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**ARTICLE / ARTÍCULO**

# Educa Offline: Design of a Learning Management System (LMS) in Contexts of Low Connectivity and Social Vulnerability

## Educa Offline: concepção de um Ambiente Virtual de Aprendizagem (AVA) em contextos de baixa conectividade e vulnerabilidade social

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**Abstract**: The COVID-19 pandemic made visible the centrality of access to digital devices and connectivity for ensuring educational continuity, especially in contexts of social vulnerability. This article presents Educa Offline, an open-source Learning Management System (LMS) designed to reduce inequalities derived from low connectivity and digital exclusion. The system's design process is described, including a review of LMS-based solutions for low-connectivity contexts, a workshop with teachers and students to prioritize essential asynchronous tools, and the definition of navigation, synchronization, and processing requirements for offline work. In addition, interface design decisions are summarized together with the results of usability testing and usage trials with technical education students in a hybrid learning modality. The results of testing with end users showed a positive student experience of the system's usability regarding low bandwidth scenarios – with mobile networks or intermittent internet access. We conclude that the platform has the potential to offer a more inclusive means of accessing knowledge and education.

**Keywords**: Learning Management System (LMS), Low connectivity, Social vulnerability, Digital inclusion, Digital divide, Hybrid education.

**Resumo**: A pandemia evidenciou mais do que nunca a importância de ter acesso a dispositivos digitais e conectividade para a vida social, profissional e educacional. Neste artigo, investigamos como um ambiente virtual de aprendizagem (AVA) pode ser projetado e implementado para lidar com instabilidades na Internet que são comuns em regiões pobres de países em desenvolvimento. A principal contribuição do nosso trabalho é mostrar princípios de design, requisitos de sistema e arquitetura do Educa Offline, um sistema de gerenciamento de aprendizagem de código aberto resiliente a interrupções de conexão à Internet. A plataforma foi criada com particular ênfase na inclusão digital para um público que precisa do e-learning, mas tem conexão via redes móveis ou instáveis. Os resultados dos testes com usuários finais demonstraram uma experiência positiva de alunos em relação à usabilidade do sistema em cenários de baixa largura de banda – com redes móveis ou acesso intermitente à internet. Concluímos que a plataforma tem o potencial de oferecer um meio mais inclusivo de acesso ao conhecimento e à educação.

**Palavras-chave**: Ambiente Virtual de Aprendizagem (AVA), Baixa conectividade, Vulnerabilidade social, Inclusão digital, Desigualdade digital, Educação híbrida.

## 1. Introduction

Internet access fosters knowledge sharing between cultures in the rapidly developing digital age, hence reducing the digital divide in remote locations. The absence of Internet connectivity can be attributed to foreign locations, insufficient revenue, inadequate infrastructure, and low investment. Consequently, the lack of equal access to Internet connectivity widens the gaps in the education system in remote areas (Valarezo, Mendieta, Maza, Quiñones-Cuenca, et al., 2021).

The digitization process is influenced by the infrastructure and policies of each location, with Internet access being crucial (Hadriana et al., 2021). While governments in developing countries are primarily responsible for improving Internet access, non-governmental institutions like foundations and universities also play a key role. They can enhance educational opportunities by integrating ICT (Information and Communications Technology) and promoting innovative teaching strategies, thus democratizing education and benefiting individuals in areas with low broadband connectivity (Valarezo et al., 2021).

The social isolation experienced during the pandemic made educational differences even more evident, mainly in developing countries and in remote areas. E-learning was adopted as an alternative to face-to-face education, distributing materials via electronic media or the Internet, allowing access anytime and anywhere. Some benefits of e-learning include multimedia use, flexibility, and virtual communication. The possibility of accessing virtual classes was crucial for millions of students to continue their studies. However, challenges such as technical problems, limited teacher creativity time, operational skills, and funding hinder its effectiveness (Hadriana et al., 2021). Limited Internet connection was one of the reasons that demotivated students to attend online classes during the pandemic period (Afrilyasanti & Basthomi, 2022; Maya et al., 2022; Patel & Patel, 2021; Susila et al., 2020; Yawisah et al., 2022). To students in rural and remote areas, the problem was even greater, highlighting social problems concerning vulnerable populations (Almelhes, 2021; Chadda & Kaur, 2021; Santiago et al., 2021). When thinking about scenarios where connectivity is not possible or limited, choosing platforms that make it possible to work and to study offline can make a difference to a significant audience.

The objective of this article is to describe Educa Offline, an open-source Learning Management Systems (LMS) designed and developed to improve gaps regarding social issues relating to inequalities in Internet access and digital exclusion. Educa Offline LMS can work offline on intermittent networks and can be installed on low-cost hardware.

LMS are important solutions for teaching and learning in general, as they have the potential to reach many people. They are developed with the purpose of allowing their users to interact through technology to perform educational activities in face-to-face, hybrid, and distance learning modalities. They are composed of tools that enable the availability of materials, the synchronous or asynchronous communication of those involved, the construction of content and the management of courses.

In a previous work we studied the problems raised from the lack of Internet for education during the pandemic, as well as possible solutions for e-learning with LMS

(Linhalis & Silva, 2023). The study shows that the lack of Internet had a strong impact on the lives of students and teachers, especially in vulnerable situations. For many people, continuing their studies in a situation of social isolation was an obstacle. Therefore, it is worthwhile to investigate and to create systems that take social isolation into account and can be utilized to e-learning with constrained Internet access.

But, is it feasible to have an offline LMS? By its very nature, an LMS requires a server connection in order for users to communicate with the system. Working "completely offline" with a standard LMS like Moodle, Google Classroom, or Edmodo is simply not feasible. However, working with an unstable network with offline periods is feasible, as long as the LMS can function in the event of an Internet outage. At some points throughout the interaction, students and teachers must also get ready in addition to the LMS resilience characteristics (Linhalis, Silva & Santos, 2022).

