Techno-pedagogical Solution to Support the Improvement of the Quality of Education in Technical and Vocational Training in Mauritania

Cheikhane SEYED[1], Jeanne Roux NGO BILONG[2], Mohamed Ahmed SIDI[3], Mohamedade Farouk NANNE[4]
Laboratory LIRT, Polytechnic Superior School, University Cheikh Anta DIOP (UCAD), Dakar, SENEGAL[1, 2]
General Director of Society DCS-SARL, Nouakchott, Mauritania[3]
Faculty of Sciences and Technologies, University of Nouakchott Al Aasriya (UNA)[4]
Department of Mathematics and Computer Science[4]

***Abstract*—E-learning is the most promising and fastest growing activity since the advent of the COVID-19 pandemic. Although the pandemic seems to have been eradicated in several countries of the world, it is worth mentioning that some positive cases of the covid-19 variant have been detected. This could accelerate the rate of infection again. Hence the interest generate in reinforcing the quality of distance learning platforms. Technical and vocational training (TVT) in Mauritania is based on science, technology, engineering, and mathematics (STEM) disciplines. Unfortunately, the expansion of the COVID-19 pandemic has negatively impacted the quality of education with a halt in teaching affecting 8000 students. Yet, the quality of education in these disciplines is a key factor in meeting the demands of emergence and economic growth. This paper advocates the mixed pedagogical model by proposing a techno-pedagogical solution to improve the quality of teaching and learning processes. The proposed solution combines the use of technologies such as Modular Object-Oriented Dynamic Learning Environment (Moodle) and Web Real Time Communication (WebRTC) to provide pedagogical services in a context with a limited Internet connection. In addition, we set up a signaling system to maintain direct communication between the pairs, Application Programming Interface (API) of Multipoint Control Unit (MCU) to ensure simultaneous collaboration in a peer-to-peer context, used implementations of security protocols such as Datagram Transport Layer Security (DTLS) and Secure Real-time Transport Protocol (SRTP) to secure data transport.**

***Keywords*—TVT; STEM; Mixed education; Moodle; WebRTC; signaling system; MCU; DTLS; SRTP**

I. INTRODUCTION

Education is a key instrument for promoting growth and economic development. In view of this, the Mauritanian government, with the support of its partners, has launched a project under the leadership of DCS-SARL for the development of the technical and vocational training sector (TVT).

The training centers in Mauritania welcome around of 8,000 students each year in Science, Technology, Engineering and Mathematics (STEM) disciplines. These disciplines require the implementation of strategies to ensure the quality of the teaching system in order to meet the requirements of economic development requiring the performance of the educational process.

In addition, the pandemic of the COVID-19 impacted the living and working conditions and has in turn forced the States to take measures concerning social distancing in order to prevent its propagation in the society. To this effect, these professional technical training (FTP) centers have been victims of a blockage in their teaching-learning processes, drastically reducing the number of class sessions. This has had serious consequences on both the pedagogical continuity and the quality of teaching.

In spite of these shortcomings, these training centers must work to improve their teaching in accordance with quality assurance standards to enable students to be competitive and effective in the labor market, but also to increase the ratio of the population of age to attend these professional training courses.

The lack of a suitable pedagogical model for these training centers and the lack of a better techno-pedagogical infrastructure have favored the migration to ICT-based solutions in order to improve the quality of teaching, while ensuring pedagogical continuity online.

The need for a pedagogical model adapted to these training centers and the poor quality of the techno-pedagogical infrastructure led us to encourage these training centers to migrate to ICT-based solutions in order to improve the quality of teaching, while ensuring pedagogical continuity online in case face-to-face courses are not possible.

In the literature, authors [1] [2] have shown the usefulness of adopting the blended learning model for traditional training. The latter consists in combining traditional teaching methods with e learning in order to increase the efficiency of the teaching systems.

Other authors [3] have proposed mechanisms to improve the effectiveness of blended learning by adopting the model of teaching based on the integration of online and offline activities (O2O). This strategy aims to increase the utilization of the teaching system by providing access to learning content in an environment with limited internet connection.

In the works [4] [5] [6], the authors have advocated the so-called social-constructivist pedagogical model to improve the quality of teaching, according to which the teacher creates

learning situations that invite learners to collaborate and cooperate via innovative techno-pedagogical services in order to develop concrete professional skills.

Teaching must rest on professional practice to meet the needs of the labor market. The authors [7] have proposed strategies to involve synchronous education development in the learning process.

