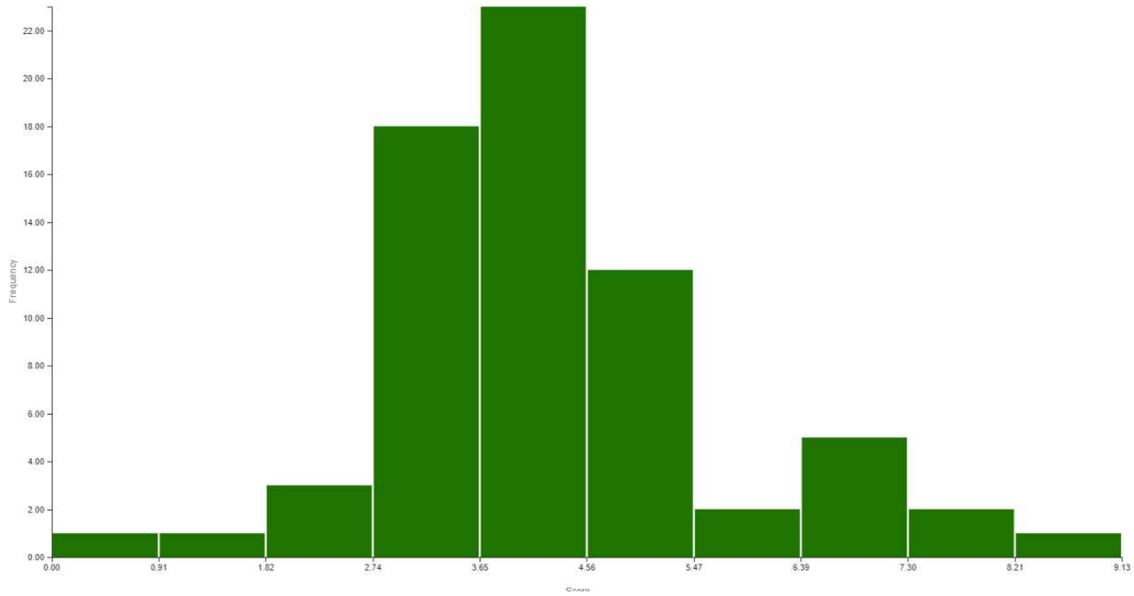

Figure 5 - Assessment Results Histogram

"*Instituto Politécnico de Leiria*" holds the maximum assessment score of 9.125 with a mean web accessibility score of 8.33 and having an accessibility statement. "*Instituto Politécnico de Lisboa*" and "*Instituto Superior de Administração e Línguas*" have the highest mean web accessibility scores with 9.5 but neither displaying an accessibility statement. The first being a public HEI is ruled by the Decree Law 83/2018, the latter being a private HEI may be exempt from compliance provided it doesn't benefit from public fundings these outliers reach near perfect scores.

Looking at the three dimensions assessed in accessMonitor 2.1 would reveal means of 5.5, 5.6 and 5.5 for the homepages, programs pages and application pages which would made apparent that there is not much difference between the different pages and, although it is the case in some HEI websites during the data collection process was possible to observe how some HEI websites apply different accessibility features between these pages with differences of up to 3.1 points between different pages in the same website.

"Universidade de Trás-os-Montes e Alto Douro" is the only university, public or private, with a digital accessibility score over 7.5 points out 10.

Looking at the boxplots graphs in Figure 6 where maximum and lower whiskers stand at 15^{th} and 85^{th} percentiles one can see how low the median rating is in each sector (public or private) and each subsystem (university, polytechnic and polytechnic units not attached to a university). It is possible to observe that each subsystem in each sector holds a negative mean rating, with only the public universities holding a slight positive mean. All samples hold a high concentration around the mean where even the larger boxes concentrate 50% of the observations in an interval of less than 2 points out of 10. That interval is less concentrated in the university sub-system than the others, but more concentrated on the polytechnic. Military and police HEI are very few in number (3 total) which causes the box to appear to be a line crossing the mean value. The ratings are less concentrated in the public sector than in the private.

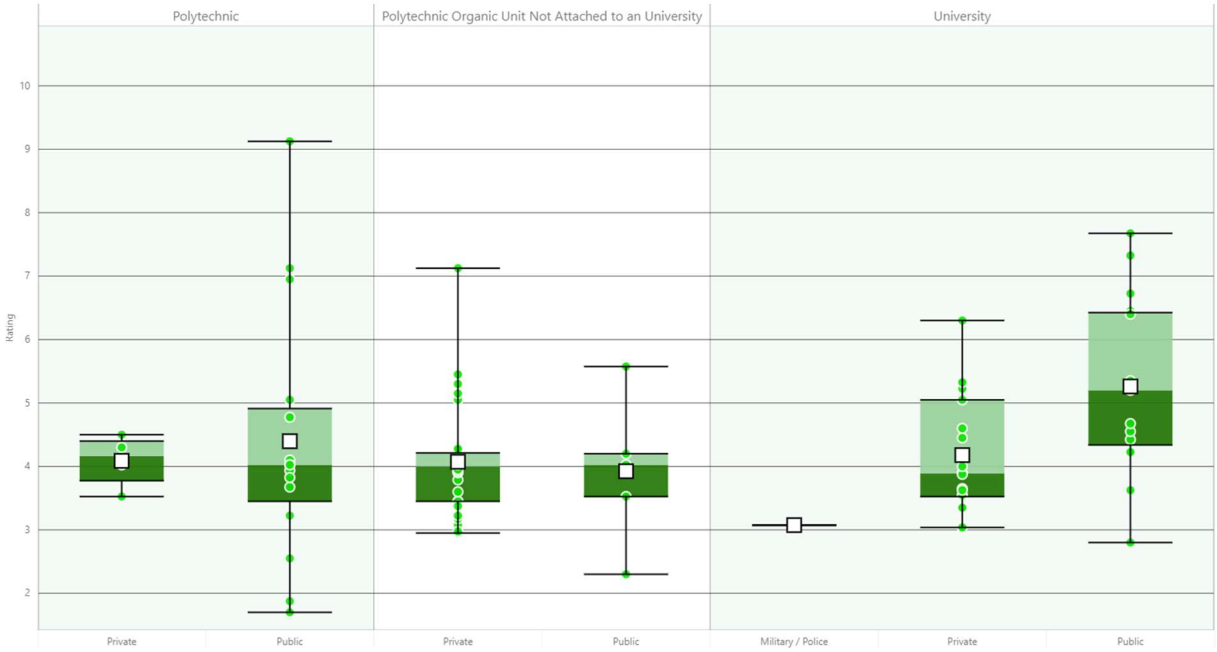

Figure 6 – Portuguese Higher Education Institutional Websites Digital Accessibility Ratings Box and Whiskers Plots by Sector and Subsystem

4.3. Results and Discussion

The 25% weight may be penalizing for websites of private HEI. Still in the perspective of end users with disabilities complying with Decree Law 83/2018 would raise awareness of the site designers to their web accessibility.

Even disregarding the accessibility statement, having a mean web accessibility score of 5.5 per page show how inaccessible the Portuguese HEI websites are for all their students but especially for those with disabilities.

It is not possible to infer how accessible the HEI learning platforms and their pedagogic materials can be from this assessment as not all HEI use the same platform and its settings are in most cases completely independent from the institutional websites. Yet these sites are the business cards of each HEI and may be perceived for how much each HEI cares about accessibility issues.

The best ranked HEI in this study is known for holding an international conference on inclusion (Includit).

4.4. Assessment Conclusions

The results raise concerns regarding the low digital accessibility Portuguese students face on the national higher education system. The assessment score designed for this study revealed that the average accessibility of Portuguese HEI websites is negative. And the 3rd quartile is just barely positive. Even disregarding the compliance with the accessibility statement law requirement the mean accessibility rating measured by accessMonitor 2.1 would be of 5.5 out of 10.

A conclusion that may be deduced from the exposed results is that it is possible to build near perfectly accessible websites by WCAG 2.1 standards, yet most sites fall far behind. Although it may be a subjective judgment, looking at the best rated sites reject any aesthetic sacrifice is necessary to comply with WCAG 2.1 guidelines.

For those with sensory disabilities the digital accessibility is most impacting as it may affect their ability to receive important information or even to succeed in their learning processes, yet, by definition, accessibility is applicable to everyone with or without temporary or permanent impairments that may result from intrinsic or external factors such as the weather conditions.

The literature review shows that there is available technology that is yet to be used, and the study developed in this paper shows that despite some HEI are pioneers in the accessibility issues, the Portuguese higher education system is still insufficiently digital accessible.

COVID-19 has made this issue more noticeable when it forced Portuguese (and worldwide) students to start learning remotely. Students with disabilities weren’t the only ones to express missing the tutoring experience during remote learning experiences.

The available technology and the gap identified by previous authors in its implementation on the education system suggest that future work can be done to virtualize an accessible tutoring experience in the context of remote learning. The literature review reveals that there have been technology developments widely available on entertainment and commercial contexts. Yet, despite some models and frameworks have been published revealing an immense potential that intelligent technologies have to enhance education, business processes and industrial optimization, a gap exists both in its implementation on field and even between how frequently solutions like IPAs are tested in these contexts, opposed to more commercial uses, independently of the social impact that implementing it would have inclusion wise, or the cost reductions and production efficiency these technologies can bring to business and industrial contexts.

It does seem evident that IPAs have the potential to enhance accessibility in any context they may be applied to, not only being widely implemented on our personal lives but also making our academic and labor lives just as accessible and more productive for anyone with or without disabilities.

5. THE INCLUSIVE INTELLIGENT LEARNING MANAGEMENT SYSTEM FRAMEWORK

5.1. Assumptions

Higher Education Inclusiveness is more than a technological challenge to find the perfect assistive technology, or more accurately, a set of assistive technologies suitable for each individual in a diversity of disabilities, not forgetting those without any impairment but occasionally affected by internal or external factors (temporary sickness, or weather conditions, e.g.). To reach that goal there is also the need for a major cultural and systemic challenge to motivate students with disabilities to continue their studies into higher education, creating the conditions to allow their success and the conditions for their teachers to instruct students with special education needs.

There are numerous articles on adaptive Learning Management Systems, but comparatively a gap in adaptive Electronic Document Management Systems.

Universal Design and Web Content Accessibility Guidelines are the standards to produce these web-based tools in an effectively inclusive manner. Affective computing can play a key part in an adaptive learning system.

From the extent of assistive technologies available it becomes obvious that there isn't a technology that fits everybody, but there is at least one example of a technology tested on people with almost any kind of learning handicap induced by the most different disabilities. A multimodal approach is therefore the one with more potential to provide equative and inclusive Higher Education.

Sensory disabilities are the most researched and the ones to which more assistive technology have been developed in terms of web accessibility. Even mobility impairments that are commonly associated to physical accessibilities, can benefit from web accessibility as much as everyone, but examples were found of assistive technology for the most severe cases. YouTube, the most used video sharing tool used in education doesn't comply with the highest levels of the WCAG and more research is needed to detect if currently there is a better option.

It was also possible to detect the importance application mobility have reached and the potential of smart and wearable devices to be used as assistive technology being part of Universal Design for Learning.