Given the above, our research question is: How can an LMS be designed and implemented to deal with Internet instabilities that are usual in poor regions of developing countries? Overall, the contribution of our work is to show suitable design principles, system requirements and system architecture of Educa Offline Platform – An Asynchronous Offline LMS.

### *1.1. State of the Art and Related Work*

We identified and characterized LMS-based solutions that have been implemented to mitigate the issue of Internet connectivity and to leverage the use of ICT in education. «What are the LMS solutions to make the use of ICT in education feasible in regions with low Internet connectivity?» To answer the question, a systematic review was conducted (Linhalis & Silva, 2023). As discussed in the remaining of this section, the investigation reveals certain deployments of LMS-based technologies in remote places with poor or no Internet connection, which allows the reduction of the inequalities and ICT integration on education.

KA Lite is an offline version of Khan Academy[1], that extends the classroom model to remote locations by enabling users without Internet access to watch and to complete Khan Academy lessons in an entirely offline environment. It provides a free library of movies in multiple languages covering a range of subjects, including computing, physics, medicine, and mathematics. A large portion of Kan Academy's content is offered as blackboard videos.

KA Lite has been gradually substituted by Kolibri, which has advantages in terms of interface, material availability, content/user administration, and usability (Learning Equality, 2023). Once a device is in an area with Internet coverage, Kolibri content, updates and installers can be downloaded. After that, through an offline local network, the device can communicate with other devices about upgrades and new content, thereby reaching even the most isolated populations.

Cossa et al. (2021) described their experiment with the Aptus system. Installable on tablets, Aptus was designed to access course materials, on a local network, without requiring Internet access or grid electricity. The Aptus tablet showed how using a mobile device to access and engage with digital resources enhanced students'

[1] Khan Academy, is an NGO (Non-governmental organization) with the goal to spread education. https://www.khanacademy.org/

academic achievement and also their ICT abilities (Balaji & Cheng, 2016; Cossa et al., 2021).

Wiebe et al. (2022) describe the use of mobile learning labs with the tablet RACHEL (Remote Area Community Hotspot for Education and Learning). RACHEL is a battery-operated, portable device that connects to an LMS with a variety of digital libraries, websites, curriculums, instructional games, and open educational resources (OER). It wirelessly sends the content to laptops, smartphones, and tablets without requiring an Internet connection or data plan. It is used offline, and new content can be uploaded to the RACHEL by bringing it to a location with an Internet connection (Wiebe et al., 2022).

A hybrid online/offline approach was developed by Pugoy et al. (2016) as a potential solution for places with limited bandwidth. In a hybrid setup, the learner connects to the Internet to download and synchronize OERs from a CMS (Content Management System) repository. A CMS served as the LMS in this approach. The repository was a WordPress CMS (Pugoy et al., 2016). On the server side, there is a repository where OERs can be created, arranged, and modified. It makes content management possible for OER providers without requiring them to have prior knowledge of web programming. In order to download or update OERs from the repository, the client (learner) establishes an internet connection. After that, he/she can access OER content from any location, online or offline.

A method that combines two Internet browsing modes is described by Valarezo et al. (2021): i) the offline approach, which requires little or no Internet access; and ii) the online method. IP table rules are used by a traffic manager service on a small local server (KAMU Server) to route network traffic. It redirects users between the two ways they can browse the Internet. The instructional resources that are available online are accessible to users of the online method. Users which are offline can access only the educational resources stored on the local web server (Valarezo, Mendieta, Maza, Quiñones-Cuenca, et al., 2021).

While the methods discussed so far in this section take into account offline access, they do not address social isolation because they depend on a local network for operation. In this case, access to local digital content is made possible via an LMS that is installed on a local server and connected to the school or university's local wireless network. Consequently, mobile devices connected to a private local network enable instructors and students to access the course materials. When a student or teacher is inside the local network's coverage boundaries, they engage with the content and produce new digital content that is saved, accessible locally on their own devices, and synchronized with the school server (Linhalis, Silva & Santos, 2022).

According to the literature review that was undertaken, the Moodle app is an option that takes social isolation into account and may be utilized in e-learning in asynchronous activities when there is no steady Internet (Linhalis & Silva, 2023). Those who live in rural areas or even in cities that occasionally face network access restrictions can find it to be a workable alternative in cases when they have limited access to the Internet.

There are features in Moodle for situations in which the network is unstable. Because of its traditional focus on online collaborative learning, the course materials must be downloaded before going offline. Once offline, the changes can be automatically synced with the server and sent to the clients whenever they are able to connect to the Internet - as long as they use the Moodle app, which is compatible with desktops, laptops, tablets, and smartphones.

Using the Moodle app, instructors and students can access and engage with offline information on the Moodle platform, including reading forum postings, posting on discussion boards, responding to messages, turning in assignments, taking quizzes, and other activities (Allela et al., 2020). These are asynchronous activities that, when the device is connected to the Internet, automatically synchronize with the content on the Moodle platform.

In Moodle, collaboration only occurs when students and teachers have Internet access. Dai et al. (2022) built a collaborative learning system that can operate in an offline setting and transfer data asynchronously with other devices that have internet connection. Moodle is used as LMS. The authors built a server syncing to handle synchronization between Moodle and the clients. The syncing framework developed by them was based on the idea of having audit log (Dai et al., 2022). Our solution was built using PWA (Progressive Web App), as described in section 2.3. Dai et al. (2022) have considered the possibility to turn Moodle into a PWA, but Moodle is a huge system that has over 500 Megabytes of resources. When using Moodle as a PWA, users in remote areas would need to download 500 Megabytes of data to each device via the Internet in order to load and run the system (Dai et al., 2022). This is a big difference between Educa Offline and Moodle. As explained in more detail in section 2.3, only 2.4 Megabytes are required to load Educa Offline, including all files and images. This is all the data that needs to be downloaded by the client so that the website can run in a browser, without taking into account data from specific courses. Unlike Moodle, Educa Offline is designed for offline and/or low-bandwidth scenarios.

