SOLUTIONS TO ENABLE THE USE OF ICT IN EDUCATION IN REGIONS WITH LOW INTERNET CONNECTIVITY: A LITERATURE REVIEW

SOLUÇÕES PARA POSSIBILITAR O USO DE TIC NA EDUCAÇÃO EM REGIÕES COM BAIXA CONECTIVIDADE À INTERNET: UMA REVISÃO DA LITERATURA

Flávia Linhalis
Universidade Estadual de Campinas, UNICAMP
Campinas, Brazil
flalin@unicamp.br

André Constantino da Silva
Federal Institute of São Paulo, IFSP
Hortolândia, Brazil
andre.constantino@ifsp.edu.br

Abstract. The lack of Internet access increases the digital divide in the educational sector of developing countries, specifically in vulnerable and remote areas. In this article, a literature review was conducted to identify and to characterize LMS solutions adopted in regions with low Internet connectivity to leverage ICT integration in education. What are the LMS solutions to make the use of ICT in education feasible in regions with low Internet connectivity? Results found that, the Moodle app is the only solution that considers social isolation and can be used in distance education, in asynchronous activities, where there is no stable Internet. This result shows that it is worth investigating other solutions that considers social isolation and can be used in e-learning, with limited Internet access. Other solutions consider access to digital content on a local network, experienced by people living in remote areas with very little or no access to the Internet. The results of this study can be used to consider actions, projects and policies related to e-learning and ICT dissemination, mainly to people in vulnerable situation.

Keywords: digital inclusion; ICT; LMS; literature review; offline.

Resumo. A falta de acesso à Internet aumenta a divisão digital no setor educacional de países em desenvolvimento, especificamente em áreas vulneráveis e remotas. Neste artigo, foi realizada uma revisão da literatura para identificar e caracterizar as soluções de LMS adotadas em regiões com baixa conectividade à Internet para promover a integração das TIC na educação. Quais são as soluções de LMS para tornar o uso de TIC na educação viável em regiões com baixa conectividade à Internet? Os resultados encontrados indicam que o aplicativo Moodle é a única solução que considera o isolamento social e pode ser utilizada no ensino à distância, em atividades assíncronas, onde não há Internet estável. Esse resultado mostra que vale a pena investigar outras soluções que considerem o isolamento social e possam ser utilizadas no ensino online, com acesso à Internet limitado. Outras soluções consideram o acesso a conteúdo digital em uma rede local, experienciada por pessoas que vivem em áreas remotas com acesso muito limitado ou nulo à Internet. Os resultados deste estudo podem ser utilizados para considerar ações, projetos e políticas relacionadas ao ensino online e à disseminação das TIC, principalmente para pessoas em situação vulnerável.

Palavras-chave: inclusão digital; TIC; LMS; revisão da literatura; offline.

INTRODUCTION

Access to the Internet facilitates the exchange of knowledge between societies in the expanding digital age, making it possible to reduce the digital divide. The lack of Internet access is due to low investment and poor infrastructure, mainly in remote locations. The differences in the education sector are further aggravated by the unequal access to the Internet, making it difficult to develop and to spread digital content to educational purposes (Valarezo et al., 2021).

The infrastructure and policies of each location influence the digitization process, considering Internet access as a primary service. Improved Internet access is certainly an issue that most developing countries are working on (Hadriana et al., 2021). Although this is a development issue, most related do governments, it is not just the government that have a role to play. Other non-governmental institutions, such as foundations and universities, can also contribute to improve educational opportunities, for example, by promoting innovative teaching and learning strategies with ICT (Information and Communications Technology) integration. Fostering novel initiatives encourages the democratization of education using digital technology, generating opportunities for vulnerable individuals residing in locations with inadequate broadband connectivity (Valarezo et al., 2021).