Finally it became evident that AI and it's diverse fields played a major part in the conception of tools that capacitate students with SEN, whether by means of Deep Learning and increasingly reliable automated image description or the part it plays in Affective Computing, Natural Language Processing and the possibility to use instant captioning of not only recorded or live video streaming but inclusively presential attended classes, remembering also the live translation in sign language by 3D avatars.

Machine Learning has a contribute to make in Recommendation Systems but also on Predictive Analysis allowing the detection of students “at risk” (with or without disabilities) in time for preemptive measures that may stop them from failing that class.

5.2. FRAMEWORK

A framework for education that allows different type of students to have an intelligent access to adapted resources according to their personal capacities and preferences.

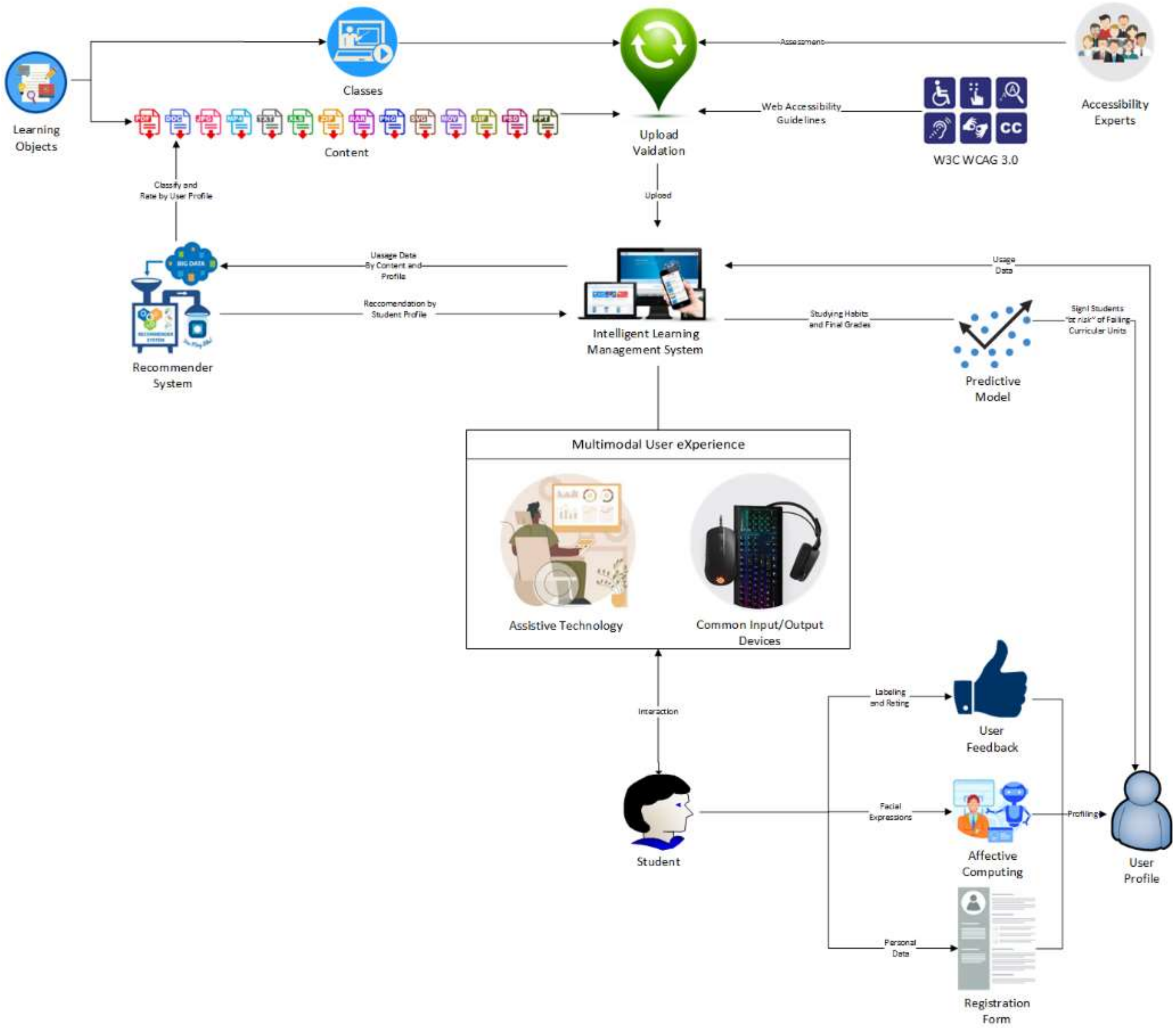

Figure 7 - Inclusive Intelligent Learning Management System Framework

5.2.1. Framework Introduction

The purpose of IILMS framework is to tend to the needs of different end-users for whom their capacities are relevant information provided when creating their accounts (registration form). The IILMS learns from its users either by their inputs when suggesting additional labeling and rating the consumed contents, but also from real-time emotional reaction analysis to documents or sections of these documents by means of affective computing. This Deep Learning resource completes the standard user input assuring not only that users' needs are tended differently according to different disabilities they may present temporarily or permanently, but also treating people with similar disabilities as different individuals with distinctive personalities, preferences, and tastes.

All these users' characteristics are stored in their profiles which can be clustered by different characteristics beyond their disabilities (biographic data, education program or courses they are enrolled in, their grade performance or their emotional responses to different stimulus. Besides categorizing users, Machine Learning features may be used to predict user's performance in each class based on their study habits, interactive activities and relating previous emotional responses to pedagogic materials and courses classifications. This feature may signal students in stress or in need of additional tutoring to achieve success in their courses.

On the other end of the IILMS are the pedagogic materials presented in different kinds of digital content. From the literature review we have learned that the technological advances in assistive technology, operating systems natively offering accessibility features to integrate these assistive technologies, and the existence of accessibility guidelines make it possible that users with different capacities may consume digital content that would otherwise be inaccessible for them. This leads this thesis author to understand that the missing link to near-total accessibility is the content producer's initiative to make their contents accessible and WCAG 2.1 compliant. Therefore the frameworks include a document accessibility compliance validation module that prevents inaccessible content from being uploaded into the platform. Content uploaders must be the first to label the contents being uploaded, allowing these contents to be categorized.

The multi-modal presentation is made possible by strict compliance with WCAG 2.1 document accessibility guidelines. If these are scrupulously followed, the same content may be consumed by different assistive technologies in the most suiting fashion for the end-user, or at least be described in alternative text that may be presented in visual, audio, sign language, touch, or symbolic interfaces, using either operative systems native features or drivers for assistive technologies. Still, while present specific content types like video, the interfaces used may be more, less, or not accessible. In European Union (EU) public websites are forced by law to comply with WCAG 2.1 AA level guidelines. Worldwide, ISO/IEC standard 40500:2012, last revised in 2019, requires compliance with WCAG 2.0 Guidelines. Content compliant with WCAG 2.1 is also compliant with WCAG 2.0 or ISO/IEC 40500:2012. YouTube complies only with level A and half of the AA level guidelines, hence despite its wide implementation it should not be used to host videos on any public university or other public organizations nor by any inclusive organization that aims to be WCAG 2 or soon WCAG 3 compliant. More inclusive options exist as cited in the literature review.

A recommendation system relates the documents, courses and students' profiles matching them with not only other content available uploaded to the platform but also external content, such as open-access scientific papers, offering the student not only the materials suggested by the teachers but also resources most often and successfully used by other students in similar contexts.

Classes will be possible to watch through web-conference software even when attended in presential mode so users with hearing disabilities can benefit from live captioning features.

The user-interface is also obliged to follow each WCAG 2.1 web accessibility guideline making it truly inclusive by making it accessible for everyone. Even if everyone cannot be interpreted literally as is beyond the scope of this thesis to discuss if everyone independently of their disability type and severity may achieve success in a higher education program. Even if in literature review some cases are cited and even the thesis author experience proved that in some cases the scarce odds can be beaten it would be a stretch to claim that everyone using such a system would be assured to succeed. Still, inclusion by definition starts by reducing or suppressing the person's handicap giving them a chance they wouldn't have otherwise. It is not the objective of the author to draw a line where people with more or less severe different disabilities have higher, lower or no chances to succeed, specially after himself being told not to worry about continuing his studies at some point during his medical recovery. So, it is most important that the interface complies with every single guideline in WCAG 2.1 so it becomes accessible to the wider possible set of end-users, only so earning the first I in this framework's name.

5.2.2. Modules Detail

5.2.2.1. Users Profiles

Registration Form

The registration form is the first point of input from the user to the system.

In it the users present its biographic data, course enrollment and disabilities or impairments.

The registration form must also include user agreement clauses regarding the collection and process of data, specifically the personal data but also the performance prediction, and the biometric features used in affective computing.

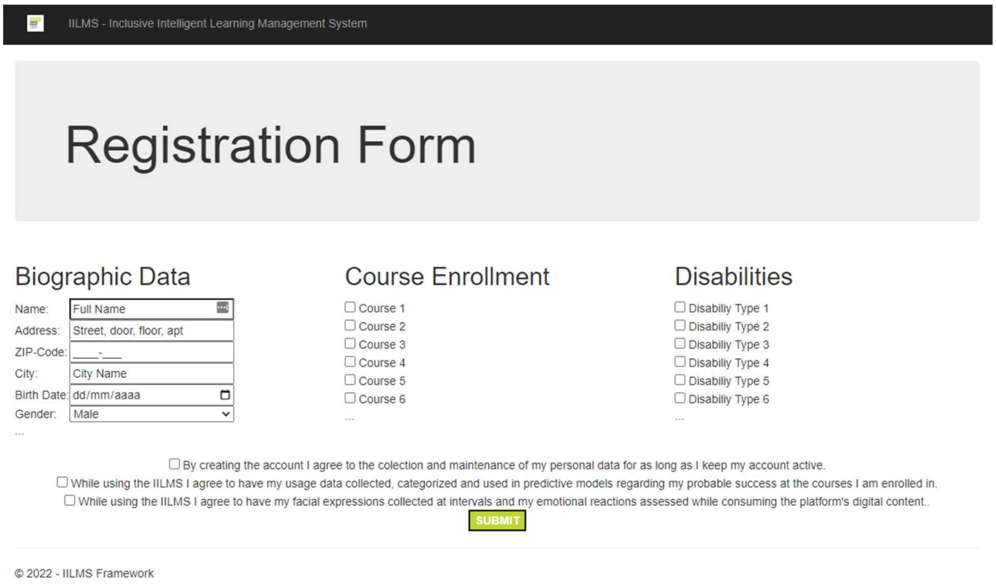

Figure 8- Registration Form Mockup

Affective Computing

Affective computing is done by comparing the real-time captured user's facial expression and having an artificial neural network compared it to a trained dataset of labeled pictures to detect emotional state.

Figure 9 demonstrates emotion recognition by using the thesis author picture in F.A.C.E. API[4] demo that estimates the subject age, gender and emotional state.

[4] https://face-api.sightcorp.com/demo-basic/

Figure 9- F.A.C.E. API Emotion and Age Recognition Demo

The most useful application for this feature is relating the individual reaction to certain types of digital content and therefore learning the contents that provide the most satisfying learning experience. Clustering users on other features and calculating their class aggregate reaction to certain contents may help predict how users fitting on the same cluster will react to a kind of content they haven't tried yet.

