ORIGINAL ARTICLE

# Inclusive Intelligent Learning Management System Framework

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**Abstract:** The article finds context and the current state of the art in a systematic literature review on intelligent systems employing PRISMA Methodology which is complemented with narrative literature review on disabilities, digital accessibility and legal and standards context. The main conclusion from this review was the existing gap between the available knowledge, standards, and law and what is put into practice in higher education institutions in Portugal. Design Science Research Methodology was applied to output an Inclusive Intelligent Learning Management System Framework aiming to help higher education professors to share accessible pedagogic content and deliver on-line and presential classes with a high level of accessibility for students with different types of disabilities, assessing the uploaded content with Web content Accessibility Guidelines 3.0, clustering students according to their profile, conscient feedback and emotional assessment during content consumption, applying predictive models and signaling students at risk of failing classes according to study habits and finally applying a recommender system. The framework was validated by a focus group to which experts in digital accessibility, information systems and a disabled PhD graduate.

**Keywords:** Intelligent Systems, Learning Management Systems, Digital Accessibility, Affective Computing, International Legal Framework.

## Introduction

There is a shift in higher education toward more inclusive institutions and increasing access for under-represented groups like students with disabilities [1]. According to researchers, it is a well-established fact that there are impaired students in higher education, hence it is necessary to update the instructional strategies and resources [2]. However, according to recent studies, some governments continue to oppose the inclusion of disabled students [3]. These oppositions are primarily caused by historical reluctance to involve in familiar concerns and decisions, a lack of funding for anything other than the most basic educational needs, and a continued refusal to acknowledge the advantages of educating students with disabilities.

Concerns are raised about how young people with disabilities make the transition to maturity, which is symbolized by the accomplishments of finishing high school, enrolling in college, and accepting a full-time job [4]. For instance, the most recent census in the United States of America in 2020 revealed that more than 12.2 percent of the population overall and 6.6 percent of those between the ages of 18 and 34 had some form of handicap [5].

This concern can also be seen in Portugal's most recent legislation, Decree Law 54/2018, even though it still establishes the legal framework for students with disabilities, with admittedly integration policies and rules that are concentrated on guiding the student through the compulsory education cycle, marked by numerous adaptations to the course materials and objectives rather than inclusive measures that actually lessen the student's handicap [6].

Digital accessibility in the European Union is governed by the European Accessibility Act [7], the European Standard EN 301 549 [8]. The World Wide Web Consortium (W3C) Web Content Accessibility Guidelines (WCAG) 2.1 Level AA assures compliance with the European Accessibility Act [9]. All public organizations or those who get public financing in the EU are required to comply to this minimal standard.

As a consequence of several studies, professors have acknowledged that they lack the skills and knowledge necessary to provide students with disabilities with the optimum learning opportunities [10]–[12]. The refusal to modify information, according to Smith, remains a barrier to the inclusion of disabled students in school despite the rising acceptance of disability. Martins ties this hesitation to a lack of knowledge and experience.

As a result, the goal of this research is to allow authors of pedagogical materials to take the initiative to share their work with students and other professors while also enabling automatically adapted reproduction of these materials for students with various disabilities using the media format and accessibility criteria that best suit their condition. To achieve that goal, the authors only need to comply with the guidelines and European Directives criteria, which are mandatory in public or private but publicly supported higher education institutions.

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.

Before deciding on some solution for this problem the author's considered a systematic literature was essential to know the available state of the art of inclusive intelligent systems.

## Systematic Literature Review

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [13] 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:

1. What technologies have been successfully deployed to develop accessible intelligent systems for students with different disabilities?
2. 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 1 exhibits the results obtained in each database when querying "Intelligent Systems Accessibility" on articles or conference papers published between 2018 and 2022.

**Table 1.** References Obtained on April 13th, 2022

| ***Database*** | ***Query Results*** |
|---|---|
| Scopus | 315 |
| Science Direct | 76 |
| Web of Science | 62 |
| IEEEXplore | 198 |
| Springer | 1504 |

Prisma methodology was applied to screen the 1978 distinct references retrieved from the databases. Figure 1 depicts the screening flow and the criteria applied in this systematic review. The 29 references retrieved (before reading the articles) were studied and clustered in 10 categories presented in Table 2.