Regarding access to education, the Covid-19 pandemic made the situation of vulnerable people even worse. With social isolation, schools were closed, teachers and students were pressured to change work and organization routines (Afrilyasanti & Basthomi, 2022). Online learning or e-learning were adopted as an alternative to suspending face-to-face activities. E-learning may be defined as "the use of computer network technology, primarily over or through the Internet, to deliver information and instructions to individuals" (Tiwari et al., 2021, p. 504–505). The important concept of e-learning is that the distribution of learning material is carried out via electronic media or the Internet. In ideal conditions, students can access it anytime

and from anywhere (Welliver, 2022). Just like other learning models, e-learning also has various benefits and weaknesses. Some benefits are the use of multimedia as Internet contain text, audio, graphics, video animation; flexibility to teachers and students; students can talk to teachers, experts or exchange opinions with other students without having to meet face-to-face. But some weaknesses may become obstacles to online learning: technical problems, for example, electricity that often goes out and unstable Internet networks; time constraints, teachers do not have much time to be more creative in preparing learning materials; limited operational skills, not all teachers can operate computers; and limited funds to improve the facilities and infrastructure (Hadriana et al., 2021).

E-learning solutions did not reach people that live in areas with low broadband speed during the pandemic social isolation. It was a nightmare for those with inappropriate Internet at home. A research about students' lack of motivation in Spain while attending online learning revealed that 90% of students were demotivated because the e-learning required more effort for them to learn. They had to struggle not only with their learning mastery but also with limited Internet connection as well as technology devices (Afrilyasanti & Basthomi, 2022).

In a study conducted in Saudi Arabia, students pointed out various obstacles that hindered the learning, including the lack of Internet access in some villages, frequent Internet disconnection during study, lack of modern devices that facilitate learning, failure to provide space for personal expression in remote learning, and many other. The biggest obstacle was the lack of Internet access to online learning and constant Internet disconnections. The results of the survey align with others, that showed that the lack of interest in using online learning programs was a result of problems related to the access and use of ICT (Almelhes, 2021).

In Ukraine, a survey reported that the absence of constant Internet access (33%), inconvenience in using distance learning platforms (26%) and the absence of clear requirements for the tasks (26%) were the most widespread difficulties that students had to face in the process of distance learning (Boyko et al., 2021).

In Punjab (India), the sudden transition from regular to virtual mode impacted education with students coming from diverse backgrounds like urban areas, rural areas, remote areas, rural-urban areas etc. The majority of students (94%) used smartphones to attend their online classes and the remaining 6% of students used laptops/personal computers for the classes. The study also revealed that the level of acceptance by students depended on the availability of IT infrastructure (Chadda & Kaur, 2021). Another study in India (at Kerala region) reported that around 90% of college students were not satisfied with the online classroom system, as they faced digital infrastructure challenges such as poor Internet connectivity, lack of good digital devices, power failure, etc (Maya et al., 2022).

Patel and Patel (2021) found out that psychology students in India are more comfortable with face-to-face than online learning, and that 75% of university students prefer face-to face to online classes. The study pointed out that a fundamental advantage of the face-to-face learning is that it is less subject to the quality of Internet connection (Patel & Patel, 2021).

According to Yawisah (2022), students in Indonesia showed weakness in using LMS (Learning Management System) application mainly because of poor signal problems, lack of interaction in learning, and the impossibility of uploading videos and photos for practical assignments. It was concluded from these findings that using the LMS requires strong network support and the region was not ready for this (Yawisah et al., 2022). Another study in Indonesia, at Baturaja University, showed that all of the students had their own mobile (100%) and owned Internet access (86,8%) but only 52,6% students had ease in accessing the Internet. The lack of facilities, especially Internet connections, were pointed out by the authors as the main cause of students' dissatisfaction with e-learning (Susila et al., 2020).

Teachers faced many problems in using technology for teaching, specially due to the lack of training. They did not have sufficient infrastructure like configured laptops, Internet, microphones, etc. Challenges related to teachers training, Internet access and technology use leaded to lower students engagement in sustaining academics during Covid-19 pandemic (Almelhes, 2021; Barabási, 2021; Joshi et al., 2020).

Many teachers faced connectivity issues, system failure, and bandwidth issues while conducting online sessions and due to lack of technical assistance, they were unable to resolve problems (Almelhes, 2021; Joshi et al., 2020). In Romania, almost half of the teachers (49.8%) considered that the range of options for digital tools that could be used in schools was unsatisfactory and according to 36.2% of the teachers, the Internet access was also inefficient (Barabási, 2021).

Santiago et al. (2021) conducted a study at Cavite State University, Philippines. According to the authors, the use of smartphones as learning tools improved remote education in teaching and learning.

However, areas of concern such as financial condition and poor connectivity of the students deserve more attention in the future (Santiago et al., 2021).