User Feedback

After consuming a content the user can be required to contribute labeling and rating the content

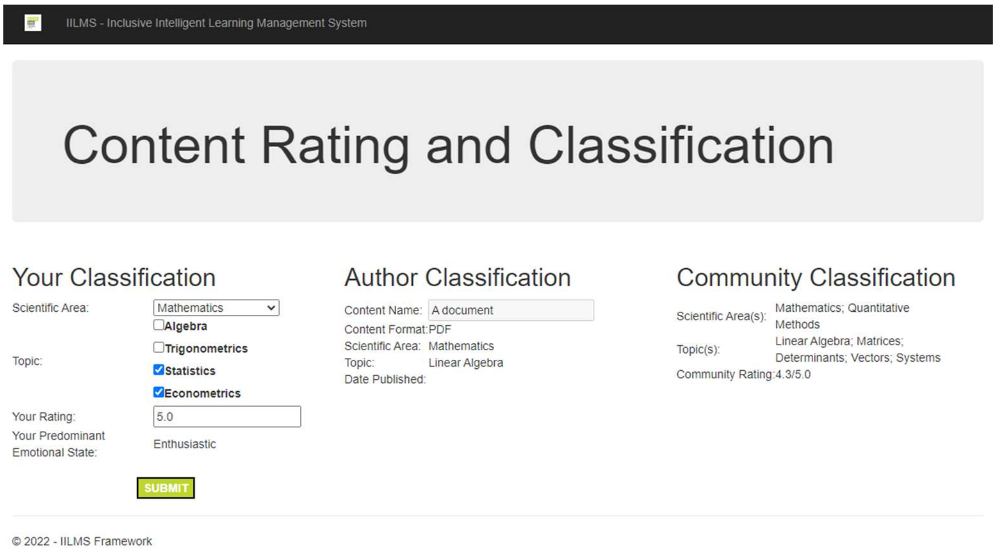

Figure 10 - User Feedback Mockup

Students Preventive Performance Assessment

A variety of Machine Learning algorithms may be used to access the likelihood of student's success on each course while there is still time to take corrective pedagogic measures. From Multivariate Linear Regression (MLR), Support Vector Machine (SVM), Random Forest (RF), Artificial Neural Network or some simple K-Nearest Neighbours(K-NN), these algorithms may have more or less accurate results depending on the features selection and pre-processing, and very distinct processing efficiency levels depending on the dataset dimension.

Content Uploading

This module is responsible for assuring that not only the user interface is accessible but mainly the contents the students are going to consume while taking the courses are accessible according to the WCAG 2.1 guidelines. It doesn't take a specific conversion of the same material to several formats according to each student's capacities. It suffices to be WCAG 2.1 compliant so assistive technologies can take care of making the same material multimodal being consumed in entirely different forms by blind or deaf students, e.g.

Yet, the literature review revealed that this is still something that despite being technically feasible, it is not something that everyone knows or cares about.

To assure all materials in IILMS are accessible it becomes necessary to assess contents upon upload and only accepting them if they are WCAG 2.1 compliant.

One of the most evident facts from the literature review is that most video contents are made available on a not accessible platform like YouTube, for some authors, whereas other authors recommend it as an accessibility enhancement. In this thesis the author supports Acosta's claim that if YouTube doesn't comply with half of AA level criteria it can't be called generally accessible, even if on specific cases it may present a valid solution. Still the goal of IILMS is to be accessible for everyone, so it can't support YouTube knowing it fails that much accessibility criteria.

Classes Streaming and Captioning

It doesn't take literature review to have noticed how much e-learning have boomed since the Coronavirus pandemic outbreak led to periods of mandatory confinement and remote working and schooling.

The goal of this module is not to prolong the remote attendance to classes but to make use of a feature that became available or known during the pandemic: the live automated captioning of streamed events.

In fact, it became possible not only to automatically caption streamed events but to use the streaming capacities to watch presential classes using a laptop or smart device to instantly caption what everyone is saying in the classroom, in an Augmented Reality (AR) fashion.

The literature review presented another AR feature already available like live sign language avatars. Their integration in the implementation is positively encouraged, provided a license agreement is reached with a developer of an avatar that communicates in the desired language.

Recommendation System

People are so used to be suggested what to watch next on the television, what to shop, even what to read for leisure, or what online courses to take next. It won't come as a surprise to any IILMS user that the system recommends what to study next, according to the course curriculum, content ratings and the student's personal preferences. Even two students with the similar capacities may one prefer to read the course recommended manual, and other to watch that content on videos, or to take interactive activities. This feature will allow the student to be offered additional or alternative contents, from the platform or openly available on the web to learn the courses.

Ever since the 90s that students can browse and surf additional content but even that is becoming a lost habit as people tend to consume feeds and suggestions.

5.2.3. Implementation Guidelines

Assuming nearly no one has experienced all different disabilities, no developer is likely to have a conscient mindset for all different disabilities or even for external factors that temporarily affect even those without any disability (studying outside on a sunny day, e.g.). Therefore, It is highly recommended that EN 301 549 is deeply studied and considered during the requirements identification stage. A school must be ready to include students with any or multiple disabilities. If a school is specially oriented to teach deaf students, e.g., what if one of them is also blind? He won't see sign language or captions. If he is deaf-blind, he won't be able to ear audio-descriptions either. Hopefully he will be able to read a refreshable braille display… Unless that student is also severely motion impaired. The answer to "Is there a set of disabilities that totally incapacitates someone from succeeding at a higher education program?" goes beyond the scope of this thesis. Even the Portuguese General Board for Higher Education despite the efforts to include students with disabilities refrains from openly encouraging any student to enrol, rather stating that it should be an informed and responsible decision.

The core concept of the framework is compliance with WCAG rather than worrying with assistive technology. WCAG compliance is the requirement for any assistive technology bringing accessibility for all students.

5.2.3.1. User Interface

Overall, the system must be compliant with every guideline on WCAG 2.1, therefore it must follow the same four founding principles:

1. "Information and user interface components must be presentable to users in ways they can perceive";
2. "User interface components and navigation must be operable";
3. "Information and the operation of user interface must be understandable";
4. "Content must be robust enough that it can be interpreted by a wide variety of user agents, including assistive technologies".

As stated in Framework Introduction all IILMS Framework implementations should comply with all WCAG 2.1 guidelines therefore assuring a AAA level rating and more than enough qualification for ISO/IEC 40500:2012 (WCAG 2.0) and EU regulation for web sites of public or public funded organizations. For that purpose, the cited WCAG 2.1 Quick Reference is a tool that allows checklist validation of each guideline, but also offers technique description to meet its success criteria.

Any Cross-Platform Develop Framework such as Xamarin or React Native may be used to implement IILMS but code must be developed when that development framework fails to support the operating systems native accessibility APIs. No WCAG 2.1 guideline is to be excused because the development framework doesn't support it.

Beyond legal compliance an accessibility focused implementation must meet the WCAG 3.0 guidelines or whatever version is the most recent at the implementation date as these guidelines have been updated over time considering new assistive technologies or setting more adapted solutions for different disabilities.

The goal of this thesis is not to implement front-end solutions that may be developed in a myriad of programming languages or cross-platform development frameworks but to stress the importance of WCAG compliance in any front-end development.

5.2.3.2. Registration Forms

The registration forms must state the purpose for which the data is being collected, how it will be processed and explicitly collect user's agreement on the act of creating the account.

Affective computing may be rendered optional, as it includes biometrics. User's agreement may be collected separately, or the creation of the account may depend on user's agreement with the collection of biometric facial expressions during the usage of the application. The feature may be absent on devices that don't support the technical requirements (webcam) but mustn't ever be used without user's content. It is up for the developer to decide if using the IILMS requires agreement with affective computing or to make that feature optional.

Again, front-end development is not the purpose of this thesis, provided WCAG compliance is observed.

5.2.3.3. Affective Computing

It is possible to implement some licensed component or to use pre-trained openly available datasets and Neural-Network models as the ones cited in the literature review.

The author would recommend the development of datasets using and labelling images of people with different disabilities, to assure everyone's expressions are more accurately recognized.

The Neural Network architecture may follow Jain's CNN or hybrid models. The following code exemplifies the implementation of the CNN convolutional and pooling layers.

```
from keras import models, layers
model=models.Sequential()
model.add(layers(Conv2D(8, (5,5), activation="relu", input_shape=(100,100,1))))
model.add(layers.MaxPooling(3,3))
model.add(layers(Conv2D(16, (5,5), activation="relu")))
model.add(layers.MaxPooling(3,3))
model.add(layers(Conv2D(32, (5,5), activation="relu")))
model.add(layers.MaxPooling(3,3))
model.add(layers(Conv2D(64, (5,5), activation="relu")))
model.add(layers.MaxPooling(3,3))
model.add(layers(Conv2D(128, (5,5), activation="relu")))
model.add(layers.MaxPooling(3,3))
model.add(layers(Conv2D(256, (3,3), activation="relu")))
model.add(layers(AveragePooling2D(pool_size=(3,3), strides=(1, 1), padding='same')
```

Figure 11 - Implementation of Convolutional and Pooling Layers from Jain's CNN model in Python

There are many open repositories with code implementing Neural Networks for this purpose, some are more supported by a development community than others and there are licensed tools too that can be used for this purpose. Scarcer is the availability of open datasets. Two were referenced in the literature review and they are often used by different authors in this field.

Annex "Affective Computing"

5.2.3.4. User Feedback

The user must be provided with a very simple interface to collect their feedback and require the least effort to fill.

Developers must consider users relying on screen readers to navigate and provide proper labelling for every element. The user feedback must be made available before accessory information, even if for users with perfect sight these could make sense coming last. A user without visual impairments can imagine listening to an immense list of options in automated telephone answering services to imagine how a screen reader user feels when the information he needs is on the bottom right corner of the screen.

5.2.3.5. Students Preventive Performance Assessment

One could choose an ANN to run a nation-wide or continental analysis or just a K-NN on some small college.

The number of features and the dimension of the dataset will be determinant to choose the most suiting model for each occasion. If necessary, several models may be tested to choose the best option considering each model's effectiveness and efficiency.

5.2.3.6. Content Uploading

There are numerous document accessibility validators with Microsoft and Google having accessibility checkers on their office software packages. PAVE-pdf.org provides an online tool to automatically fix accessibility issues on PDFs. However, it's Adobe who makes available an API to check PDF accessibility on several programming languages such as Java, Node.js, .Net or Python [5].

It is recommended to accept only PDF documents filtered by this API validation into the IILMS. Authors may or may not use other available tools to validate their documents accessibility but using this API is the only open-source tool available and only for this format. Most of the documents uploaded by professors are already in this format, making it the rule may be a path to force the production of accessible WCAG 2.1 compliant documents.

As for video contents, from literature review it became obvious that the most used video sharing platform is not inclusive as it doesn't comply with half of the AA level criteria. There are several

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[5] https://opensource.adobe.com/dc-acrobat-sdk-docs/acrobatsdk/pdfs/acrobatsdk_access.pdf

alternatives more accessible than the market leader, ableplayer[6] is just one of the examples of more accessible digital media players that can be used in any web site or web application.