## 2. Method

When thinking about offline scenarios, we are faced with the challenge of having the client's device to host the courses. Students and teachers must download the course and its files onto their devices (smartphone, tablet, etc.) so that offline browsing is possible. Courses resources need to "fit" on the client device. In this section, we describe the design principles that guided the development of Educa Offline, the potential users, the main system requirements, the system architecture, the technologies, and tools used in the development. Our goal was to create a slim environment that could function even in the absence of an Internet connection.

### *2.1. Potential users*

Potential users of the Educa Offline have different profiles, varying in age, education, technological knowledge, skills in using computers and smartphones, etc. This is due to the fact that the platform was developed to support teaching and learning activities that occur in different modalities and levels of education (basic education, technical education, higher education, postgraduate education, teaching through short courses, etc.). Our aim is that teachers and students of different ages and locations are able to use the system whether they are experienced in the use of digital technologies or not.

In developing countries, when we talk about remote learning, we are referring to learning that will often take place over a smartphone, using an intermittent 3G or 4G network (Aarreniemi-Jokipelto, 2020; Berényi et al., 2021; Cahyadi, 2020; Santiago et al., 2021; Susila et al., 2020). Although current web applications are designed considering a stable connection between users and the server, the reality of Educa Offline potential users is different. So users have unstable connections, especially in the case of connections via mobile device networks, which also vary due to location.

### *2.2. Design Approach*

We held a workshop in order to identify a simplified set of tools to an LMS with offline features. The goal was to design a lighter system, without giving up the organization needed in distance and hybrid education (Arantes & Freire, 2018).

We invited five students whose undergraduate courses were previously assisted by e-learning environments, four educators with expertise in e-learning environments, and a researcher who was in charge of carrying out the scheduled activities of the workshop. Our intention was to bring together a small but experienced group of people so that we would have adequate time to hear one other out and exchange views.

The workshop was divided into two parts. The first part was about prioritizing tools - the objective was to hear the participants' opinion about the asynchronous tools they considered most important in hybrid and distance learning. As a result, we had some tools prioritized - Timeline, Notifications, Activities, Calendar, Course Material and Grades (Arantes & Freire, 2018; Linhalis et al., 2022). Each of the tools has a set of requirements, which varies according to the users' permissions/roles (Administrator, Teacher, or Student). The prioritized tools refer to a minimum set of tools to an asynchronous LMS:

- Activities: It is where the teacher posts the activities (or assignments) that must be carried out by the students and they, in turn, deliver them.
- Timeline: It is a communication tool, where the participants can make posts, comments and "like" posts. It is similar to the Facebook timeline.
- Notifications: It sends an alert whenever the user receives a comment on her/his post, when the teacher posts a new activity, new material or releases grades.
- Course Material: It is where teachers place the course material: class slides, articles, media, among others.
- Calendar: Shows events (assignments delivery, for example) in a calendar format.
- Grades: It is used for teachers to assign grades/comments and for students to view them.

- Participants: Shows the course participants and the role of each one, which can be a student or teacher. There is also the Administrator role, but this is not listed as a course participant.
- Profile: Refers to information about a participant.
- Administration: This is the part of the system that manages courses, students and teachers.

The second part of the workshop was about the collective design of a course homepage - the objective was to jointly design the homepage considering the tools prioritized in the first part of the workshop. We had to create a lightweight system without giving up the organization required for a blended or distant learning course. Furthermore, we made an effort to create a more dynamic and user-friendly system, aligned to social networks, where people are used to shorter and faster interactions.

The timeline was identified as the central component of the interface. It shows how social interactions have an impact on the activities that teachers and students engage in. This collective design of the site demonstrated the significance of interactions. The interface project of the Educa Offline Platform is conceptually sustained by the interactions between individuals (timeline and participants/profiles) and their activities (refer to Figure 1).

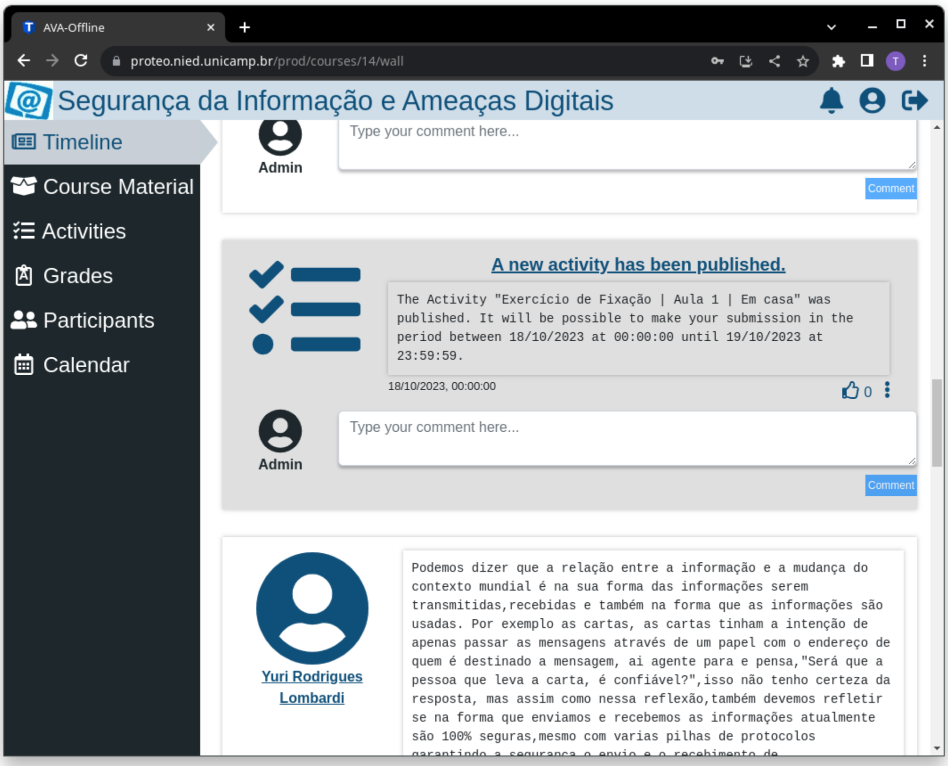


**Figure 1**. Educa Offline timeline, showing desktop version and admin role.
The course was given in Brazil, so some texts are written in Portuguese.