This form of education, involving instantaneous, face-to-face interaction, allows schools to train students in correct concepts and awareness of work and mastery of professional skills through specialized synchronous courses.

These research discussions led us to propose a quality hybrid solution using innovative and flexible technologies to the profile of TVT centers. The proposed solution offers synchronous and asynchronous pedagogical services appropriate and adapted to the context of the TVT centers.

The rest of this paper is organized as follow: Section II describes technical and vocational training and discusses of Technological background in e-learning; Section III presents software architecture of system proposed; Section IV describes hybrid learning architecture; Section V is dedicated to discussion and result and finally in Section VI provides the conclusion and perspectives of ours works.

II. Related Work

In [8], the authors propose a survey. This survey reveals the fear, the anxiety of learners for the handling of distance learning platforms.

The authors' contribution [9] presents the collaborative platforms Google Classroom, Zoom and Microsoft Team and compares them. They show the negative impact of using distance learning platforms on the mental health of learners.

These limitations have led us to propose a technological solution appropriate and suitable to the context of technical and vocational training.

A. Technical and Vocational Training

The technical and vocational training (TVT) in Mauritania is provided by the National Institute of Promotion [10]. Its purpose is to provide individuals with the knowledge and skills necessary to practice a trade or profession in order to integrate into the labor market as a worker's helper, specialized worker, skilled worker, technician or senior technician.

The mission of the TVT articulated around the following axes:

1) Satisfaction the needs of the labor market in qualified personnel.

2) Improving the professional skills of workers.

3) The development of the individual's potentialities in the perspective of the accomplishment of his professional project.

4) The promotion of the entrepreneurial spirit, with a view to self-employment.

5) Educational and professional orientation, information and advice on skills.

The Technical and Vocational Training system under the MENFTR composed of: (1) 16 technical education and vocational training schools (EETFP); (2) Higher Center for Technical Education (CSET) and (3) Six private training establishments that train mainly in the tertiary and service sectors.

Concerning the training curriculum, the TVT offers initial training courses organized as follows:

- Certificate of Competence (CC); 6 to 9 months duration.
- Certificate of Professional Aptitude (CAP), lasting 2 years.
- Technician's Certificate (BT), lasting 2 years.
- Higher Technician Certificate (BTS), lasting 2 years.
- Technical Education Certificate (BET), lasting 4 years.
- Technical baccalaureate, lasting 3 years.

The number of TVT students for the 2020-2021 training year is 7,885, including:

- 238 at CSET.
- 7,125 students in EETFPs.
- 190 students at the Ighraa Institute.
- 332 Pupils in Private Establishments.

These students divided according to educational level as follows:

- BTS : 722.
- BT : 2726.
- CAP : 2895.
- Technical baccalaureate and BET: 1542.

B. Technological Background in e-learning

Today, ICT have become an integral part of the culture of society. Their places are increasingly important in all areas of life. This presence of ICT is all the more felt at the level of education systems.

Several studies such as [11] [12] show that the appropriate use of technological innovations in teaching can contribute to improving the quality of teaching and learning.

Nevertheless, technical and professional training resting essentially on STEM disciplines requires the adoption of learning practices that promote interactivity and collaboration to develop practical and professional skills in students that will enable them to compete on the market of work.

In addition, the low level of TVT students in the field of ICT encourages the adoption of flexible technological solutions to use in order to eliminate any obstacle to the use of ICT to the detriment of the deep exploitation of educational services.

Indeed, the authors [13] have shown the relevance of using Moodle technology to facilitate interaction and create a

dynamic learning environment for mixed-mode courses. According to the authors [14], Moodle is a practical tool containing versatile and rich enough functionalities for teaching.

Moodle remains an asset for learners because it offers the possibility of working at their own pace by alternating course sessions and face-to-face and distance learning activities. In this context, we use this technology to provide, through our techno-pedagogical solution, an adaptation and organization of lessons with the aim of developing a certain autonomy in the learner: we are talking about asynchronous learning.

In addition, asynchronous teaching via Moodle illustrates some insufficient of teaching when one is looking for real-time exchange. For the authors [15], face-to-face interaction between teaching actors is a key factor in improving the quality of online teaching.

This synchronous teaching modality reflects traditional classroom teaching where students become actively involved in their learning by interacting with each other, but also with their teacher to produce their educational activities.

Several technologies have materialized the synchronous mode in the online teaching process by promoting collaboration between actors.