**Table 2.** 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 |

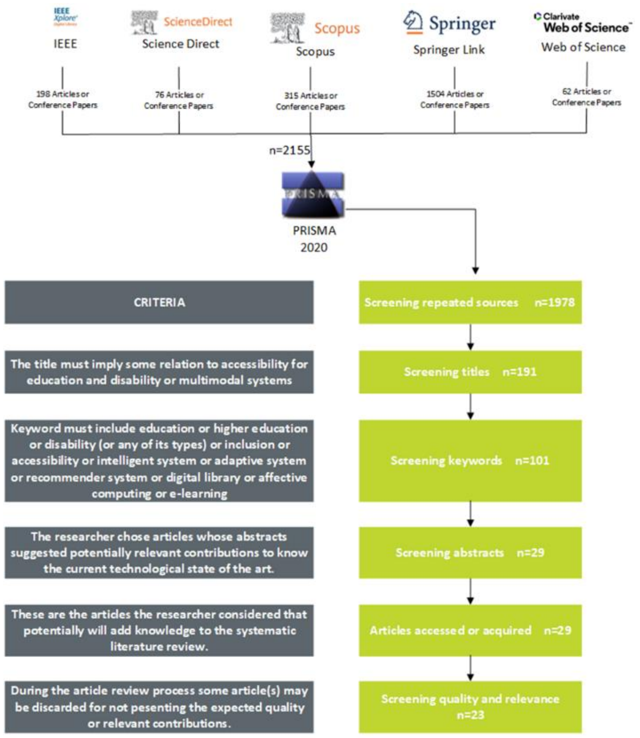


**Figure 1.** PRISMA Flow Diagram, adapted from [13].

## *Higher Education Accessibility*

One article, while assessing the accessibility of American Universities identified problems that can be perceived globally [14]:

- Increasing demand and expectation;
- Content and tools;
- Knowledge and Skills;
- Policy and Practice;
- Culture;

The cited author 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.

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 [15]. 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 (UDL) concept 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.

## *Web Accessibility*

In the COVID-19 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 [16]. Acosta state that by World Health Organization (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 WCAG 2.1 guidelines for audiovisual content.

Acosta concludes that most videos published by universities worldwide aren’t accessible, 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 W3C has published an article suggesting applying AI to evaluate Web Accessibility [17]. 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;
2. AI-Based Voice Recognition;
3. AI-Based Text Processing;
4. AI-Based Affective Computing;

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.

## *Adaptive Systems*

Apoki proposed an adaptive e-learning system with enough parameterization to offer the student a curriculum tailored to his particular needs [18]. 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.

Apoki's model was in fact an adaptive e-learning system that accommodate 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 [19]. 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 [20]. 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.

Edmond 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 [21]. 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 [22]. 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 [23]. 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.

## *Affective Computing*

El Hammoumi states that in sophisticated e-learning systems, facial expression recognition is becoming increasingly crucial [24]. 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).

## *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) [25].

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 author 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.

## 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 [26]. 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.

## 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) [27]. 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;
- BCI for Educational Purposes;
- BCI for TV-Based Home Care.

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.

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## 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 [15] 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 [28]. 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);
- Corpus-based Machine Translations (CBMT):
- Example-Based Machine Translation (EBMT);
- Statistical Machine Translation (SMT);
- Hybrid Machine Translation (HMT);
- Neural Machine Translations (NMT);

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) [29]. 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.

## 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 [30]. 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

 https://doi.org/10.5875/ausmt.v13i1.2423

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 Agentand a Math Expression Parser and Evaluator.

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.

Mikulowski presents a tool with the similar goal applied to the concept of flipped classroom, with a 4-Layers of augmented reality architecture [31].

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

Cross referencing this project’s fourth layer with [16] 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.

## *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 [32]. 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 [33].

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 [34], 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.

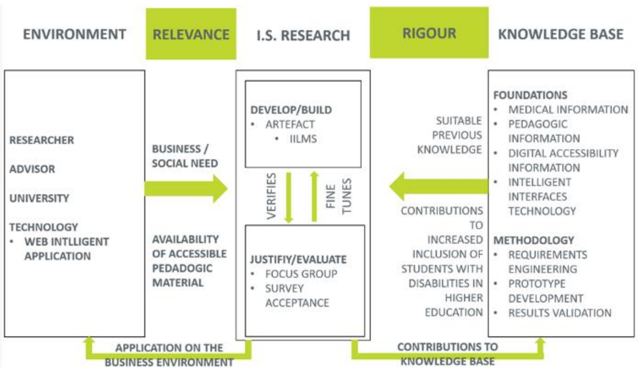


**Figure 2.** Design Science Research Application Plan, adapted from [36]

Sinha and Dasgupta approach the case when the user has speech and severe motor impairments [35]. 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.