### *2.3. Design Principles*

*Responsive Interface*

During the pandemic, many students and teachers had only mobile devices – mainly smartphones – to attend the online classes (Chadda & Kaur, 2021; Santiago et al., 2021; Yawisah et al., 2022). The increase in the processing power of mobile devices has led to the development of responsive interfaces, where much of the processing of web pages is done on the client. With responsible interfaces, it is possible to generate web pages and to perform appropriate client-side adjustments based on screen size (Marcotte, 2011). The benefit is having a single source code, which makes version control and maintenance much easier. Educa Offline frontend was developed with Angular, a responsive interfaces framework. Without needing to develop custom apps, the platform frontend can adjust to the screen size, making is user friendly on tablets, laptops, and desktop computers.

*Less bandwidth intensive*

The bandwidth usage is one of the most fundamental aspects of an application that aims to work well for people with unstable internet connection. With that in mind, the system communicates via RESTful API, which is less bandwidth intensive since it only transfers a JSON file per request. Furthermore, other strategies were implemented to avoid bandwidth usage, as described in the remaining of this section.

The first of them is the incorporation of the Angular Service Worker module. After configured, it intercepts every HTTP request made by the application, caching the information transmitted and automatically responding to next requests, avoiding the need of constant communication with the server. It also helps to make the application faster, as it removes the delay caused by the response time.

Another approach focuses on the offline functionality of the application. In the absence of a connection, the PWA saves user modifications – such as creating a post or editing an activity – and employs other structures to track these changes. Consequently, when the connection is restored, the application can selectively make requests to the server only for the altered data, minimizing the data transfer required for synchronization. Finally, the system implements a method to optimize data transfer in file transactions, which changes the quality and size of the image files based on the quality of the connection at the moment of upload/download. This mechanism is further detailed in section 2.4.

*Less resource intensive*

The resources are the pages and the files needed to run the application, including the images it needs to load. After building the application with Angular we can see that the total load of the application, including all necessary files and images, is 2.4 Megabytes. That includes the initial load and the files that are loaded later in the application. That's all data that needs to be downloaded by the client so that the LMS can run on a browser. It does not take into account the data that will be retrieved from the server about specific courses.

Educa Offline downloads only two images: the logo and the favicon. These images are each less than 5 Kilobytes, significantly minimizing the resource requirements. Additionally, as previously mentioned, the PWA employs a service worker to cache this data, ensuring it is loaded just once, unless the browser cache is cleared. After caching, only the course data is necessary, and since it primarily consists of text content, the amount of data needed for loading is minimal. This is one of the differences between Educa Offline and the Moodle application.

Moodle is a huge system that has more than 500 MB of assets and resources. If we turn Moodle into a progressive web app, users in remote areas will need to preload and cache 500 MB of data on each device through internet to be able to run the system (Dai et al., 2022, p. 3). Unlike Moodle, Educa Offline is designed and developed for offline work in low-bandwidth scenarios. Furthermore, Educa Offline is lean enough to be installed and run on the Raspberry Pi, a low-cost, open-source hardware.

### *2.4. System Requirements*

Three moments can be distinguished in offline scenarios: the instant before going offline, the moment after going offline, and the moment in between. The time frame during which instructors and students have access to the Internet is the «before offline» moment. In this moment, all of the application's features are available, it is the perfect time to get ready for offline work. This is accomplished by preserving the resources that will be required for offline work and accessing the courses that are of interest in the Educa Offline LMS.

In the offline time, students and teachers have to complete their work in applications without requiring a connection to the LMS. In this scenario, the LMS have to allow content replication that permits course browsing through local copies. Furthermore, the material can be altered by teachers and/or students while the LMS is offline. Because of this, as soon as the application detects an open network, it must synchronize with a server. Moreover, it is preferable to process large files – mostly videos – and deliver them to the client at a lower resolution when considering low-bandwidth conditions.

A methodology was described and validated for assessing offline requirements in an LMS (Linhalis et al., 2020). The remaining of this section will clarify the necessity of navigation, synchronization, and processing requirements, as described in the methodology.

*Navigation*

The goal of the navigation requirements is to enable offline course browsing for the user. It is important to maintain a history of pages visited in cache, to permit the download of a course, and to create user interfaces that indicate which files are available offline and which ones are not.

As users navigate through their enrolled courses, all data retrieved from the server is stored in the Store on the client' browser with the framework NgRx, designed to preserve information seamlessly when transitioning between pages. This structure remains intact even when the connection is lost, allowing users to access course content, including posts and activities, even when offline. Notably, files associated with the course, such as those in the 'Course Material' section, are not downloaded merely through navigation to prevent unnecessary use of the connection and space to storage on the client.

For users who want local access to a course's information without a connection, a feature called 'Toggle Offline' is available on the main courses page. When activated for a specific course, it downloads all its content and regularly fetches updates, ensuring synchronization with the server. This functionality encompasses downloading course files, making them accessible even without an internet connection. The user interface also includes intuitive icons indicating whether a course or file has been downloaded locally or if it's not locally available.

*Synchronization*

Synchronization is the process of updating server information modified by users working offline, such as uploading files or commenting on a post. The system should automatically transmit these changes to the server when the connection is restored, without requiring user intervention. To accomplish this, the application regularly checks for server connection through small requests to the server, they are made every 4 seconds. If the request fails, the system recognizes the offline status and notifies the user with a bottom screen bar. When there are changes requiring synchronization, the bar changes color to alert the user. The regular requests continue, also detecting when the connection is back online.

In our application, data is continuously stored in the NgRx Store, a framework that maintains the application state. This state includes information received from the server. When working offline, modifications are saved in the Store. Within the Store, structures are created and maintained to indicate items requiring synchronization. When reestablishing the internet connection, specific actions are triggered. These actions prompt the application to search within the Store structures and synchronize only for modified items. Offline modifications are also stored in the browser's storage using IndexedDB. It is important because the Store resets when the application tab is closed. However, IndexedDB persists, allowing recovery and synchronization of changes when the user accesses the application online.