5.2.3.7. Classes Streaming and Captioning

Zoom and Teams have become widely known since the COVID-19 pandemic outbreak, and one of the features some people with disabilities, or people watching classes in a different language than their native one became familiar with was the live captioning or translation of meetings.

Students with hearing impairments got used to use this feature even to watch presential classes receiving instant captioning.

Both platforms and other competitors facilitate their integration with LMS.

Sign language digital interpreters are becoming available. The literature review indicates two examples of these tools that provide Portuguese Sign Language live interpretation. None of these tools is open access software or available under licensing. It is possible to browse many examples of these tools in other countries' sign languages available on open repositories.

5.2.3.8. Recommender System

This is where the IILMS is supposed to go from FER to appear an empathetic machine making the best use of the affective computing capacities.

From: "Don't look so bored, try this video instead", to "there is an author from across the world who just made a breakthrough in this area, let me translate the article or video for you", to simply "you are struggling not to fall asleep, at least take a power nap, don't drink another coffee" the recommender system can be implemented with strictly technical features or attempting to simulate human advices to the fullest extent.

There are lots of open repositories with recommender systems, in all imaginable programming languages, some even in the e-learning context, yet none was found on the disability or inclusion contexts.

In common, among different open-source recommender systems are five stages in the development of their algorithms:

[6] https://ableplayer.github.io/ableplayer/

1. Data Collection of users and products/items;
2. Compare each user with all other (classification/clustering);
3. Find items each user hasn't tried but others from the same cluster have;
4. Rank the products/items that were used by most of the users in the same cluster;
5. Assess the model accuracy and retrain it periodically to improve its learning. Rate negatively the failed recommendations and improve item's labels when possible and/or necessary

5.3. VALIDATION

The framework was assessed by a focus group composed by:

- Tânia Rocha (PhD)
  Professor at UTAD & Senior Researcher at INESC TEC
  Vila Real, Vila Real, Portugal

- Alexandre Barão (PhD)
  Professor at Universidade Europeia & Book Author
  Lisboa, Lisboa, Portugal

- Márcio Martins (PhD)
  Rehabilitation Engineer, Ambassador for Associação Salvador in Northern Portugal & ITC Services at UTAD
  Amarante, Porto, Portugal

Figure 12 - Focus Group Panel

The author introduced an earlier version of the framework, shown on Figure 13. At that point in the research the framework proposed an Inclusive Intelligent Learning Management System that is still the core of the framework presented in the the previous section (Figure 7).

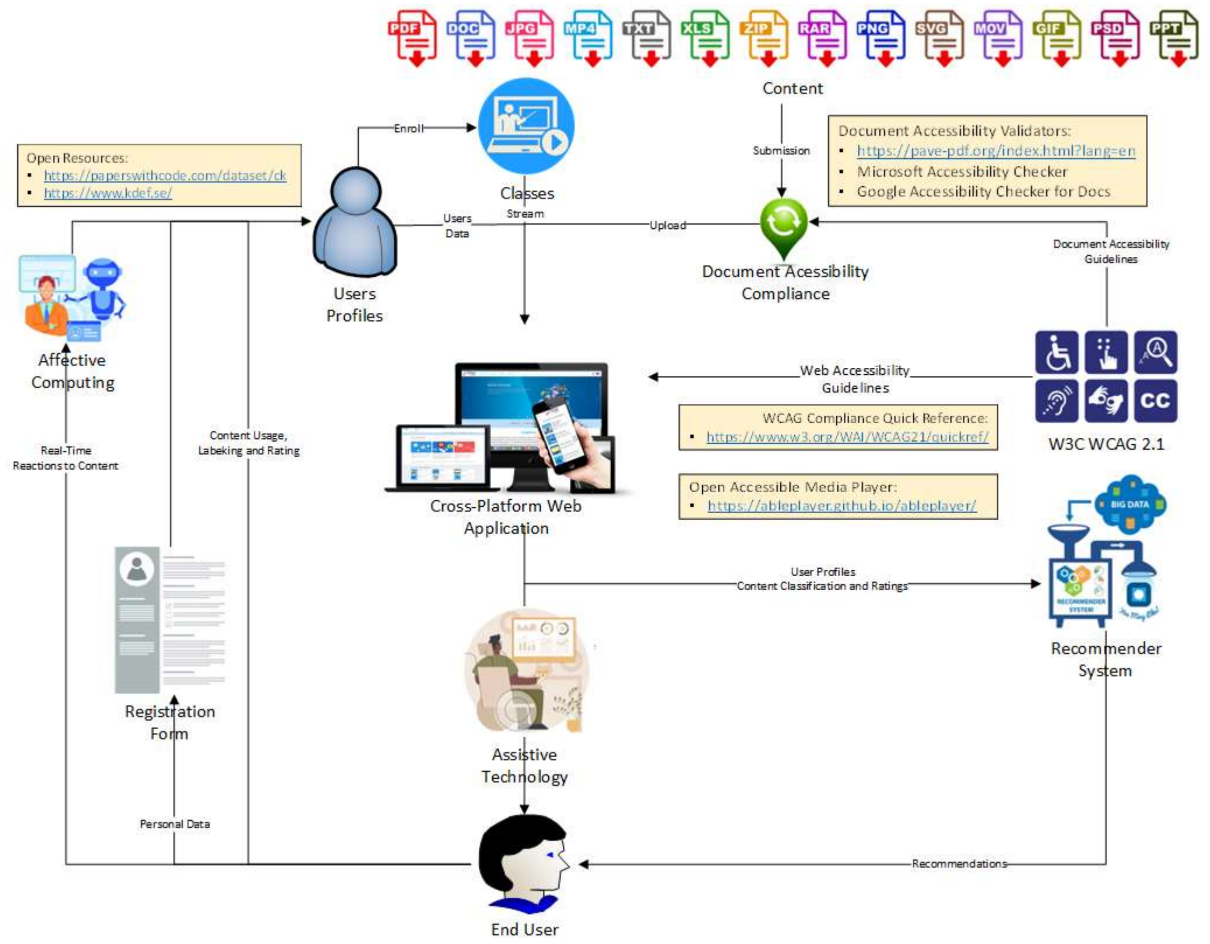

Figure 13 – Framework Version Presented to the Focus Group

Four questions were asked, targeting validation, limitations, future research, and social and scientific relevance:

1. Does the presented framework offer a solution for the identified problem?
2. Would you be able to identify some aspect of the framework that may compromise its purpose?
3. Could you envision some requirement overlooked by the framework, or what could it evolve into?
4. Do you consider the framework has the potential to have some social impact and some contribution to the scientific base of knowledge?

The first questions received unanimous positive feedback. The framework appeared relevant, innovative, and presented a solution for a wide range of accessibility issues for students with different disabilities and for those without them.

The second question raised feedback from the panel that would be incorporated on the current stage of the framework. Tânia Rocha noted that an automatic validator can easily produce false positives if an ”alt *text”* tag, e.g. is used with just ”Figure 1”, ”Figure 2”, etc. meaning the criteria could be met with meaningless information, hence suggesting this should be complemented with human validation by accessibility experts. Alexandre Barão suggested the framework forgot facilitating the professors with some aid to produce accessible content and suggested the utility of learning objects that would promote the reusability of content components as an alternative to producing entire documents or other materials over and over. Adopting the OOP paradigm in pedagogy would promote reusing already validated content components previously uploaded to the platform and its potential to be indexed by metadata. Márcio Martins suggested following the W3C guideline to always use the most recent version of WCAG, even if still labeled as working drafts and if that version is still not mandatory by law.

The third question was answered by Alexandre Barão while answering the second question. The other participants considered the platform complete and already a breakthrough the current state of the art.

In the final question the participants were unanimous to consider the inclusion value represented in the framework with Alexandre Barão alerting that inclusion mustn’t exclude users without disabilities as those also benefit from raised accessibility. The potential contribution to the scientific base of knowledge was also unanimously recognized therefore confirming the compliance with Design Research Science methodology.

The full focus group session transcripts are available in the “*Focus Group Transcripts*” Annex

6. CONCLUSIONS

6.1. SYNTHESIS OF THE DEVELOPED WORK

Revisiting the motivation for the dissertation it becomes evident that despite tending to the same problem: the need for more accessible pedagogic content and platforms; the ambition for the proposed platform immensely outgrew the initially thought digital library with a recommendation system, which was already proposed as future research on a previous Masters Dissertation. This is due both to what was possible to learn during the first year of NOVA IMS' Master Degree Program in Data Science and Advanced Analytics and to what the systematic literature review allowed finding besides what the author previously researched on specific points of interest, looking for both concept definitions and the state of the art on those fields of knowledge.

Doing a systematic literature review motivated going beyond some biased mindset and taking not only justification for a pre-conceived project citing the original references in each field of knowledge but to look for what different authors are discussing more recently and mostly to what the state of the art is these days.

Instead of finding the best way to adapt each content to each different disability, possibly having *n* different versions of each document, such as document x for the blind and visually impaired, video y adapted for the deaf and hearing impaired, speech to text inputs for the mute and other speaking impairments, etc. a broader study of the state of the art was important to find that all that has been invented already. There will be no need to reinvent the wheel or discover fire or steam if *"only"* developers and authors follow the WCAG guidelines as If they were required by law, which they actually are.

The literature review also unveiled there were authors naming education and digital accessibility or inclusion in higher education as possible applications for the various disciplines of Artificial Intelligence. After finding out about Minsky and Picard it was impossible not to bring Affective Computing into any user centered platform when we need further understanding of users in a learning process and even more so when we are speaking of students with special education needs.

Early in the Masters Degree Program, Professor Roberto Henriques mentioned a regression problem where the machine would predict the success chances or probable grade for a student as he used a LMS. That feature instantly became a requirement in this dissertation.

After designing the framework, the focus group panel had the merit to more than patting the author on the back, challenging him with inputs that couldn't just be annotated as future research. After all, designing and validating and then evaluating, justifying or validating the artifact and recursively going back to the drawing board is all the Information Systems DSR Research Cycle is all about. In fact, having found the inclusion and accessibility needs in society and his personal experience as a disabled student and designing and proposing a solution for that problem justifies the DSR Relevance Cycle and the traditional and systematic literature reviews followed by attempting to publish the framework and presenting this dissertation justify the Rigor Cycle. Therefore the DSR methodology is validated.

Reviewing each of the intermediate goals on the roadmap for solving the research problem:

1. The different disabilities are extensively described and categorized by WHO ICF;
2. EN 301 549 describes the accessibility needs for each type of disability;
3. Compliance with WCAG (always in the latest version) assure that digital products and content will be accessible for all students regardless of their disability type through the assistive technology available for them;
4. The framework met the requirements;
5. The focus group validated and improved the artifact.

Regarding the gap identified in digital accessibility the proposed framework enables implementations that may bring more accessible content and classes for students, making it easier for professors to build content that being compliant with WCAG 3.0 won't require specific adaptations for students with different disabilities. This justifies the first word in the framework and thesis title: Inclusive.

Proposing modules featuring different disciplines of Artificial Intelligence the framework is able to profile students according to their characteristics, classify content, predict the probability of students failing their courses enabling timely pedagogic interventions. Bringing affective computing to the framework may raise legal or ethical debate, and more

6.2. Limitations

This research lacks field data that could enable prototyping all modules in an integrated fashion. Still, recurring to open-source datasets it was possible to prototype those functionalities separately.