However, online collaborative solutions applying in an organizational network and including interactive spaces in STEM fields require a certain type of access to resources. The generalization of broadband access is one of the fundamental conditions for quality online education.

Unfortunately, the context of technical and vocational training centers often has a limited internet connection. This can pose a problem of efficiency of the distance education system. Research work [16] on technologies that can operate in a local IP environment and offer innovative collaborative services via the web, led us to take an interest in WebRTC technology.

According to the analysis study in the works [17], WebRTC technology is better compare to other real-time interaction tools for several reasons: (1) WebRTC allows interaction in peer-to-peer mode without the using an intermediate server. This remarkably reduces latency; (2) WebRTC integrated into the bandboxes of recent browsers without any intermediate configuration or installation.

In view of these discussions, we combine these two technologies, namely Moodle and WebRTC, to provide a quality e-learning solution offering educational services in synchronous and asynchronous mode, with the possibility of operating in an intranet network. In addition, these services are accessible via a simple browser requiring neither download nor installation of plugins on client workstations. This could have a positive impact on the implementation of services adapted to the needs of TVT centers

III. Software Architecture of the Proposed Solution

This paper aims to improve the quality of hybrid training, both theoretically and in terms of the development of tools that promote interaction and collaboration between the various actors in teaching and learning activities.

The architecture proposed (Figure 1) below consists of several software components interacting with each other via the network.

It aims to improve the quality of education in TVT centers through the following inputs.

A. Simultaneous Multi-communication Model

In our system, several services are outcome from WebRTC technology using VoIP to foster collaboration between educational participants. Gold, This technology is based on a "peer-to-peer" exchange mode allowing reduces the need for network infrastructure and minimizes latency without needing additional facilities.

These services hold into account socio-constructivist aspects that require the integration of several simultaneous connections.

Indeed, several researchers [18] advocate a mesh model based on a multipoint control unit (Figure 2) to centralize the processing of all audio and video streams. The MCU, also called a conference bridge, is a central gateway in a multipoint video conferencing system.

For this purpose, we used a software implementation of MCU based on a pairwise architecture named P2P-MCU to allow teachers to initiate simultaneous communications with their students via WebRTC.

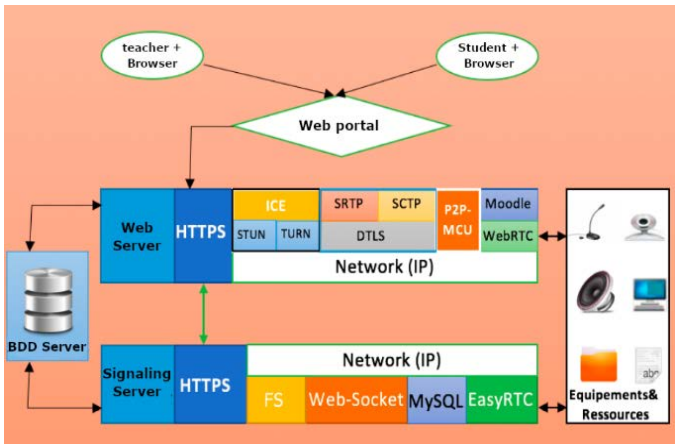

Fig. 1. Architecture Logicielle du Système D'enseignement.

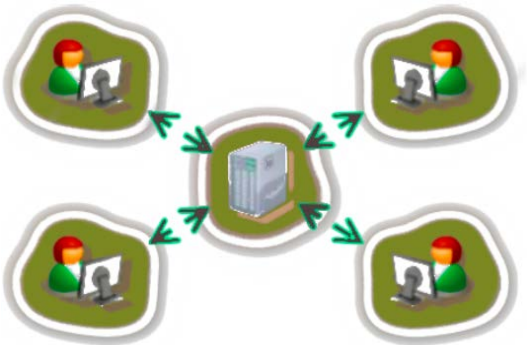

Fig. 2. "Mesh" Topology based on a Multipoint Control Unit.

B. Data Transit System

Most WebRTC capable devices sit behind one or more layers of NAT and may have security layers that block certain ports and protocols (sometimes with Deep Packet Inspection or DPI).

In addition, many of them placed behind corporate proxies and firewalls, not to mention firewalls and NAT on home Wi-Fi routers. In intranets, NAT gateways pose techniques that prevent direct communication between peers. Indeed, the main reason for this problem is because NAT corrects IP addresses and port numbers in order to hide private hosts.