Another aspect to take into account is file uploads, which may be interrupted if the connection is lost during the upload process. In such cases, the system halts the upload and displays an icon, signaling that the file still needs synchronization. When reestablishing the internet connection, the upload process restarts from the beginning, ensuring the upload is successfully completed.

*Processing*

The purpose of processing requirements is to perform some level of processing on files prior to transferring them across the network. For instance, the system may have to reduce the resolution if the user requests to upload or download a particularly large video, depending on the available bandwidth.

A method was implemented in the Educa Offline LMS to manage shared files within courses, specifically those located in the 'Course Material' section and those embedded in Activities. This method involves two distinct processes: Upload and

Download. During the upload process, the files are pre-processed on the client side before initiating the upload, adjusting its quality and size based on the current internet speed. When the server application receives a file, it creates smaller versions of it, varying qualities and storing them. This approach enables the client to request a file version that aligns best with the current internet connection speed during the download. Users can also select their preferred version, with options displaying various resolutions and their respective file sizes.

### *2.5. System architecture*

The Educa Offline Platform is a client-server web application. The MVC (Model-View-Controller) software pattern is used in the development of the system, which is entirely built with open-source technology. Separation of concerns is the primary benefit of MVC; the application is split into three sections: Model, Control, and View. Because of this division, source code maintenance is made easier and multiple developers can work on the software implementation at once.

*Server Side (backend)*

The central server is a physical server running on Linux operating system. Its architecture is illustrated in Figure 2.

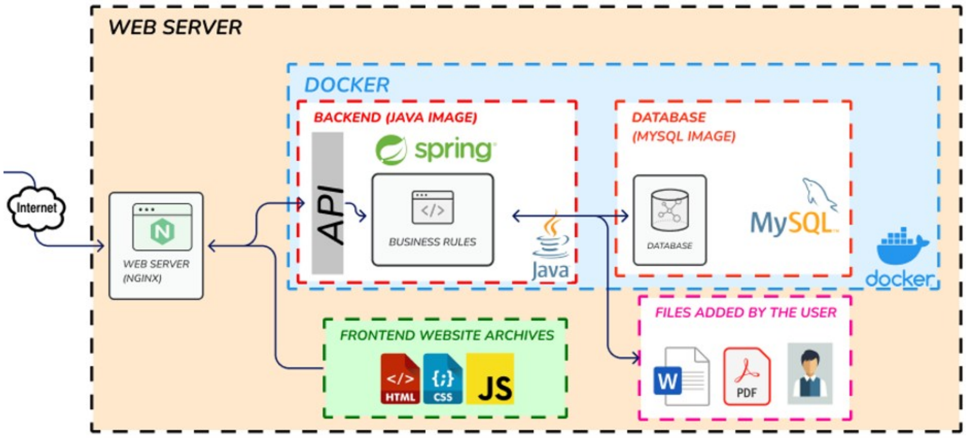


**Figure 2**. Educa Offline backend architecture.

We used technologies on the server side, often known as the backend, to manage permissions, organize user data, and arrange courses. Table 1 provides a quick overview of the server-side technologies utilized in the development of the Educa Offline Platform.

**Table 1**. Technologies used in the backend of the Educa Offline.

| Technology | Description |
|---|---|
| Spring/Spring Boot | Base framework for the application backend. It encompasses tools for request handling, database, data formatting, permissions and others. |
| Java | Backend programming language. |

| Technology | Description |
|---|---|
| Maven | External libraries manager (dependencies). |
| Spring Data JPA | Creates an abstraction in communicating with the database and Java objects, so that it is not necessary to write SQL files to communicate with the database. |
| MySQL | Database used for all application information, except upload files (which are saved directly on the server's file system). |
| Spring Security | Facilitates permissions and authentication management. |
| OAuth2 | Used together with Spring Security to control user authentication. |

In order to expose its data to the client, a RESTful API was developed on the backend to reply to several endpoints and queries made from the frontend.

*Client Side (frontend)*

The client is the part of the system that will be used by students and teachers when they access courses. Through a web browser, users can use their own devices, such as tablets, computers, and mobile phones. By entering the learning system's pre-defined URL, users can access Educa Offline.

The frontend architecture is illustrated in Figure 3. The technologies used for client-side development are briefly described in Table 2.

**Table 2**. Technologies used for frontend development.

| Technology | Description |
|---|---|
| Angular | Responsive framework that that includes a number of tools to make it easier to create complex and responsive web applications. Responsive interfaces can adapt to the screen size, so Educa Offline can be utilized on laptops and desktop computers, tablets, and smartphones without the need to develop specialized apps. |
| Typescript | Programming language used in Angular, instead of JavaScript, that makes it easier to produce code with an advanced type system and newer features. |
| HTML, CSS e JavaScript | Known as the web triad, these are the languages used directly in the web browser. These are the final files generated by Angular after development. |
| Bootstrap | Library with several visual and interactive elements that speed up the construction of a website. This, along with the ng-bootstrap library, which adapts bootstrap's interactive components for integration with angular and typescript. |
| FontAwesome | Library with several SVG icons to use in the application. |
| Angular PWA | Library that helps in the development of the PWA and allows website data to be locally saved for offline consumption. |
| NgRx | It is a state management library. Data received via the Internet is saved, organized, and arranged so that changes are easily synchronized when the Internet connection is restored. |

## 3. Results

Two types of tests were carried out: usability tests and end-user tests, as described in the next subsections.

### *3.1. Usability tests*

To carry out a usability test and evaluate the experience of using a system through observation, Barbosa and Silva (2010) recommend a series of four planned activities in order to obtain more effective results: preparation, data collection, interpretation and consolidation of results. In the preparation activity, we defined: i) user tasks, ii) a good usability interaction criteria, iii) properties to be studied, and iv) preparation of the questionnaires to be answered.