According to UNESCO Education Monitoring Report, about Latin America and the Caribbean (2020), before the pandemic, Latin America and the Caribbean was already the most unequal region in the world. Specifically with regard to access to education and the Internet, it is estimated that more than 32 million children live in households that are not connected to the Internet. The heterogeneous nature of those societies means that experiences differ depending on the contexts of Internet access, digital skills, educational opportunities, and inequality in each country of that region (UNESCO, 2020b).

For example, while 70% of households in Uruguay own a computer and 64% have Internet access, Internet access levels are below 30% in the Plurinational State of Bolivia, Cuba, and El Salvador (UNESCO, 2020b).

A report from CETIC.br, a Regional Center of Studies about Latin American and Portuguese-speaking countries in Africa, operating under the auspices of UNESCO, shows that, in 2021, there were about 59 million households with Internet in Brazil, representing 82% of Brazilian households. In rural areas presence of Internet was about 71%. Fixed broadband was present in 71% of households with Internet access in the country. In poorest regions of Brazil, this type of connection appeared in smaller proportions in rural areas (58%), in the North (61%) and Northeast regions (64%), in households with low income families this number decreased to 52% (CETIC.br, 2021).

UNESCO Education Monitoring Report (UNESCO, 2020a) showed that, at the end of 2018, 3.9 billion people, or 51.2% of the global population, were Internet users. In OECD countries, 1 in 20 students, and almost 1 in 10 of those attending disadvantaged schools, lack an internet connection at home. The latter share rises to 1 in 4 in Chile, 1 in 2 in Turkey and almost 3 in 4 in Mexico. Not all internet connections are strong enough to download data or take part in video calls. In Italy, while 95% of households are connected, 1 in 4 have a connection below 30 Mbps, lower than required to download and stream education content.

> Low-and middle-income countries are at a far more disadvantaged starting point for an effective transition to online learning platforms. In Burkina Faso, Burundi and Chad, at least 85% of the population did not even have access to electricity in 2018. The share of households with internet access at home was 47% in developing countries and 12% in the least developed countries in 2019, compared with 87% in developed countries. Internet bandwidth per internet user was 91 kbit/s in developing countries and 21 kbit/s in the least developed countries, compared with 189 kbit/s in developed countries.
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> In Morocco, while 71% of households had internet access in 2019, 93% was by phone. Fixed internet infrastructure is insufficient, especially in rural areas. As about 90% of mobile internet data is paid according to consumption, it is much more expensive than a regular subscription, but the latter is not feasible for households without regular income or a bank account (UNESCO, 2020a, p. 59–60).

School closures placed unprecedented challenges to learning continuity. Disparities in access to the most basic infrastructure like the Internet, mean that much of the potential of education for inclusion is a challenge for many in the world's poorest countries (UNESCO, 2020a).

Internet connectivity and even the lack of Internet in some areas were a great challenge, contributing to the slow pace of ICT integration in education. Technological tools, such as LMS, and access to the Internet are important elements to e-learning and ICT integration on education. It became even more evident during social isolation caused by the pandemic.

LMS are tools that enable remote access to a set of learning activities to be developed by students - viewing videos, reading texts, participating in discussion forums, among others (Linhalis et al., 2020).

There is a wide variety of LMS available (Capterra, 2023). These platforms depend on an Internet connection to interact with the system. As already known, during the pandemic, the lack of Internet access was a determining factor in the exclusion of a portion of the population. With schools and universities closed, we could see that the right to study occurred in an unequal way, that the lack of access to technology and the Internet further aggravated social and educational issues in poor countries.

The purpose of this study is to identify and to characterize LMS-based solutions adopted to reduce the lack of Internet problem and to leverage ICT integration in education. This study can serve as input for the assessment of programs, policies, and initiatives related to ´e-learning offline solutions´, mainly to people in vulnerable situation.

What are the LMS solutions to make the use of ICT in education feasible in regions with low Internet connectivity?

The pandemic was a period that showed us the urgency of integrating ICT in education. So, to answer the posed question, a systematic review considering the pandemic period was conducted. The methodology, along with the criteria and search processes, will be explained in the following section.