## Methodology

This research followed Design Research Science [36]. The relevance cycle is justified by delivering a solution for a problem that was identified in society. The rigor cycle is reflected in the systematic literature review conducted before designing any solution and by returning this research findings to the academic community as a contribute to expand the base of knowledge. The research in information systems cycle consisted of design and validation iterations. Figure 2 displays the methodology application plan.

## Framework Design

In the research stage between identifying the gap in digital accessibility on higher education platforms and contents, the idea that was considered initially by the author was a digital library that would apply multiple assistive technology to adapt pedagogic contents to users with different or no disabilities.

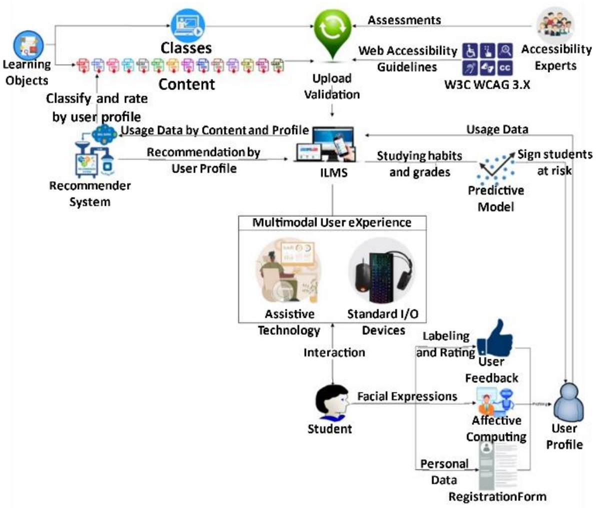


**Figure 3.** Inclusive Intelligent Learning Management System Framework

EN 301 549, WCAG and ISO/IEC 40500:2012 suggest that compliance with these norms and guidelines would be enough to enable every assistive technology to adapt the same content to different users, and studies have proven that the knowledge exists and not even being mandatory by law enforced compliance with the norms. Figure 3 displays the Framework Architecture.

It was considered that not only the platform should solve the students' problem but also enabling professors to produce and share digital accessible content easily. This is where the Learning come into play, offering the reusability of atomized contents applying the Object-Oriented Programming paradigm to pedagogic content. This will allow professors to share pictures, texts, videos, and content objects, validating each object accessibility instead of entire documents. From the professors' reutilization perspective this will allow building new content using already validated components without needing to produce entire contents when they want to use one object and not the whole document, presentation, or other content type.

Data Mining will enable clustering users and content according to their features. Affective Computing enables retrieving unconscious feedback from the students using Deep Learning's Convolutional Networks to perform emotion recognition from facial expression analysis while they study using the platform and consuming each content. The collection of this data is important to enable an empathetic recommender system rather than offering content just because other users highly rated it, or the content covers the subjects in the courses the student is enrolled in.

Accessibility wise, the framework contemplates using an Application Programming Interface (API) to automatically validate WCAG compliance. Yet, this validation must be validated by human administrators, accessibility experts preferably, so they can detect false positives. An alt text tag may be filled with meaningless content, e.g., but still be automatically validated as filled.

Classes may be streamed or even attended in-person and benefit from automatic captioning or translation. This can benefit not only deaf students but Erasmus students attending classes in a foreign language

It is highly recommended that media players are chosen according to their accessibility, and the literature review that one player may be considered inaccessible by one author, or a positive example for others.

Machine Learning predictive models allow identifying students on the path to fail some course based on studying patterns by comparison to the platform users' past experiences and results. The timely identification of these students may enable a pedagogic intervention while it may still affect the outcome. This feature has a higher relevance in higher education than in secondary school. Not only direct contact with students is harder on higher education given the larger number of students but COVID-19 confinements and remote teaching increased the distancing between students and professors.

## Validation

A Focus Group was conducted with academic experts in digital accessibility, information systems and a PhD graduate that studied as a person with a disability. They were asked four questions targeting the framework validation, weaknesses, future work and expected impact on society and the base of knowledge.

More than unanimous positive feedback, important contributes were made and incorporated in the framework:

- Human co-validation of uploaded content accessibility to prevent false positives;
- Using the latest version of WCAG rather than only the one required by law;
- Using Learning Objects to enable a more positive reception and adhesion from the professors;

## Conclusions

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.

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. 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.

On future works, 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 belonging there.

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