6.3. Recommendations for Future Works

On the PhD thesis, capacitating the IILMS with Intelligent Personal Assistant technology will allow extending the accessibility of the system but will offer the opportunity to extend the recommendation system to virtualize the tutoring or studying companion figures tackling the loneliness of studying in higher education as a disabled person that still doesn't always feel like expected to be there.

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APPENDIX

Body Functions (Second Level)

Chapter 1 Mental functions

Global mental functions (b110-b139)

b110 Consciousness functions

b114 Orientation functions

b117 Intellectual functions

b122 Global psychosocial functions

b126 Temperament and personality functions

b130 Energy and drive functions

b134 Sleep functions

b139 Global mental functions, other specified and unspecified

Specific mental functions (b140-b189)

b140 Attention functions

b144 Memory functions

b147 Psychomotor functions

b152 Emotional functions

b156 Perceptual functions

b160 Thought functions

b164 Higher-level cognitive functions

b167 Mental functions of language

b172 Calculation functions

b176 Mental function of sequencing complex movements b180 Experience of self and time functions

b189 Specific mental functions, other specified and unspecified

b198 Mental functions, other specified

b199 Mental functions, unspecified

Chapter 2 Sensory functions and pain

Seeing and related functions (b210-b229)

b210 Seeing functions

b215 Functions of structures adjoining the eye

b220 Sensations associated with the eye and adjoining structures

b229 Seeing and related functions, other specified and unspecified

Hearing and vestibular functions (b230-b249)

b230 Hearing functions

b235 Vestibular functions

b240 Sensations associated with hearing and vestibular function

b249 Hearing and vestibular functions, other specified and unspecified

Additional sensory functions (b250-b279)

b250 Taste function

b255 Smell function

b260 Proprioceptive function

b265 Touch function

b270 Sensory functions related to temperature and other stimuli

b279 Additional sensory functions, other specified and unspecified

Pain (b280-b289)

b280 Sensation of pain

b289 Sensation of pain, other specified and unspecified

b298 Sensory functions and pain, other specified

b299 Sensory functions and pain, unspecified

Chapter 3 Voice and speech functions

b310 Voice functions

b320 Articulation functions

b330 Fluency and rhythm of speech functions

b340 Alternative vocalization functions

b398 Voice and speech functions, other specified

b399 Voice and speech functions, unspecified

Chapter 4 Functions of the cardiovascular, hematological, immunological and respiratory systems

Functions of the cardiovascular system (b410-b429)

b410 Heart functions

b415 Blood vessel functions

b420 Blood pressure functions

b429 Functions of the cardiovascular system, other specified and unspecified

Functions of the hematological and immunological systems (b430-b439)

b430 Hematological system functions

b435 Immunological system functions

b439 Functions of the hematological and immunological systems, other specified and unspecified

Functions of the respiratory system (b440-b449)

b440 Respiration functions

b445 Respiratory muscle functions

b449 Functions of the respiratory system, other specified and unspecified

Additional functions and sensations of the cardiovascular and respiratory systems (b450-b469)

b450 Additional respiratory functions

b455 Exercise tolerance functions

b460 Sensations associated with cardiovascular and respiratory functions

b469 Additional functions and sensations of the cardiovascular and respiratory systems, other specified and unspecified

b498 Functions of the cardiovascular, hematological, immunological and respiratory systems, other specified

b499 Functions of the cardiovascular, hematological, immunological and respiratory systems, unspecified

Chapter 5 Functions of the digestive, metabolic and endocrine systems

Functions related to the digestive system (b510-b539)

b510 Ingestion functions

b515 Digestive functions

b520 Assimilation functions

b525 Defecation functions

b530 Weight maintenance functions

b535 Sensations associated with the digestive system

b539 Functions related to the digestive system, other specified and unspecified

Functions related to metabolism and the endocrine system (b540-b559)

b540 General metabolic functions

b545 Water, mineral and electrolyte balance functions

b550 Thermoregulatory functions

b555 Endocrine gland functions

b559 Functions related to metabolism and the endocrine system, other specified and unspecified

b598 Functions of the digestive, metabolic and endocrine systems, other specified b599 Functions of the digestive, metabolic and endocrine systems, unspecified

Chapter 6 Genitourinary and reproductive functions

Urinary functions (b610-b639)

b610 Urinary excretory functions

b620 Urination functions

b630 Sensations associated with urinary functions

b639 Urinary functions, other specified and unspecified

Genital and reproductive functions (b640-b679)

b640 Sexual functions

b650 Menstruation functions

b660 Procreation functions

b670 Sensations associated with genital and reproductive functions

b679 Genital and reproductive functions, other specified and unspecified

b698 Genitourinary and reproductive functions, other specified

b699 Genitourinary and reproductive functions, unspecified

Chapter 7 Neuromusculoskeletal and movement-related functions

Functions of the joints and bones (b710-b729)

b710 Mobility of joint functions

b715 Stability of joint functions

b720 Mobility of bone functions

b729 Functions of the joints and bones, other specified and unspecified

Muscle functions (b730-b749)

b730 Muscle power functions

b735 Muscle tone functions

b740 Muscle endurance functions

b749 Muscle functions, other specified and unspecified

Movement functions (b750-b789)

b750 Motor reflex functions

b755 Involuntary movement reaction functions

b760 Control of voluntary movement functions

b765 Involuntary movement functions

b770 Gait pattern functions

b780 Sensations related to muscles and movement functions

b789 Movement functions, other specified and unspecified

b798 Neuromusculoskeletal and movement-related functions, other specified

b799 Neuromusculoskeletal and movement-related functions, unspecified

Chapter 8 Functions of the skin and related structures

Functions of the skin (b810-b849)

b810 Protective functions of the skin

b820 Repair functions of the skin

b830 Other functions of the skin

b840 Sensation related to the skin

b849 Functions of the skin, other specified and unspecified

Functions of the hair and nails (b850-b869)

b850 Functions of hair

b860 Functions of nails

b869 Functions of the hair and nails, other specified and unspecified

b898 Functions of the skin and related structures, other specified

b899 Functions of the skin and related structures, unspecified

ANNEXES

Focus Group Transcripts

Before starting the focus group session the panel members were asked for permission to record the online meeting so it would be possible to transcript the presentation, questions and answers.

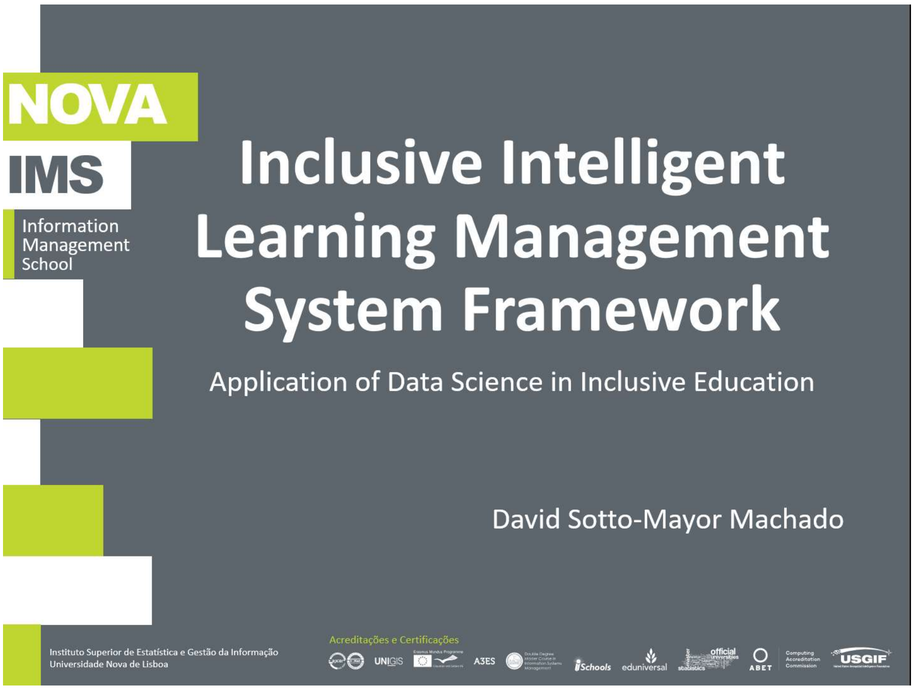
The transcripts are presented in 5 sections:

1. Presentation;
2. Question 1 (targeting validation): Does the proposed framework seem to meet the identified need?
3. Question 2 (targeting limitations): Do you identify any aspect of the framework that seems to diminish or compromise its chances of success?
4. Question 3 (targeting future research or improvement opportunities): Do you identify any related requirements that have not been contemplated?
5. Question 4 (targeting social applicability and scientific relevance): As stakeholders and experts do you consider that the proposal has room for practical implementation and can become a contribution to scientific knowledge?

Later written consent was requested to by email or written message to use the panel participants' LinkedIn profile pictures and header information to identify them as panel members of this focus group. These authorizations are transcribed in the end of this annex.

Presentation

Author: *"The title of the dissertation is Inclusive Intelligent Learning Management System Framework, Application of Data Science in Inclusive Education.*



That title reflects the goal of delivering such an artifact to face the students' need to access pedagogic materials in a multimodal and accessible format according to their preferences and capacities, whether the students have some disability or not.

This tool must potentiate the share of accessible pedagogic materials among the academic community (teachers and students).

For that purpose the following intermediate goals are set:

1. *Identify the different disabilities and the needs of adaptation to each;*
2. *Identify the best way to ensure the digital accessibility of the platform and content for each student profile;*
3. *Categorize user profiles;*
4. *Monitor the emotional impact during the consumption of pedagogical materials by users;*
5. *Collect user feedback;*
6. *Make recommendations depending on usage, profile, emotional reactions, and user feedback;*
7. *Monitor the evolution of each user signaling the risk of failing a curricular unit while there still is the possibility of pedagogical intervention.*

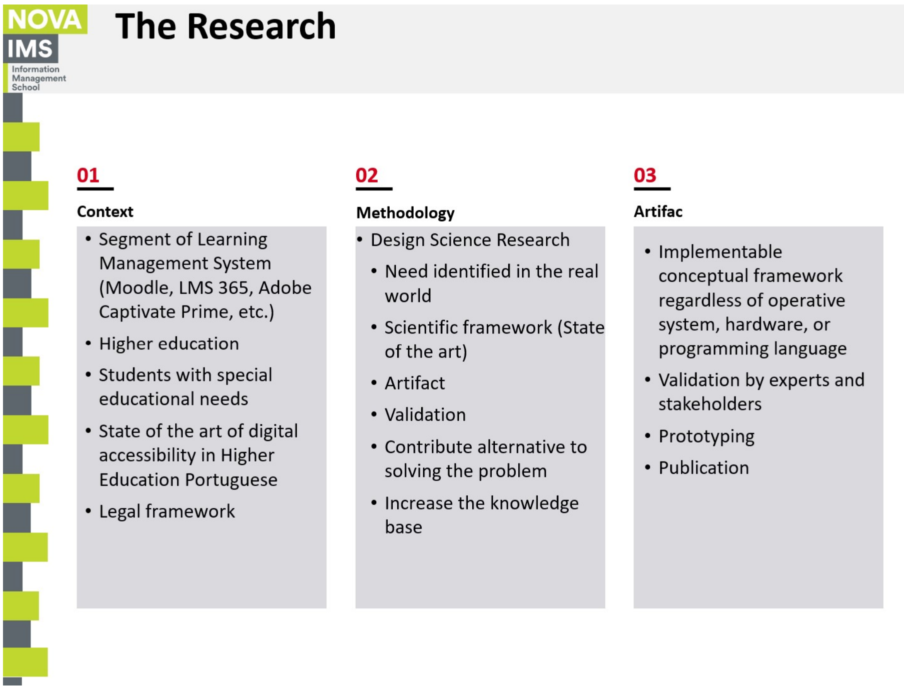
Problem Definition

1. Allowing students to access pedagogical materials in multimodal format accessible to the different capacities of each student with or without disabilities;
2. The tool should enhance the sharing of educational materials accessible among the academic community (teachers and students).
3. Intermediate objectives:
   1. Identify the different disabilities and the needs of adaptation to each;
   2. Identify the best way to ensure the digital accessibility of the platform and content for each student profile;
   3. Categorize user profiles;
   4. Monitor the emotional impact during the consumption of pedagogical materials by users;
   5. Collect user feedback;
   6. Make recommendations depending on usage, profile, emotional reactions and user feedback;
   7. Monitor the evolution of each user signaling the risk of failure while there is some possibility of pedagogical intervention.