METHODOLOGY

Search criteria

The academic databases Web of Science (WoS), Scopus, and ERIC (Education Resources Information Center) were searched for scientific articles published between the years 2020 and 2022, which correspond to the pandemic years, in order to conduct a systematic literature review (Kitchenham & Charters, 2007).

Three concepts, each separated by the boolean word AND, and synonyms of each, separated by the boolean OR, comprised the search. Thus, the first concept had various terms associated with virtual learning environments, the second related to offline solutions, while the third referred to the educational segment: ("Virtual Learning Environment*" OR VLE OR LMS OR "Learning Management System*") AND (offline OR off-line) AND (Teaching OR Learning OR Education)

Inclusion Criteria

The following inclusion criteria were considered:

- The period between the years 2020 and 2022: corresponding to the pandemic years.
- Peer reviewed articles: only scientific peer reviewed journal or conference articles were considered.
- LMS-based solutions: A key component of the research is to limit the search to articles related to LMS solutions to overcome the lack of Internet.

Exclusion Criteria

The following exclusion criteria were considered:

- Educational or technological applications that do not address offline solutions to e-learning or m-learning.
- Research focused on telecommunication infrastructure, instead of software and/or hardware solutions.

The search initially yielded 313 results. All abstracts were read and 65 results were obtained from the identification of articles that met the inclusion criteria. Next, in order to apply exclusion criteria, a superficial reading of the 65 publications was done while taking note of the research findings. Six documents were chosen for a depth read, as listed in Table 1.

Table 1. Articles published in the pandemic years.

As cited in the text	Complete Reference
Allela et al. (2020)	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.
Cossa et al. (2021)	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.
Dai et al. (2022)	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
Leshchenko & Bezlutska (2021)	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
Valarezo et al. (2021)	Valarezo, D., Mendieta, G., Maza, B., Quiñones-Cuenca, M., & Morocho, M. (2021). *An Offline Educational Resources Access System for the Galapagos Islands*. *1456 CCIS*, 157–171. Scopus. https://doi.org/10.1007/978-3-030-89941-7_12

Wiebe et al. (2022)	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.

Source: Authors.

Due to the low number of articles, the search was expanded to consider the following additional inclusion criteria:

- Papers of the group that investigated offline features in LMS.
- The related works of the selected articles.
- Articles suggested by WoS.

The additional inclusion criteria added 4 more articles (Table2), totaling 10 articles that were read in depth.

Table 2. Articles with additional inclusion criteria.

As cited in the text	Complete Reference
Balaji and Cheng (2016)	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
Linhalis et al. (2020)	Linhalis, F., Machado, A. C. P., Vascon, L. E. de L., & Silva, A. C. da. (2020). Uma Metodologia para Avaliação de Recursos Off-line em Ambientes Virtuais de Aprendizagem. Revista Novas Tecnologias na Educação, 18(2), 204–214. https://doi.org/10.22456/1679-1916.110228
Linhalis el al. (2022)	Linhalis, F., da Silva, A. C., & Santos, M. L. (2022). Ambientes Virtuais de Aprendizagem em Cenários Offline. Anais do CIET:EnPET|CIESUD:ESUD|2022, 1–13.
Pugoy et al. (2016)	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

Source: Authors.

RESULTS

An overview of the relevant literature is provided in this section. This study reveals some implementations of LMS-based technologies in remote areas with no Internet or low bandwidth, that permits the reduction of the inequalities and ICT integration on education.

The Moodle APP

Four papers in this systematic review pointed to Moodle as a solution for offline asynchronous e-learning activities (Allela et al., 2020; Leshchenko & Bezlutska, 2021; Linhalis et al., 2020, 2022).

The Moodle mobile app allows students and teachers "to access and interact with content on the Moodle platform whilst offline such as posting on discussion forums, replying to messages, attempting quizzes and activities, reading forum posts, or submitting assignments"(Allela et al., 2020). These are asynchronous activities that are automatically synchronized with the content on the Moodle platform when the device is connected to the Internet.

A study conducted by Linhalis et al. (2020; 2022), highlights Moodle as a good option to asynchronous activities, considering an unstable network. The study considered navigation, synchronization and processing features of LMS (Linhalis et al., 2020):

- Navigation: It concerns whether the LMS supports offline navigation through content. Some expected features are about keeping a history (in cache) of the accessed pages, download an entire course, and to show which files are available offline and which ones are not.
- Synchronization: Content can be changed by teachers and/or students while the LMS platform is offline - submit a comment or file, for example. For this reason, it is necessary to perform synchronizations with a server when the client (e.g. desktop computer, laptop, tablet) finds an available network.