As a result of the puncture technique limitation, it is necessary to use the services of an intermediate host that serves as a relay for the packets. This relay is usually located in the public Internet and relays packets in a direct communication between two hosts that are behind NAT.

For this specification, we use the relay tools STUN, TURN and ICE [19] to bypass NAT or firewall restrictions.

C. Media / Data Security Mechanism

Our scope of work requires real-time multimedia applications that require the use of SRTP as a transport protocol for the following reasons: fast delivery is preferred over reliable delivery and packet loss is acceptable to avoid delays resulting from rescheduling or retransmission of packets.

TLS (Transport Layer Security) cannot be used because it requires a reliable and slower protocol than a datagram-based protocol. In this perspective, DTLS (Datagram Transport Layer Security) brought adaptations to the TLS protocol to work in datagram communications by introducing counters and explicit messages [20].

Due to the unreliability of datagram-based protocols, DTLS incorporates mechanisms to retransmit the packet. This involves sending verification messages back to the server within a timeout period of 500-1000ms to ensure proper receipt of the messages. These verification messages also provide a means of avoiding denial of service (DoS) attacks, which in UDP, are very easy to carry out thanks to the exchange of a cookie.

In regard to these discussions, we have used in our scope the DTLS protocol as a basic security protocol for data and SRTP to ensure end-to-end confidentiality, message authentication and replay protection (Figure 3).

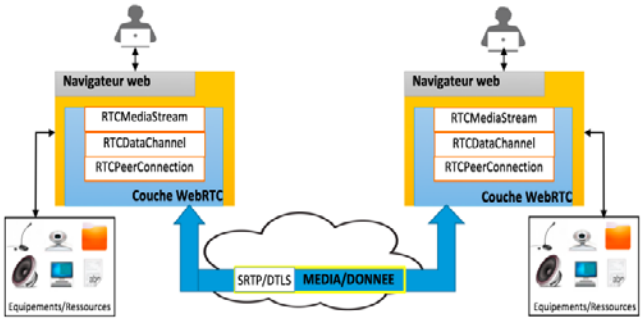

Fig. 3. Secure peer-to-peer Communication using DTLS/SRTP.

D. Signaling System

Signaling (Figure 4) is the mechanism for coordinating communication by exchanging identification and control messages between WebRTC pairs. In effect, it allows two or more WebRTC-capable web browsers to join, exchange contact information, negotiate a session that defines how they will communicate, and then finally establish the media channels between pairs for the transport of media streams exchanged directly between them [21].

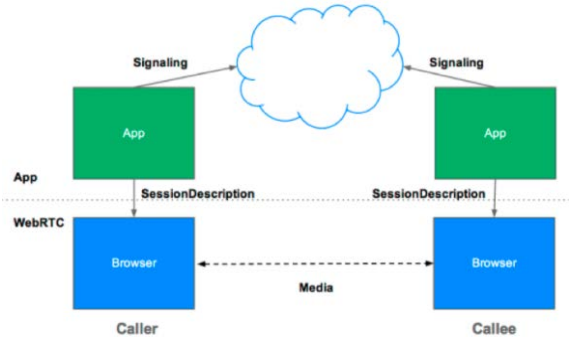

Fig. 4. Signaling Architecture.

The W3C and IETF standardization bodies have not imposed a particular signaling protocol in WebRTC in order to leave developers free to choose one of the existing protocols (SIP or Jingle) or to customize their own signaling protocol using web sockets. This signaling protocol choice strategy avoids redundancy and maximizes compatibility with already established technologies.

In this context, we used the EasyRTC implementation based on the Web-Socket protocol to create our own signaling system.

IV. Hybrid Learning Architecture

The proposed architecture (Figure 5) aims at proposing a device offering not only collaborative services while respecting the social-constructivist aspects but also the adaptation of the course flow to the learners' needs in order to ensure the same or better levels of interaction than those of traditional class's level.