The context of the research includes the learning management systems (Moodle, LMS 365, Adobe Captivate Prime, etc.), higher education, students with disabilities, state of the art of digital accessibility in the Portuguese higher education system and related technologies, and the legal and standards framework.

The chosen research methodology was Design Science Research, not only because it involved iterations of designing and developing an artifact and validating it, but because the relevance and rigor cycles are clearly identified as this research tries to offer society a contribute to solve a problem that was identified in it, and the rigor cycle as the research draws it's context and state of the art from the scientific base of knowledge to which the author brings a contribution while publishing this research findings and results.

The artifact is the conceptual framework which can be implemented independently of the chosen platform, operating system, or programming languages. This is the artifact you were invited to validate or reject as different stakeholder, some for-teaching web development or researching accessible human computer interaction other also researching digital accessibility while representing the students with disabilities, like myself. This artifact is still to be prototyped before the thesis submission, even if modularly, and the framework design will be published, as will the state of the art of the Portuguese higher education institutions websites accessibility.



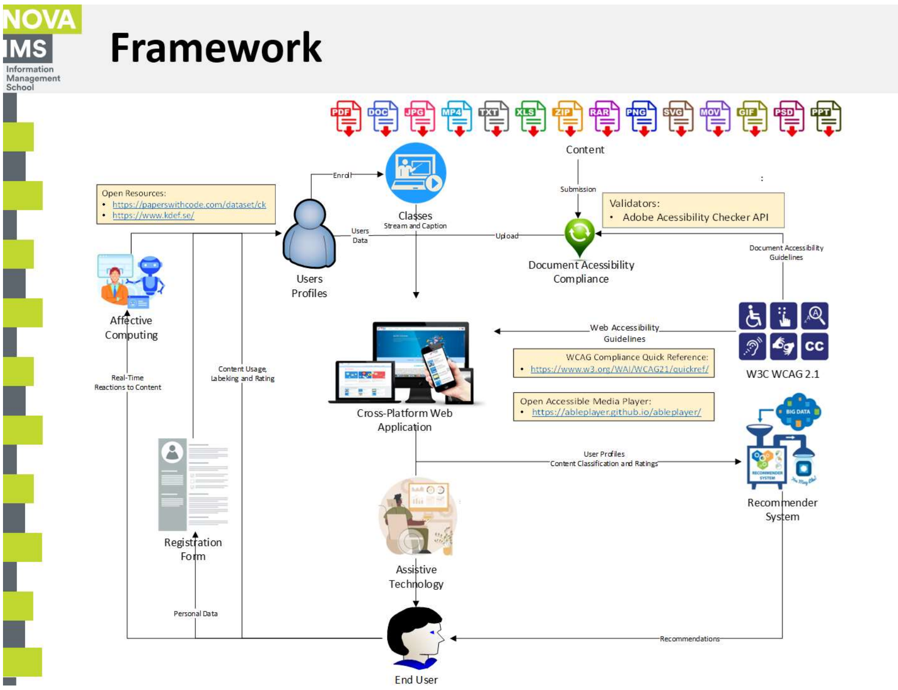
The actual framework is centered on the user who is profiled since the registration form submission, through the identification, processing and recording emotions detected from facial expressions while consuming pedagogic material and by retrieving their own rating and labeling of consumed resources.

Classes and digital content are uploaded or live streamed through the platform while the upload is verified for accessibility by an API that will only allow uploading accessible content.

The WCAG 2.1 Level AA criteria will be considered when implementing the application, producing, and assessing the digital content before publication.

An accessible media player must be used as recent studies have proven the most used online video player (YouTube) doesn't meet half of the WCAG 2.1 AA criteria therefore not possibly being considered accessible.

The multimodality desired was found to be assured by the assistive technologies students already use or others that may and must be included on the platform such as text to speech through screen readers, live captioning of streamed or recorded content and many other devices described in a systematic literature review, finally all the data collected about users and content allows deploying a recommender system."



Q1: Does the proposed framework seem to meet the identified need?

Tânia Rocha: *"The way you presented it appears well thought and structured. I believe it can effectively tend to the need that was identified."*

Márcio Martins: *"The platform seems important for the students making available accessible pedagogic materials and allowing professors, possibly from different higher education institutions to share these contents, maybe working as a shared repository, which presently doesn't exist. It does seem to effectively address the necessity and proposes innovative features such as student's emotions recognition capturing important feedback that may go unnoticed by the end-users themselves. The captioning and translation of streamed or live classes may be useful not only for deaf users but if these subtitles can be read by a screen reader, then it is also extremely helpful for blind or visually impaired students as well. Other than a suggestion (moved to the answers to question 2), I think the framework as it is presented is very complete, very detailed in user profiling."*

Alexandre Barão: *"The framework itself seems complete and well designed. I have an observation to make from the academic or scientific formal perspective. I advise you to distinctively separate the problem from the context and motivation. In one sentence, explicit, unambiguous, and closed (no reticence marks). Otherwise it seems that you presented your strategy to solve the problem as the problem itself and those are different matters."*

Q2: Do you identify any aspect of the framework that seems to diminish or compromise its chances of success?

Tânia Rocha: *"May you please go back to the framework's architecture slide? It doesn't appear to be a weak link in the framework. However, I would suggest not using only this automated validator. The automated validation is important; but it should be a mixed validation mode complementing the automated validation by human validation, preferably by accessibility experts. We know how easily an API may validate a false positive, meaning, e.g. than an "alt text" tag may be filled with meaningless information (Figure 1, Figure 2, etc.) and that can make the automatic validator mark a document as accessible when a visually impaired student will be oblivious to whatever those figures are illustrating. Mind that some recent versions of such tools already signal this improper use of the tags, while other try to apply automated image descriptions that say something but still insufficient to allow such users to obtain knowledge from those elements of the document. Accessibility and usability experts may help even if only validating the first automated screening."*

Márcio Martins: *"If I understood correctly, the platform and contents accessibility is going to be evaluated according to its compliance with WCAG, right? But you indicate version 2.1, the version required by law. Even if that is the version currently in production in 2021 versions 2.2 and 3.0 became available offering a set of important new guidelines or perfecting those already available, what can, or actually offer importantly improved accessibility standards for people with different disability types, therefore making the platforms that adopt them more accessible for a broader audience or more accessible for those already considered in previous versions. W3C actively suggests using always the most recent version, even if these may still be under development or being assessed and debated. In my opinion these newer WCAG dive deeper into the spirit of European Norm 301 549 that only addresses the web accessibility guidelines but a complete scope of digital accessibility including contents such as documents, presentations, vídeos, live streams and the adaptations required for each disability or the guidelines to make sure each assistive technology can make that content accessible for users with different profiles as your framework proposes. I strongly advise you to take this into consideration."*

Alexandre Barão: *"I strongly agree with Márcio's opinion regarding the adoption of WCAG 3.0."*

Q3: Do you identify any related requirements that have not been contemplated?

Tânia Rocha: *"The way you presented it appears very complete indeed. Of course that after profiling the users we want to optimize the content presented to them. I already know your PhD Thesis Plan and it seems well thought and planned and structured. I might as well add that I particularly appreciated the affective computing module because in the accessibility area we need to understand the end users in a much empathetic way, isn't it so? So I find very interesting this comprehension of the emotional impact of what the students are reading or watching. Maybe with some psychology assistance we can find some metrics to extract from it, like motivational evaluation, and learning process related, not only satisfaction about usability or more globally user experience."*

Márcio Martins: *"I would just add that maybe the framework can add the accessible content production 'how tos' increasing the availability of this knowledge to professors. These 'how tos' can be found on the web if someone is really looking for them, but it would be easier for a professor to click on a link in the platform than 'Googling' it outside."*

Alexandre Barão: *"I see lots of technology aspects in the framework. I can't see any more technology aspects that you could add to it, but you know the framework is only going to work if the professors feel motivated to use it. It's all good when we think about making the academic life easier for the students, but does the framework make the professors life any easier when it comes to producing accessible content for them? Or is it going to penalize the professors work and raise objections from them? Most of us may not even know how to. We were not educated or trained in pedagogy or accessibility matters. And I speak against myself here. So, how can you make professors lives easier, accessibility-wise speaking? I suggest you look into Learning Objects. Remember the Object-Oriented Programming paradigm? Objects reusability, still rings any bells? Look at your framework top-down, it starts with that myriad of contents. PDfs, docs, spreadsheets… Complete contents that may contain topics A, B, C, D, E, F… If I am a professor also producing content about… History of Lisbon e.g., or Oporto, let's all move up North, I will have to produce an entire document again… So what if someone uploads the contents as more atomized objects? Let's say that instead of uploading the document someone upload their text and some figures already with their "alt text". The next professor may not copy/paste the entire text, because he may apply the same content on a different context, and may even need to rewrite it entirely, but he will not have to rewrite the "alt text" for the same picture anymore. See where I am getting at? Make it efficient for the professors and you may make it more effective for the students. If you need to rely on the professors, this may motivate them to follow your path. So, why not starting the framework with some contribute (this one not technological) to the accessible digital production and submission? Atomize content production with object reusability building Learning Objects with bits of accessibility validated atomic objects. That way instead of validating an entire document and later duplicating content you enable reusability. You have much technological added value in the framework, now to promote accessibility and to spread the accessibility 'Gospel' you need to add value for the professors and not only for the students."*

Q4: As stakeholders and experts do you consider that the proposal has room for practical implementation and can become a contribution to scientific knowledge?