- Processing: In addition to synchronizations, when thinking about low bandwidth it is desirable that large files (especially videos) are processed and returned to the client at lower resolutions.

The authors made a comparison between Moodle and Google Classroom, as shown in Table 3. According to Linhalis (2022), Moodle is better prepared for situations where there is an intermittent network. It is possible to use the Moodle app on both - mobile devices and desktops - to browse the entire course, make changes and synchronize with the server. The same actions are not possible with Google Classroom.

Table 3. Moodle and Google Classroom comparison about offline features.

	Moodle	**Google Classroom**
Navigation	Moodle does not allow to browse content in offline mode when using a browser (Chrome and Firefox, for example), only when using the Moodle app. In the Moodle app, it is allowed i) to browse previously accessed pages offline, ii) to decide which files to download while online and the selected files will be available for offline use, and iii) to download an entire course.	As in Moodle, when using the platform through the browser, Google Classroom does not allow browsing in offline mode. The app works only on mobile devices, not on desktops (like the Moodle app). In the mobile version, it allows to browse offline previously accessed pages. Therefore, it is not possible to use Classroom in offline mode on desktops and laptops. Regarding the files, the platform allows to download them, but there is no highlight that the file is available offline as in Moodle. It is not possible to download an entire course.
Synchonization	In the Moodle app, it is possible to make comments offline and after the connection is re-established the app automatically synchronizes with the necessary updates. When trying to send a comment without a network, an alert is displayed stating that it had not been sent yet, and that new updates must be synchronized. Moodle app also allows to upload files without a network - it informs that synchronization is needed, and when connecting to the network the file is sent automatically, without any additional user action.	Google Classroom does not allow to enter comments or files whilst offline. It does not synchronize with the server.
Processing	When uploading videos and images, the platform does not do any processing on the files. Both uploaded and downloaded files, maintain their original sizes and formats.	Google Classroom works integrated with other Google tools such as Drive, Sites, Meet and Gmail. When uploading a video, Classroom saves it in Drive with the original size.

Source: (Linhalis et al., 2022).

LMS with local network

Dai et al. (2022) adapted Moodle with synchronization features to allow colaboration between teachers and students. As stated in the previous section, Moodle has some features for situations where there is an intermittent network. But traditionally, it focuses on online collaborate learning, so the course contents have to be downloaded before moving offline, and the changes made offline can be synchronize with the server and delivered to the clients automatically when it can access the Internet, only using the Moodle app (available to desktops, laptops, tablets and smartphones).

The authors build a collaborative learning system that works offline in a local network and asynchronously share data with other devices when it can access the Internet. The solution makes use of Raspberry Pi-based server hardware and Moodle. Thus, students in isolated and underdeveloped areas could save their assignments on the device offline and communicate their data via a low-cost local network with other students and instructors (Dai et al., 2022).

The solution was successfuly evaluated in the remote Australian Northern Territory, where just 58.7% of households reported having Internet access in 2016, far below from the 78.8% national average. This

indicates that a major issue impeding equitable access to learning resources in the area is Internet connectivity. Even those who have access report that it is sporadic or requires travel in order to connect to the Internet.

KA Lite and Kolibri

KA Lite is an offline version of Khan Academy, that allows users without Internet to access, to watch, and to do Khan Academy exercises in completely offline settings, bringing the classroom model to remote areas. Khan Academy, is an educational NGO (Non-governmental organization) with a mission to spread education. It offers a platform with a free collection of videos from various areas of knowledge in various languages - mathematics, medicine, physics, computing, etc. Much of Kan Academy's material is made available in the style of blackboard videos.

Currently, KA Lite can be downloaded, but it is no longer under active development. It has been gradually substituted by Kolibri. The same team is involved in the development of both and encourages migration from KA Lite to Kolibri as it has improvements with regard to interface, available material, content/user management and usability (Learning Equality, 2023).