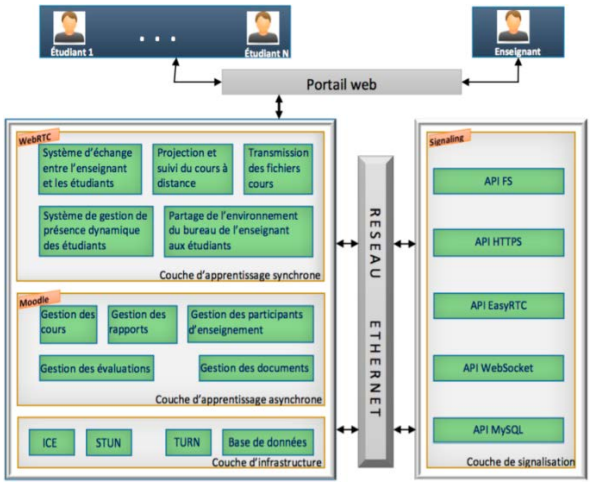

Fig. 5. Hybrid Learning Architecture.

Our approach allows TVT centers to improve the quality of their teaching system by integrating a hybrid system using both the capabilities of the Moodle platform and WebRTC technology. This architecture is structured in four layers:

1) Synchronous Learning Layer (SLL).
2) Asynchronous Learning Layer (ALL).
3) Infrastructures Layer (IL).
4) Signaling Layer (SL).

A. Synchronous Learning Layer (SLL)

This layer provides synchronous and real-time socio-constructivist learning activities based on WebRTC technology. Such a technology containing the MediaStream, PeerConnection and DataChannel APIs enables VoIP to operate in web browsers. Indeed, this layer essentially allows teachers and their students, through a simple browser:

1) To make projections and follow courses at a distance via video conferencing.
2) To transmit files (courses, exercises) to students in real time.
3) Share the teacher's office environment with students Interfaced with practical equipment.
4) To ensure the exchange system between the teacher and the students via instant messaging.
5) Disable the user's webcam.
6) Reactivate the previously deactivated webcam in the middle of a conversation.
7) Allow a teacher to eject a student from the system.

B. Asynchronous Learning Layer (ALL)

This layer, which ensures asynchronous learning, allows learners to follow the educational activities at their own pace. This flexibility of time for course delivery is a relevant solution to maximize access to higher education because it offers flexibility to the constraints that usually prevent professionals from participating in the classical course in universities.

To do so, we adopted the Moodle platform, which offers powerful and learner-centered tools. It also offers a collaborative environment that enhances both teaching and learning.

This layer also has a simple to use and easy to learn interface thanks to Moodle's constant usability improvements. It essentially offers the following tasks:

1) User, class and course management.
2) Scheduling of courses at a given date and time.
3) Course content management via a rich and versatile activity system.
4) Document management.
5) Reports and statistics management.
6) Learner evaluation management.

C. Signaling Layer (CL)

The signaling layer enables the creation of a real-time communication channel by defining a coordination mechanism between e-learning users.

Several developers have relied on the WebRTC API to provide libraries that hide the complexity associated with signaling and thus facilitate the development of WebRTC signaling servers. Figure 6 shows the software components of the signaling server. The operation of our system depends essentially on the signaling server implemented from the following modules:

1) Web-socket: allows creating bidirectional flows allowing the exchange in real time in both directions of communication.
2) EasyRTC: provides a library to simplify the development of WebRTC applications.
3) MySQL: allows connecting and making queries on the database.
4) FS: allowing the import of HTTPS server configuration files with SSL keys.

D. Infrastructures Layer (CS)

This layer hosts the physical servers allowing implement the physical infrastructure management applications. These are servers for traversing NAT/Firewall and the database server:

1) Servers to traverse NAT/Firewall: An ICE framework offered at this level, to overcome the difficulties of networking in the real world. ICE uses the highly reliable Xirsys STUN and TURN servers to try to find the best path to connect pairs. It tries all the possibilities in parallel and chooses the most efficient option that works. It tries to establish a connection using the host address from the operating system and a network card of a device.
2) Database servers: This layer contains a database server in order to keep or find all the data or information related to the educational activities of the system. The database is at the center of our computerized system allowing the collection, formatting, storage and use of data

V. Discussion and Result

A. Discussion

The proposed solution was used for one year by two technical and vocational training centers. These centers have experienced and appreciated the structural management of the trainings such as classes, pedagogical levels, teachers, students and annual enrollment in classes.

More than 40% of the students in these centers have benefited from online courses. They have been able to follow course sessions, practical work and even exams at a distance.

These students have shown remarkable progress in understanding and absorbing the courses, which is reflected in their exam scores. According to the observation, the online courses attract the intention of the students to cooperate and collaborate more with the teachers and each other to better understand the course concepts.

B. Results

We designed the system following an architecture composed of two main parts such as the back-end and the front-end.