The tasks were specified so that it was possible to investigate the functionalities of the following tools: Participants, Timeline, Activities, and Course Material. The Notes, Calendar and Notifications tools were not part of the tests, as they were not ready yet. About the questionnaires, we chose three already validated questionnaires: the SUS (System Usability Scale) (Brooke, 1995), the QUIS (Questionnaire for User Interaction Satisfaction) (Harper & Norman, 1993) and the USE (Lund, 2001). We used a five point Likert scale for all statements. Members of the development team (5 people) were invited for this test. We recognize the limitation of involving people who already know the application, especially to evaluate the user interface, but this was the first test and aimed to evaluate usability on different devices and to identify bugs.

As the tests were carried out at home, the volunteers' own equipment was used. The tests were carried out on desktops, laptops, tablets and cell phones, with different operating systems (Windows, Linux, MacOS, iOS, Android) and different browsers (Chrome, Firefox, Edge, Safari). The different combinations of browser and devices were called context, so ten contexts are planned and distributed among the volunteers. After completing the tasks, three volunteers (60%) responded to the questionnaire and two (40%) did not respond. Only one volunteer answered the questionnaire three times, each time corresponding to a context in which he participated. The others respondents answered one time for all participated contexts. The contexts and responses are described in detail in a technical report (Silva & Linhalis, 2024).

Briefly, we can say that QUIS and USE questionnaires pointed out that the Educa Offline has a good usability since all items were marked as favorable (agree or completely agree on the Likert scale). About SUS, Educa Offline got an average score of 73, a good usability, according to the scale of Bangor, Kortum, and Miller (2008). But it is important to highlight the limitation of this result considering the low number of volunteers.

Results obtained by SUS pointed out some usability problems. Considering the odd statements (whose the high agreement is favorable to the system having good usability), a high score (selection of the Totally Agree or Partially Agree options) was observed in 90% of the answers. In one of them (10%) there was a lower score, which implies that the volunteers felt that the various functions of the system needed to be more integrated. We believe this is because the volunteers encountered functionality problems in the interaction.

Regarding the negative questions (the low agreement is favorable to the system having good usability), the volunteers found the system unnecessarily complex and inconsistent. We believe this is due to the process of enabling or disabling the offline feature, as well as knowing what needs to be sent to the server via synchronization. Still on the negative points of the SUS, in relation to finding the system difficult to use, the contexts with a computer with Linux and Firefox and a computer with Windows and Edge were the most difficult to use, while the context of a smartphone with Android and Firefox was described as "partially disagree". We believe that this is due to the mobile first technique used in the development of Educa Offline. In QUIS questionnaire, the answers to describe three system's negative points show:

- User difficulty in activating the option to enable/disable offline mode on the device with the Android operating system when compared to its performance on the desktop device with the Windows operating system. We believe this is due to the size of the interaction element and is a usability problem caused by the change from mouse to touch mode;
- Difficulty to access files: this problem is a software malfunction as it occurred in different contexts (with devices on different operating systems);
- Need to modify enabling and disabling offline option;
- Do not show the status of what is available offline or needs to be synced;
- Malfunction in data synchronization in the desktop context with Windows and Chrome.

Analyzing questionnaires data, despite the pointed problems, we can conclude that Educa Offline have good usability. The negative points served as input so that the development team could improve the system before testing with end users.

### *3.2. End user tests*

Tests with end users were carried out in the city of Hortolândia, São Paulo state, Brazil. Six students from a technical school, from technological courses, participated in the tests during the Science and Technology Week, which took place in October 2023[2]. During this week, the students participated in a mini-course on Information Security in which the Educa Offline platform was used as an LMS. The mini-course was done in a hybrid way, with a face-to-face part and activities carried out in the students' homes, totaling six hours.

The activities in the students' homes were carried out without the Internet or with the mobile network, with the aim of evaluating the offline navigability of the system and the synchronization features. Students were asked about their experience with offline access to the main tools (Timeline, Course Material and Activities), in relation to navigation and synchronization.

The students' feedback was collected using a custom questionnaire. As a result, we can have insights if the system affected the students' learning experience. In

[2] Ethics number (CAAE): 67592523.3.0000.8142.

addition, the results pointed out areas for system improvement, particularly with regard to interactions and user experience.

Only one student reported difficulty finding the option for offline access to the course (toggle offline). Issues were reported only with the Timeline tool. One student reported that he submitted the same post more than once due to a lack of clear feedback in the interface while the system was offline. Another student reported that he sent a post while offline and his post was duplicated after synchronization. The students also reported that they felt comfortable using the system without the Internet and also using it with the mobile network. As improvements, it was suggested that a message should appear when a post is sent to the Timeline while offline, and to add more colors to the interface. Overall, the students were satisfied with the result.

## 4. Conclusion

During the pandemic, we realized that the lack of Internet access and/or low bandwidth were factors that greatly limited the continuation of studies, especially for vulnerable populations. We carried out a systematic review with the aim of analyzing other LMS solutions to the problem of lack of Internet. We identified and analyzed solutions such as Kolibri, Aptus, RACHEL and KAMU, as described in section 1.1. However, these solutions do not consider the situation of social isolation, as they require a local network to work. The literature review states that the Moodle app is the only one that takes social isolation into account and can be utilized for e-learning in asynchronous activities when there is unstable Internet (Linhalis & Silva, 2023).

The study allowed us to position the contribution of Educa Offline in relation to Moodle. As explained in section 2, Educa Offline was designed for low bandwidth scenarios – with mobile networks or intermittent internet access. Its design and development took into account a minimalist set of essential tools for asynchronous activities in an LMS (section 2.2), responsive interfaces that adapt to screen size (section 2.3), less bandwidth usage (section 2.3) and less resource usage (section 2.3). The development of the platform tools took into account specific requirements for offline browsing, server synchronization and large file processing (section 2.4). Furthermore, the MVC (Model View Controller) architecture provided the decoupling of the frontend and backend, with requests made via Restfull API, which made the application more agile.