The philosophy of the Kolibri platforms is to bring education to underserved areas in the world by offering a common content already thought out in its pedagogical function and developed by educational institutions. There are 3 roles in the platform – admins, coaches and learners. Only the admins have permission to add content. The teacher (or coach) is a mediator of the content made available by the system administrator, managing the content to which the learners will have access and choosing the exercises that should be done by the learners.

Kolibri installers, updates, and content can be downloaded once to a device in an area that has an Internet connection. Then the device can share new content and updates with other devices over an offline local network. To reach the most remote communities, a device can be carried to share installers, updates, and content with other devices over local networks.

Aptus System

Cossa et al. (2021) reported an experiment conducted with the Aptus system. Aptus can be installed in tablets, it was designed to connect to digital LMS platforms, and to access course materials without the need for grid electricity or Internet access.

The authors detail how it was implemented in fifteen secondary schools in Mozambique, between 2018 and 2020. The solution was successful in terms of expanding curriculum coverage, providing access to devides, supporting and developing teachers (Cossa et al., 2021).

The Aptus system use was also reported by Balaji and Cheng (2016), in Swat region, Pakistan. The project was implemented during January to March 2016, in two schools, where all learning materials were loaded on the Aptus.

Aptus tablet demonstrated that the use of mobile to access and interact with electronic learning materials benefited students' academic performance and improved their ICT skills to prepare them for technological era. Furthermore, children were more interested because of multimedia and animated videos material options (Balaji & Cheng, 2016).

According to Balaji and Cheng (2016), the Aptus system has been successfully tested in twenty locations in 15 countries across the Commonwealth since early 2014.

RACHEL MLL

Wiebe et al. (2022) described the use of an offline set of laptops connected with local digital libraries servers in ten schools in Guatemala Indigenous communities, in 2020.

Most homes in the Municipality of Comitancillo own a cell phone, but due to the area's hilly topography and sparse population, mobile phone coverage is either spotty or nonexistent. There is inadequate, and in certain places nonexistent, internet connection (Wiebe et al., 2022).

The study looked at how Mobile Learning Labs (MLLs) were implemented and utilized. The MLLs included a RACHEL Plus 3.0 and a set of tablets with keyboards for use in the classroom. RACHEL (Remote Area Community Hotspot for Education and Learning) is a portable, battery-operated device that contains websites, curriculums, instructional games, and a variety of digital libraries in addition to open educational resources (OER). Without requiring an Internet connection or data plan, RACHEL wirelessly

distributes the information to tablets, computers, and cellphones. The RACHEL's content can be updated by transporting it to a location with an Internet connection and uploading new content, but the MLLs are only used offline (Wiebe et al., 2022).

The authors qualitative findings identified four benefits that were already expected to be relevant to remote Indigenous communities - better standardized training, varied instruction, practice opportunities, and learner engagement. Newly identified benefits included teachers' and students' technological abilities and digital literacy, sharing cultural knowledge, and access to multimedia educational resources (which can replace printed materials) (Wiebe et al., 2022).

CMS with syncer

Pugoy et al. (2016) worked on a mobile solution for accessing OER in places with inadequate Internet access, that the authors called "hybrid solution". The project was conducted in Philippines, with costly broadband Internet connections and the second-slowest Internet connection in Asia.

They proposed a hybrid online/offline model as a possible strategy to bandwidth-challenged countries. In a hybrid configuration, the student establishes an Internet connection in order to synchronize and download OERs from a CMS (Content Management System) repository. Only newly updated files are copied from the repository to the mobile device during the synchronization procedure. After synchronization, the learner may view content with or without an Internet connection (Pugoy et al., 2016).

The system enables students to easily read and update educational resources on their mobile devices. So users would not need to manually download and arrange content, which could be laborious and time-consuming.

The solution focused on easily obtain and update OER content automatically, according to the available bandwidth. Updates only happen in one direction. Computers, mobile devices, and additional servers are examples of the target site, while servers, cloud storage, and other locations are examples of the source. By pushing fresh and updated files from the source to the destination automatically, a duplicate of the source is produced.

The viewer and the syncer are in the client, or target, side. Regardless the Internet connectivity state, the user can use the viewer app to browse OER content. Similarly, when the syncer is on, it automatically pulls updates from the OER repository. It then synchronizes them with the viewer after downloading.