The back-end is the processing center that is at the heart of our distance learning system. It is a set of functionalities to be implemented in the INAP-FTP system in order to ensure the integration of the online course management in the core of this system.

The front-end is used to propose a space dedicated to the actual management of the course as described in our architecture. It is a system based on Moodle that allows us to propose practical mechanisms and standards for the management of quality pedagogical activities. Indeed, we take advantage of the set of relevant tools as proposed by Moodle without any intervention to modify the basic technical settings of Moodle components.

We then illustrate some system interfaces.

1) Login area: This space (Figure 6) allows users to authenticate via the above interface in order to be able to use the various distance-learning services.

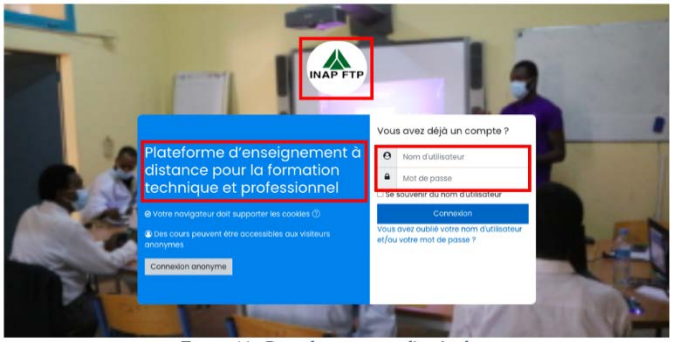

Fig. 6. Authentification Page.

2) Asynchronous and interactive educational activities: The Figure 7 allows the teacher via the activities tab to add an activity to his course. Several activities offered in this case: Workshop, Homework, Forum, Lesson, Survey, Test and Chat.

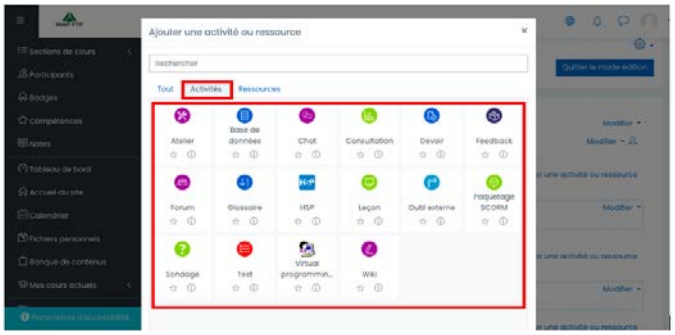

Fig. 7. Asynchronous Activities Page.

3) Sharing the teacher's desktop environment with students: The Figure 8 allows the teacher via the activities tab to add an activity to his course. Several activities offered in this case: Workshop, Assignment, Forum, Lesson, Survey, Test and Chat.

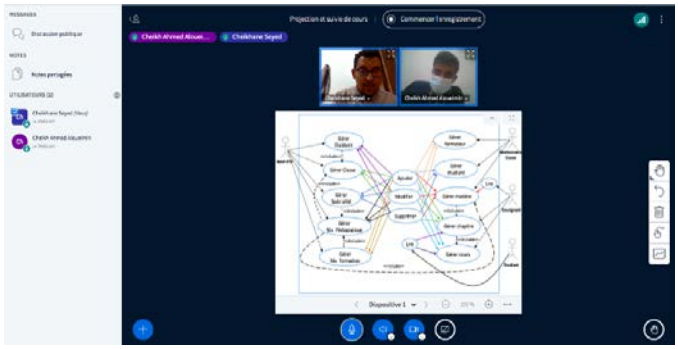

Fig. 8. Page for Teacher Desktop Screen Sharing.

VI. Conclusion

This paper deals with improving the quality of the TVT teaching system using innovative technologies adapted to the context of TVT centers in Mauritania.

Such a solution aims to offer relevant educational services both in synchronous and asynchronous mode between teachers and students.

However, innovation in distance education systems illustrates a concern for adaptation for those involved in education. It is more precisely about the integration of ICTs requiring configurations and adaptations for its members who often do not have sufficient experience in ICTs. This is why we have taken care in our work to choose flexible ICTs to use in order to concentrate as much as possible on the educational process.

The conclusive results of this work will enable education stakeholders to initiate and develop quality educational services through collaborative and innovative exchange systems. Our work provides evidence to dispel doubts about the quality of distance learning.

In terms of perspectives, our next steps will be to study the issues of availability and scalability in a context of optical fiber recently implemented in Mauritania.

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