Tânia Rocha: *"Absolutely! As you well researched and the literature review demonstrates, the actual platforms have many accessibility issues, not only in the platforms design itself but also on the content made available there. If you do achieve the goals you have set this will bring added value for students but also for professors and let me stress the importance for professors as often they want to make their contents more accessible and they don't know how. In the scientific field this is actually a trending discussion. We know there are already accessibility guidelines, standards, and laws. We have acquired knowledge about usability and user experience, and we know there is still a gap in accessible contents and accessible platforms. So what is going on? It is no longer lack of knowledge and no longer a matter of sensibilization or raising awareness. It is necessary that the tools, and even the development and productivity platforms become usable and accessible so developers can produce more accessible platforms and authors generate more accessible content. So, personally all research done in this field adds value, but this project really deeply focuses on applying technology to make inclusion in higher education come true."*

Márcio Martins: *"Regarding the scientific knowledge I don't know the state of the art you found in your research, but on my experience researching accessibility I haven't seen any similar research, so I believe you really found your very own research niche here. I really don't recall seeing someone applying the fields of science you approached for accessibility and inclusion purposes. And if that is true in the scientific knowledge base, if this framework is implemented you are tacking a problem in society for which there was still no solution. Any Higher Education Institution may benefit from adopting it."*

Alexandre Barão: *"I strongly agree with what was already said. You added value by combining all these pieces of a big puzzle, and your predisposition to altruistically research this social issue is highly commendable, so you really have this relevance space to research as difficulties arise and are real. Now, I just wanted to warn against the pitfall of speaking about inclusion and forgetting to make it useful, or accessible in this context, for anyone. Don't exclude people without disabilities when talking about inclusion or you may fall in contradiction. I was able to notice you speak about people with or without permanent or temporary disabilities, but when presenting spend a couple more seconds providing an example of when accessibility matters for someone without disabilities, so you can imprint in your audience the idea that this framework really is for everyone."*

Image Rights

All the participant members of the focus group panel were warned and questioned regarding their agreement to the recording of the Focus Group session for transcription and translation purposes.

After, while transcribing the sessions the author considered using the panel members LinkIn pictures and header data to describe and illustrate the panel. To this end, the panel members were contacted by email or instant message requesting their permission to use their image and professional data. The all agreed answering as transcribed bellow

Tânia Rocha: *"Yes, you may use it."*
Márcio Martins: *"Good evening David. You may use it. You can find more pictures in the following link: https://someurl.org".*
Alexandre Barão: *"Of course you can use it."*

Predictive Model

October 15, 2022

Annex 1

Logistic Regression Model Trained and Tested on a Dataset of Students' Performance Using Student Information System, Moodle and the Mobile Application "eDify"

Data Source: https://zenodo.org/record/5591907#.Y0oatnaZND8

Lack of available data hinders the development and training of the models featured in the framework, still it was possoble to find a set of real data of student's performance while using learning management systems

On further research the author expects to be able to gather data from students with disabilities in higer education

0.1 Importing Libraries

```
[1]: import pandas as pd, matplotlib.pyplot as plt, numpy as np, seaborn as sns,␣
     ↪warnings
     warnings.filterwarnings('ignore')
     from sklearn.model_selection import train_test_split
     from sklearn.model_selection import KFold
     from sklearn.linear_model import LogisticRegression
     from sklearn.preprocessing import LabelEncoder, OneHotEncoder
```

0.2 Importing Data

```
[2]: df = pd.read_excel('dataset.xlsx')
```

```
[3]: df.head()
```

```
[3]:   ApplicantName       CGPA AttemptCount RemoteStudent Probation HighRisk  \
     0     Student 1  Very Good          Low            No        No       No
     1     Student 2       Fair          Low            No        No       No
     2     Student 3       Fair          Low            No        No       No
     3     Student 4   Adequate          Low            No        No       No
     4     Student 5       Fair          Low            No        No       No

       TermExceeded AtRisk AtRiskSSC OtherModules …      CW1       CW2  \
     0           No     No        No         High …     Fair      Fair
     1           No     No        No         High …     Fair      Fair
```

```
2          No     No        No          Low  …      Fail      Fail
3          No     No        No         High  …  Adequate  Adequate
4          No     No        No       Medium  …  Adequate  Adequate

        ESE   Online C   Online O Played  Paused  Likes  Segment  Result
0  Adequate  Very Good  Excellent      3       1      2        2    Pass
1  Adequate       Poor       Poor      1       0      0        0    Pass
2      Fail       Fair  Very Good      2       2      1        1    Pass
3      Fail  Very Good       Fair      3       1      1        2    Pass
4  Adequate       Fair  Very Good      8      13      1        7    Pass

[5 rows x 21 columns]
```

1 Dataset Analysis

[4]:
```python
# checking for nulls
df.isnull().sum()
```

[4]:
```
ApplicantName       0
CGPA                0
AttemptCount        0
RemoteStudent       0
Probation           0
HighRisk            0
TermExceeded        0
AtRisk              0
AtRiskSSC           0
OtherModules        0
PlagiarismHistory   0
CW1                 0
CW2                 0
ESE                 0
Online C            0
Online O            0
Played              0
Paused              0
Likes               0
Segment             0
Result              0
dtype: int64
```

[5]:
```python
# Statistics per column
df.describe(include='all').transpose()
```

[5]:
```
                  count unique        top freq       mean       std  min  25%  \
ApplicantName       326    326  Student 1    1        NaN       NaN  NaN  NaN
```

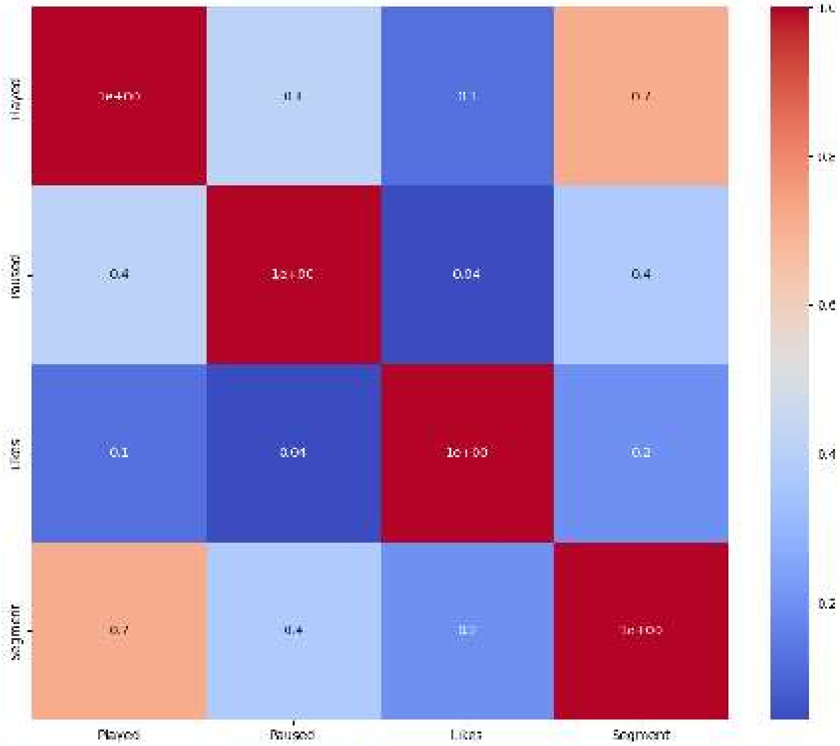
CGPA	326	6	Adequate	120	NaN	NaN	NaN	NaN
AttemptCount	326	3	Low	302	NaN	NaN	NaN	NaN
RemoteStudent	326	2	No	325	NaN	NaN	NaN	NaN
Probation	326	2	No	315	NaN	NaN	NaN	NaN
HighRisk	326	2	No	304	NaN	NaN	NaN	NaN
TermExceeded	326	2	No	320	NaN	NaN	NaN	NaN
AtRisk	326	2	No	249	NaN	NaN	NaN	NaN
AtRiskSSC	326	2	No	311	NaN	NaN	NaN	NaN
OtherModules	326	3	High	170	NaN	NaN	NaN	NaN
PlagiarismHistory	326	2	Low	325	NaN	NaN	NaN	NaN
CW1	326	6	Fail	163	NaN	NaN	NaN	NaN
CW2	326	6	Fail	174	NaN	NaN	NaN	NaN
ESE	326	6	Adequate	127	NaN	NaN	NaN	NaN
Online C	326	6	Good	111	NaN	NaN	NaN	NaN
Online O	326	6	Good	83	NaN	NaN	NaN	NaN
Played	326.0	NaN	NaN	NaN	2.131902	1.760532	0.0	1.0
Paused	326.0	NaN	NaN	NaN	2.184049	2.603522	0.0	0.0
Likes	326.0	NaN	NaN	NaN	1.0	0.967153	0.0	0.0
Segment	326.0	NaN	NaN	NaN	1.484663	1.875693	0.0	0.0
Result	326	2	Pass	264	NaN	NaN	NaN	NaN

	50%	75%	max
ApplicantName	NaN	NaN	NaN
CGPA	NaN	NaN	NaN
AttemptCount	NaN	NaN	NaN
RemoteStudent	NaN	NaN	NaN
Probation	NaN	NaN	NaN
HighRisk	NaN	NaN	NaN
TermExceeded	NaN	NaN	NaN
AtRisk	NaN	NaN	NaN
AtRiskSSC	NaN	NaN	NaN
OtherModules	NaN	NaN	NaN
PlagiarismHistory	NaN	NaN	NaN
CW1	NaN	NaN	NaN
CW2	NaN	NaN	NaN
ESE	NaN	NaN	NaN
Online C	NaN	NaN	NaN
Online O	NaN	NaN	NaN
Played	1.0	3.0	8.0
Paused	1.0	4.0	13.0
Likes	1.0	1.75	3.0
Segment	0.0	3.0	7.0
Result	NaN	NaN	NaN

[6]:
```
# Pearson Correlation (Numerical Features)
pc=df.corr(method='pearson')
```

```
[7]: def plotcorr(cor):
         plt.figure(figsize=(12,10))
         sns.heatmap(data = cor, annot = True, cmap = plt.cm.coolwarm, fmt='.1')
         plt.show()
```

```
[8]: plotcorr(pc)
```



2 Feature Selection

```
[9]: # Drop "Applicant Name"
     df=df.drop(['ApplicantName'],axis=1)
```

```
[10]: # Drop "Segment" highly correlated to "Played"
      df=df.drop(['Segment'], axis=1)
```

3 Modeling

[11]:
```
# Split independent and dependent features
X = df.iloc[:,:-1]
Y = df.iloc[:,-1]
```

[12]:
```
#Enconding Independent Features (X)
labelencoder_X = LabelEncoder()
X.iloc[:,0] = labelencoder_X.fit_transform(X.iloc[:,0])
X.iloc[:,1] = labelencoder_X.fit_transform(X.iloc[:,1])
X.iloc[:,2] = labelencoder_X.fit_transform(X.iloc[:,2])
X.iloc[:,3] = labelencoder_X.fit_transform(X.iloc[:,3])
X.iloc[:,4] = labelencoder_X.fit_transform(X.iloc[:,4])
X.iloc[:,5] = labelencoder_X.fit_transform(X.iloc[:,5])
X.iloc[:,6] = labelencoder_X.fit_transform(X.iloc[:,6])
X.iloc[:,7] = labelencoder_X.fit_transform(X.iloc[:,7])
X.iloc[:,8] = labelencoder_X.fit_transform(X.iloc[:,8])
X.iloc[:,9] = labelencoder_X.fit_transform(X.iloc[:,9])
X.iloc[:,10] = labelencoder_X.fit_transform(X.iloc[:,10])
X.iloc[:,11] = labelencoder_X.fit_transform(X.iloc[:,11])
X.iloc[:,12] = labelencoder_X.fit_transform(X.iloc[:,12])
X.iloc[:,13] = labelencoder_X.fit_transform(X.iloc[:,13])
X.iloc[:,14] = labelencoder_X.fit_transform(X.iloc[:,14])
X
```