WordPress, a CMS, was used as the repository. In this solution, the LMS role was played by a CMS. It enables OER providers to handle content without requiring them to know web programming. The repository enables the creation, organization, and modification of OERs on the server side. The resources were arranged into categories, and tags were used to facilitate searching. The mobile enabler, a little application or plugin that makes sure the OERs are mobile friendly, is another component on the server side.

KAMU Server

Valarezo et al. (2021) describe a solution to Galapagos Islands, Ecuador, where broadband speed is deficient and mobile Internet access depends on the technology and coverage area of the Internet Service Providers (ISPs) (Valarezo et al., 2021).

In their proposal, the Universidad Técnica Particular de Loja (UTPL) LMS platform is combined with a multipurpose mini local server. The university uses the virtual learning environment CanvasUTPL, derived from Canvas LMS.

The technological solution combines two Internet browsing modes: i) the offline method to low or no Internet connection, and ii) the online mode. A Traffic Manager Service on the local server (KAMU Server) uses Internet Protocol (IP) table rules to forward network traffic. Users are redirected between the two modes of Internet browsing. Users of the online approach have access to the educational materials that are posted on the Internet, while the local educational resources kept on the local web server are accessible to users of the offline system.

The solution allows the distribution of educational resources - open e-books, videos, images, among others - strengthening the university's distant learning infrastructure in a remote center.

DISCUSSION

Several approaches were considered to mitigate Internet access challenges and to continue teaching and learning during the pandemic. For example, the use of printed material was a widely adopted solution where there was no Internet. In India and Indonesia, television channels were added to reach areas where Internet connectivity was a concern (Joshi et al., 2020) (Susila et al., 2020). These were viable solutions considering the infrastructure and policies of that regions. But in this article, the focus is in LMS solutions that promoted the use of ICT.

Besides Moodle, only one non-proprietary LMS appeared in the literature review. Askari and Chen (2021) reported the personal experience of a teacher, in Iran, using the Shad LMS, provided by the government. According to the authors, more than 17 million students, teachers, and headmasters from primary to senior high schools were simultaneously using Shad LMS across the country. The congestion and slowdown of the Internet was inevitable. To overcome the situation, the teacher adopted proprietary tools such as as WhatsApp and Skyroom (Askari & Chen, 2021).

In Cavite State University, Philippines, teachers and students agree to use a range of online resources (including YouTube, mobile apps, and digital libraries) using available devices (such desktop, laptop, and tablet computers) and accessed the learning content with proprietary LMS platforms (e.g. Edmodo, Google classroom, Zoom, Google Meet) (Santiago et al., 2021).

For asynchronous classes, Google Classroom was the most popular online learning platform. According to Santiago et al. (2021), this may be attributed to the popularity, simplicity, easy access, convenient and integrated tools (such as G-mail, Sheets and Slides, Google Drive, and Google Docs) that make it possible to use physical material in digital format. According to the authors, the most popular platform for meetings during synchronously scheduled classes was Google Meet. For flexible learning, the most convenient platform was Facebook, followed by Google and Zoom (Santiago et al., 2021). WhatsApp also appeared as an easy and ready solution to interact with students in both audio and video modes (Askari & Chen, 2021).

These are all proprietary tools owned by big corporations such as Google and Facebook, which are among the most valuable companies in the world. They have offered educational institutions access to educational technologies and information storage in their data centers. These relationships were intensified during the Covid-19 pandemic, given the increase in demand for remote learning and the lack of proper infrastructure to support it (Amiel et al., 2021).

Although widely used during the pandemic, the proprietary tools with e-learning facilities found in the literature review do not provide offline features. This was pointed out as one of the difficulties with utilizing, for example, Google Classroom for learning. Students in vulnerable situation without access to high Internet connection, or weak Internet connection in the remote areas (like rural areas) could not use Google Classroom effectively (Santiago et al., 2021).

Different from Moodle, Google Classroom does not provide offline facilities. The Moodle plaftorm was mentioned in four articles of the literature review (Allela et al., 2020; Leshchenko & Bezlutska, 2021; Linhalis et al., 2020, 2022) as a viable solution to assyncronous learning with intermitent Internet access. The Moodle app allows students and teachers to access and interact with content on the platform whilst offline in asynchronous activities that are automatically synchronized with the Moodle server when the device is connected to the Internet.