Section 2.3 shows that, including all files and images, 2.4 Megabytes are needed to load the Educa Offline platform. In Moodle, loading reaches 500 Megabytes of resources (Dai et al., 2022), which makes loading very heavy in places with low bandwidth or mobile networks. Finally, Educa Offline is lean enough to be installed and run on the Raspberry Pi, a low-cost, open-source hardware. The alpha version is available for testing and the source code was made available under the open MIT license (Linhalis et al., 2025; EducaOffline GitHub, 2025).

Education is a fundamental human right, a cornerstone of sustainable development, a means of advancing labor and social inclusion, and a means of balancing economic expansion, equality, and social involvement. The pandemic has made it more clear than ever before how crucial it is to have access to digital devices and connectivity in order to maintain social, professional, and educational continuity.

This article described the Educa Offline platform, an open-source learning management system that can withstand Internet connection outages. The platform was created to give a more equitable access to education and knowledge for users that interact with mobile networks or sporadic access to e-learning. Educa Offline is innovation in LMS, with a strong call to digital inclusion. It was projected and developed to work offline with low-bandwidth or intermittent networks. Regarding the system design, we highlight a lean set of asynchronous tools, less usage of resources and bandwidth. Regarding the system development, Educa Offline is resilient to the loss of internet connection, and it was developed with responsive interfaces, which adapts to different screen sizes. The system supports navigation and processing of large files without a network connection. Is performs synchronizations when the internet is reestablished. Finally, it is lean enough to be installed on a low-cost hardware. This article contributes with knowledge about offline LMS for low bandwidth scenarios, a contribution for global citizenship education as a means to mitigate digital inclusion problems, mainly in developing countries. We know that internet access and digital inclusion has a strong call to action and it is a broad and complex issue. It needs more than just Educa Offline-style tech solutions. Political will and cooperation between legislators, educators, and communities are also crucial.

Educa Offline is in alpha version, opened under MIT license. Some improvements still need to be accomplished. The synchronization carried out in the system only concerns data that became out of date while the user was offline. No information was worked on that could be lost or out of order. It is unlikely that instructors and students will upload information to the system (almost) simultaneously in areas with low student and teacher populations, leading to inconsistencies. But it may happen in the Timeline section of the system. Data synchronization is not a trivial task, it deserves to be investigated in more depth in the future. Another subject that deserves to be investigated in more depth is the processing of video files. The platform has a method that was developed to optimize image transfer, but the process can be expanded to also support videos and other types of files in the future. The results of testing with end users showed a positive student experience of the system's usability and highlighted areas to improve the platform, particularly with regard to user interactions. As future work, we are interested in evaluating Educa Offline with teachers.

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## 6. References


Aarreniemi-Jokipelto, P. (2020). The Landscape of Mobile Learning in Brazil: From Distance Learning to On- and Offline Mobile Learning. *Journal of Educational Multimedia and Hypermedia*, *29*(4), 289–297.

Afrilyasanti, R., & Basthomi, Y. (2022). A Sudden Shift: Students', Teachers', and Parents' Adaptation to Learning during and after COVID-19 Learning. *Pegem Journal of Education and Instruction*, *12*(2), 143–150. https://eric.ed.gov/?id=EJ1343325

Allela, M. A., Ogange, B. O., Junaid, M. I., & Charles, P. B. (2020). Effectiveness of Multimodal Microlearning for In-Service Teacher Training. *Journal of Learning for Development*, *7*(3), 384–398. https://eric.ed.gov/?id=EJ1280612

Almelhes, S. (2021). Evaluation of Students' Remote Learning Experience of Learning Arabic as a Second Language during the COVID-19 Pandemic. *International Education Studies*, *14*(10). https://eric.ed.gov/?id=EJ1319464

Arantes, F. L. & Freire, F. M. P. (2018) *Uma Oficina para Projeto do TelEduc Core.* Technical Report. n.1, 2018. Núcleo de Informática Aplicada à Educação, Universidade Estadual de Campinas. https://www.nied.unicamp.br/biblioteca/relatorios-tecnicos/.

Balaji, V., & Cheng, R. (2016). *Do Tablets and Aptus Contribute to Improved Learning Outcome? Results from an Applied Research Project in Swat Region, Pakistan*. Commonwealth of Learning (COL). http://hdl.handle.net/11599/2391

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An Empirical Evaluation of the System Usability Scale. *International Journal of Human–Computer Interaction*, *24*(6), 574–594. https://doi.org/10.1080/10447310802205776

Barbosa, S. D. J., & Silva, B. S. (2010). *Interação Humano-Computador* (Vol. 1). Elsivier.

Berényi, L., Deutsch, N., Szolnoki, B., & Birkner, Z. (2021). Perception of e-Learning among Hungarian Engineering Students. *Electronic Journal of E-Learning*, *19*(5), 376–387.

Brooke, J. (1995). SUS: A quick and dirty usability scale. *Usability Eval. Ind.*, *189*.

Cahyadi, A. (2020). COVID-19 Outbreak and New Normal Teaching in Higher Education: Empirical Resolve from Islamic Universities in Indonesia. *Dinamika Ilmu*, *20*(2), 255–266.

Chadda, I., & Kaur, H. (2021). COVID Pandemic and Virtual Classes: A Study of Students from Punjab. *Asian Association of Open Universities Journal*, *16*(2), 193–210.

Cossa, S. P., Nakala, L. P. M., & Cherinda, N. A. I. E. P. (2021). Open and Innovative Schooling: An Implementation Experience in Fifteen Secondary Schools across Mozambique. *Journal of Learning for Development*, *8*(3), 601–610. https://eric.ed.gov/?id=EJ1325057

Dai, H., Nguyen, P., & Kutay, C. (2022). Offline collaborative learning approach for remote Northern territory students. *Interactive Technology and Smart Education*. https://doi.org/10.1108/ITSE-05-2022-0063

EducaOffline GitHub. (2025) https://github.com/nied-unicamp/EducaOffline

Hadriana, Mahdum, Isjoni, Futra, D., & Primahardani, I. (2021). Online Learning Management in the Era of COVID-19 Pandemic at Junior High Schools in Indonesia. *Journal of Information Technology Education: Research, 20,* 351–383. https://doi.org/10.28945/4819

Harper, P., & Norman, K. (1993). *Improving user satisfaction: The questionnaire for user interaction satisfaction version 5.5*.