[12]:
```
     CGPA  AttemptCount  RemoteStudent  Probation  HighRisk  TermExceeded  \
0       5             1              0          0         0             0
1       2             1              0          0         0             0
2       2             1              0          0         0             0
3       0             1              0          0         0             0
4       2             1              0          0         0             0
..    ...           ...            ...        ...       ...           ...
321     2             1              0          0         0             0
322     0             1              0          1         1             0
323     0             1              0          0         0             0
324     3             1              0          0         0             0
325     0             1              0          0         1             0

     AtRisk  AtRiskSSC  OtherModules  PlagiarismHistory  CW1  CW2  ESE  \
0         0          0             0                  0    3    3    0
1         0          0             0                  0    3    3    0
2         0          0             1                  0    2    2    2
3         0          0             0                  0    0    0    2
4         0          0             2                  0    0    0    0
..      ...        ...           ...                ...  ...  ...  ...
321       0          0             0                  0    0    2    2
322       1          0             1                  0    0    2    4
```

```
323        0           0             0                0    0    2    0
324        1           0             1                0    0    2    0
325        1           0             0                0    2    0    2

     Online C  Online O  Played  Paused  Likes
0           5         1       3       1      2
1           4         4       1       0      0
2           2         5       2       2      1
3           5         2       3       1      1
4           2         5       8      13      1
..        ...       ...     ...     ...    ...
321         5         1       5       2      2
322         4         1       1       5      3
323         1         1       1       3      3
324         3         5       0       3      0
325         1         5       5       0      1

[326 rows x 18 columns]
```

[13]:

```
# One Hot Encoding
onehotencoder = OneHotEncoder(categories='auto', drop=None, dtype=np.float64)
CGPA=onehotencoder.fit_transform(X[['CGPA']]).toarray()
AttemptCount=onehotencoder.fit_transform(X[['AttemptCount']]).toarray()
RemoteStudent=onehotencoder.fit_transform(X[['RemoteStudent']]).toarray()
Probation=onehotencoder.fit_transform(X[['Probation']]).toarray()
HighRisk=onehotencoder.fit_transform(X[['HighRisk']]).toarray()
TermExceeded=onehotencoder.fit_transform(X[['TermExceeded']]).toarray()
AtRisk=onehotencoder.fit_transform(X[['AtRisk']]).toarray()
AtRiskSSC=onehotencoder.fit_transform(X[['AtRiskSSC']]).toarray()
OtherModules=onehotencoder.fit_transform(X[['OtherModules']]).toarray()
PlagiarismHistory=onehotencoder.fit_transform(X[['PlagiarismHistory']]).
  ↪toarray()
CW1=onehotencoder.fit_transform(X[['CW1']]).toarray()
CW2=onehotencoder.fit_transform(X[['CW2']]).toarray()
ESE=onehotencoder.fit_transform(X[['ESE']]).toarray()
OnlineC=onehotencoder.fit_transform(X[['Online C']]).toarray()
OnlineO=onehotencoder.fit_transform(X[['Online O']]).toarray()
d=np.append(CGPA,AttemptCount,axis=1)
d=np.append(d,RemoteStudent, axis=1)
d=np.append(d,Probation, axis=1)
d=np.append(d,HighRisk, axis=1)
d=np.append(d,TermExceeded, axis=1)
d=np.append(d,AtRisk, axis=1)
d=np.append(d,AtRiskSSC, axis=1)
d=np.append(d,OtherModules, axis=1)
d=np.append(d,PlagiarismHistory, axis=1)
d=np.append(d,CW1, axis=1)
```

```
d=np.append(d,CW2, axis=1)
d=np.append(d,ESE, axis=1)
d=np.append(d,OnlineC, axis=1)
d=np.append(d,OnlineO, axis=1)
X2=pd.DataFrame(data=d, index=X.index,columns=['CGPA 0','CGPA 1','CGPA 2','CGPA␣
↪3','CGPA 4','CGPA 5','AttemptCount 0',
                                            'AttemptCount 1','AttemptCount␣
↪2','RemoteStudent 0','RemoteStudent 1',
                                            'Probation 0','Probation␣
↪1','HighRisk 0','HighRisk 1','TermExceeded 0',
                                            'TermExceeded 1','AtRisk␣
↪0','AtRisk 1','AtRiskSSC 0','AtRiskSSC 1',
                                            'OtherModules 0','OtherModules␣
↪1','OtherModules 2','PlagiarismHistory 0',
                                            'PlagiarismHistory 1','CW1␣
↪0','CW1 1','CW1 2','CW1 3','CW1 4','CW1 5',
                                            'CW2 0','CW2 1','CW2 2','CW2␣
↪3','CW2 4','CW2 5','ESE 0','ESE 1','ESE 2',
                                            'ESE 3','ESE 4','ESE 5','Online C␣
↪0','Online C 1','Online C 2',
                                            'Online C','Online C 4','Online C␣
↪5','Online O 0','Online O 1',
                                            'Online O 2','Online O','Online O␣
↪4','Online O 5'])
X=pd.concat([X2,X.iloc[:,-3:]],axis=1)
X
```

```
[13]:      CGPA 0  CGPA 1  CGPA 2  CGPA 3  CGPA 4  CGPA 5  AttemptCount 0  \
     0        0.0     0.0     0.0     0.0     0.0     1.0             0.0
     1        0.0     0.0     1.0     0.0     0.0     0.0             0.0
     2        0.0     0.0     1.0     0.0     0.0     0.0             0.0
     3        1.0     0.0     0.0     0.0     0.0     0.0             0.0
     4        0.0     0.0     1.0     0.0     0.0     0.0             0.0
     ..       ...     ...     ...     ...     ...     ...             ...
     321      0.0     0.0     1.0     0.0     0.0     0.0             0.0
     322      1.0     0.0     0.0     0.0     0.0     0.0             0.0
     323      1.0     0.0     0.0     0.0     0.0     0.0             0.0
     324      0.0     0.0     0.0     1.0     0.0     0.0             0.0
     325      1.0     0.0     0.0     0.0     0.0     0.0             0.0

          AttemptCount 1  AttemptCount 2  RemoteStudent 0  ...  Online C 5  \
     0               1.0             0.0              1.0  ...         1.0
     1               1.0             0.0              1.0  ...         0.0
     2               1.0             0.0              1.0  ...         0.0
     3               1.0             0.0              1.0  ...         1.0
     4               1.0             0.0              1.0  ...         0.0
```

```
..            ...          ...          ... ...       ...
321           1.0          0.0          1.0  ...      1.0
322           1.0          0.0          1.0  ...      0.0
323           1.0          0.0          1.0  ...      0.0
324           1.0          0.0          1.0  ...      0.0
325           1.0          0.0          1.0  ...      0.0

     Online O 0  Online O 1  Online O 2  Online O  Online O 4  Online O 5  \
0           0.0         1.0         0.0       0.0         0.0         0.0
1           0.0         0.0         0.0       0.0         1.0         0.0
2           0.0         0.0         0.0       0.0         0.0         1.0
3           0.0         0.0         1.0       0.0         0.0         0.0
4           0.0         0.0         0.0       0.0         0.0         1.0
..          ...         ...         ...       ...         ...         ...
321         0.0         1.0         0.0       0.0         0.0         0.0
322         0.0         1.0         0.0       0.0         0.0         0.0
323         0.0         1.0         0.0       0.0         0.0         0.0
324         0.0         0.0         0.0       0.0         0.0         1.0
325         0.0         0.0         0.0       0.0         0.0         1.0

     Played  Paused  Likes
0         3       1      2
1         1       0      0
2         2       2      1
3         3       1      1
4         8      13      1
..      ...     ...    ...
321       5       2      2
322       1       5      3
323       1       3      3
324       0       3      0
325       5       0      1

[326 rows x 59 columns]
```

[14]:
```python
# Split into Train and Test
X_train_val, X_test, y_train_val, y_test = train_test_split(X,Y, test_size=0.2,␣
↪random_state=15,shuffle=True,stratify=Y)
```

[15]:
```python
#Split into Train, Test and Validate
X_train, X_val, y_train, y_val =␣
↪train_test_split(X_train_val,y_train_val,test_size = 0.25,random_state =␣
↪15,shuffle=True,
                                                          stratify=y_train_val)
```

[16]:
```python
# Proportion of Train, Test and Validation from Original dataset
```

```
print('Train:{}% | Test:{}% | Validation:{}% '.format(round(len(y_train)*100/
 ↪len(Y),0),
                                                       round(len(y_test)*100/
 ↪len(Y),0),
                                                       round(len(y_val)*100/
 ↪len(Y),0)))
```

```
Train:60.0% | Test:20.0% | Validation:20.0%
```

[17]:
```
# Encoding Dependent Features (Y)
labelencoder_Y = LabelEncoder()
Y = pd.DataFrame(labelencoder_Y.fit_transform(Y))
print(Y)
```

```
     0
0    1
1    1
2    1
3    1
4    1
..  ..
321  1
322  1
323  1
324  1
325  0

[326 rows x 1 columns]
```

3.1 Logistic Regression

[18]:
```
# Functions
def run_model_LR(X,Y):
    model = LogisticRegression().fit(X,Y)
    return model

def evaluate_model(X,Y, model): return model.score(X,Y)

def avg_score_LR(method,X,y):
    score_train = []
    score_test = []
    for train_index, test_index in method.split(X):
        X_train, X_test = X.iloc[train_index], X.iloc[test_index]
        y_train, y_test = y.iloc[train_index], y.iloc[test_index]
        model = run_model_LR(X_train, y_train)
        value_train = evaluate_model(X_train, y_train, model)
        value_test = evaluate_model(X_test,y_test, model)
        score_train.append(value_train)
```

```
        score_test.append(value_test)
    print('Train:', np.mean(score_train))
    print('Test:', np.mean(score_test))
```

[19]:
```
# testing different k level for KFolding
def test_k():
    listkresults=[]
    for k in range (5,51,5):
        kf = KFold(n_splits=k)
        print (k)
        listkresults.append(avg_score_LR(kf, X, Y))
    return listkresults
```

[20]:
```
results=test_k()
```

```
5
Train: 0.914117300324197
Test: 0.8525874125874126
10
Train: 0.9148034640477352
Test: 0.8555871212121213
15
Train: 0.9147727926373308
Test: 0.8769119769119771
20
Train: 0.9147578035285522
Test: 0.8891544117647058
25
Train: 0.9156434832473173
Test: 0.8800000000000001
30
Train: 0.9152742616033755
Test: 0.8836363636363634
35
Train: 0.9154645438417351
Test: 0.8885714285714285
40
Train: 0.9153683808503462
Test: 0.8885416666666668
45
Train: 0.9150174483941564
Test: 0.8857142857142855
50
Train: 0.9150523119122258
Test: 0.8871428571428571
```

The logistic regression model with 20 kfolds appears to be effective and efficient in predicting students success based on their LMS usage

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