The solutions discussed so far in this section consider the social isolation situation caused by the Covid-19 pandemic. The remaining solutions consider offline access, but not social isolation, as they are solutions that need a local network to work.

In this situation, the school or university has a local wireless network, with a LMS installed on a local server to provide access to local digital content. Google Classroom, or other proprietary LMS solutions, would not be possible in that situation, because they are essentially cloud applications, i.e., it is not possible to install them on a private local server.

In that scenario, teachers and students can access the courses contents with mobile devices, on a private local network. They interact with the material and create new digital content, which is stored and available locally on their personal devices and is synchronized with the school server, when the student or teacher is within the coverage limits of the local network.

This is the case of Dai et al. (2022) solution, which used Moodle as LMS on a local network to allow collaboration between teachers and students in the local network limits. Synchronization with the server is performet only when it can access the Internet.

In Kolibri the courses are pre-formatted by the institution that offers them (administrators) through the Kolibri Studio platform. If a course is changed by the administrator, a new download of the content must be performed. However, Kolibri has an interesting feature of sharing between devices on the same local network, which makes it possible to share content and synchronize data between these devices (Linhalis et al., 2022).

The solution presented in Pugoy et al. (CMS with syncer) is also based of the same principle, the existence of a local network so that updates can happen. The differential of Pugoy et al. (2016) solution is that they developed a syncer for WordPress to enable automatic updates. They used a CMS to play the role of a LMS.

Valarezo et al. (2022) solution was designed for a remote center of the University, in Ecuador, which has to constantly deal with the instability of Internet Service Providers (ISP). In this solution, students and teachers at the university can access the Internet normally when the ISP is online, but when it goes offline, a local server automatically transfers the connection to the center's local network, so users can access locally hosted instructional resources on the web server.

Aptus system and RACHEL MLL are solutions used where there was no Internet. Content was previously added on mobile devices and taken to schools in regions where there was no Internet or even electricity.

CONCLUSION

Some of the results of the Sustainable Development Goals were launched at the High-Level Political Forum, in New York (USA), in a recent report of the United Nations (United Nations, 2023). According to the report, without further action, the UN estimates that 84 million children and young people will still be out of school; approximately 300 million students will lack the basic numeracy and literacy skills needed; and only 1 in 6 countries will reach the universal target of secondary school completion by 2030. Progress towards quality education was already slower than needed before the pandemic, but Covid-19 has had devastating impacts on education, causing learning losses in 80% of the 104 countries studied.

To achieve Goal 4 "inclusive and equitable quality education and promote lifelong learning opportunities for all", financing education must become an investment priority. In addition, measures such as making education free and compulsory, increasing the number of teachers, improving basic school infrastructure and embracing digital transformation are essential.

In developing counties, particularly in rural and distant locations, the lack of Internet connection expands the digital divide in the educational sector, limiting access to information and communications technology (ICT).

According to the literature review that was conducted, the only solution that considers social isolation and can be used in e-learning in asynchronous activities where there is no stable Internet is the Moodle app. It is a viable solution in situations with limited Internet access, experienced by people living in remote communities or even in urban centers that periodically deal with network access limitations.

As already known, the lack of Internet has strongly impacted the lives of students and teachers, mainly in vulnerable situation. For many people, it was an obstacle to continue the studies during social isolation. So, it is worth investigating and developing other solutions that considers social isolation and can be used in e-learning, with limited Internet access.

The other solutions consider access to digital content on a local network, which is more difficult to be implemented in a situation of social isolation. The solutions were experienced by people living in isolated areas with very little or no access to the Internet such as rural schools, indigenous populations or quilombos.

Providing the use of ICT in education in regions with low Internet connectivity is a tremendous challenge, but at the same time, an unique opportunity. Access to ICT and the Internet would provide the population living in these areas a possibility to progress on the educational and other levels. Although this is used to be a government issue, it is not only the government that has a role to play. This article presented some examples where ICT has been effectively used for the benefit of people living in remote locations to improve education, in areas with low or no Internet connectivity. The presented solutions were implemented by foundations, ONG, and universities – organizations that can study, develop, and disseminate solutions with new software and hardware technologies for remote areas, showing the social impact on the community that permits the reduction of the inequalities in education. The results of this study can be used to consider actions, projects and policies related to e-learning and ICT dissemination, considering offline solutions, mainly to people in vulnerable situation.

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