Learning Equality. (2023). *Kolibri: A Free, Open Source Education for All*. https://learningequality.org/kolibri/

Leshchenko, A., & Bezlutska, O. (2021). Traditional vs online education in the maritime training system under Covid-19 pandemic: Comparative analysis. *Pedagogika-Pedagogy*, *93*(7), 86–95. https://doi.org/10.53656/ped21-7s.07trad

Linhalis, F.; Cintra, J. S. C.; Vieira, C. A.; Vascon, L. E. L.; Pavão, T. M.; Milani, S. R. Nascimento, L. G. S. & Silva, A. C. (2025). Educa Offline. Patente: Programa de Computador. INPI - Instituto Nacional da Propriedade Industrial. Number: BR512025001894-0, 09/05/2025.

Linhalis, F. & Silva, A. C. (2023) Solutions do enable the use of ICT in education in regions with low internet connectivity: a literature review. *Brazilian Journal of Education, Technology and Society (BRAJETS).* *16*(4), 1185-1196. https://doi.org/10.14571/brajets.v16.n4.1185-1196

Linhalis, F; Silva, A. C. & Santos, M. L. (2022) Ambientes Virtuais de Aprendizagem em Cenários Offline. *Anais do CIET:EnPET|CIESUD:ESUD|2022 (Congresso Internacional de Educação e Tecnologia | Encontro de Pesquisadores em Educação e Tecnologias | Congresso Internacional de Educação Superior a Distância | Congresso Brasileiro de Ensino Superior a Distância).* 2022. p.4097-4109. 2022. Universidade Mackenzie, São Paulo, SP. https://cietenped.ufscar.br/submissao/index.php/2022/issue/view/19

Linhalis, F.; Silva, A. C.; Vieira, C. A.; Vascon, L. E. L. & Santos, M. L. (2022) Virtual learning environments with offline resources. Actas *XXV Congreso Internacional de Informática Educativa (TISE 2022).* p. 411-416. Porto Alegre, RS. https://www.tise.cl/Volumen16/index.html

Linhalis, F.; Machado, A. C. P.; Vascon, L. E. L. & Silva, A. C. (2020) Uma Metodologia para Avaliação de Recursos Off-line em Ambientes Virtuais de Aprendizagem. *Revista Novas Tecnologias na Educação (RENOTE),* *18*, 204-214. https://doi.org/10.22456/1679-1916.110228

Lund, A. (2001). Measuring Usability with the USE Questionnaire. *Usability and User Experience Newsletter of the STC Usability SIG*, *8*.

Marcotte, E. (2011). *Responsive web design*. A Book Apart. https://abookapart.com/products/responsive-web-design

Maya, M., Anjana, V. M., & Mini, G. K. (2022). University Students' Perceptions Of Shifting between Online and Offline Learning: Lessons from Kerala, India. *Asian Association of Open Universities Journal*, *17*(3), 213–228. https://eric.ed.gov/?id=EJ1359042

Patel, J., & Patel, P. (2021). Online Teaching-Learning at University Level Education from Psychological Perspective and Consequences: A Post-COVID Scenario. *Issues and Ideas in Education*, *9*(2), 121–126. https://eric.ed.gov/?id=EJ1345178

Pugoy, R. A. D. L., Habito, C. D. L., & Figueroa Jr., R. B. (2016). Hybrid online/offline mobile solutions for accessing open educational resources in areas with poor internet connectivity. *Asian Association of Open Universities Journal*, *11*(2), 182–196. https://doi.org/10.1108/AAOUJ-09-2016-0030

Santiago, C. S., Ulanday, M. L. P., Centeno, Z. J. R., Bayla, M. C. D., & Callanta, J. S. (2021). Flexible Learning Adaptabilities in the New Normal: E-Learning Resources, Digital Meeting Platforms, Online Learning Systems and Learning Engagement. *Asian Journal of Distance Education*, *16*(2), 38–56. https://eric.ed.gov/?id=EJ1332615

Silva, A. C. & Linhalis, F. (2024) *Testes de Usabilidade da Plataforma Educa Offline.* Technical Report. n.1, 2024. 36p. Núcleo de Informática Aplicada à Educação, Universidade Estadual de Campinas. 2024. https://www.nied.unicamp.br/biblioteca/relatorios-tecnicos/

Susila, H. R., Qosim, A., & Rositasari, T. (2020). Students' perception of online learning in covid-19 pandemic: A preparation for developing a strategy for learning from home. *Universal Journal of Educational Research*, *8*(11B), 6042–6047. Scopus. https://doi.org/10.13189/ujer.2020.082240

Valarezo, D., Mendieta, G., Maza, B., Quiñones-Cuenca, M., & Morocho, M. (2021). An Offline Educational Resources Access System for the Galapagos Islands. Em Salgado Guerrero J.P., Chicaiza Espinosa J., Cerrada Lozada M., & Berrezueta-Guzman S., *Commun. Comput. Info. Sci.: Vol. 1456 CCIS* (p. 171). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-030-89941-7_12

Wiebe, A., Crisostomo, L., Feliciano, R., & Anderson, T. (2022). Comparative Advantages of Offline Digital Technology for Remote Indigenous Classrooms in Guatemala (2019-2020). *Journal of Learning for Development*, *9*(1), 55–72.

Yawisah, U., Akla, Umam, A. K., Asad, M., & Wahyudin. (2022). The Implications of Learning Management System on Education Quality in the New Normal Era: Evidence from Islamic Higher Education. *Journal of Social Studies Education Research,* *13*(2), 147–169. https://eric.ed.gov/?id=EJ1355831