

Research Article

Innovative Classroom Interconnection Platform for Teaching in Large University Groups

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Abstract

The rapid increase in demand for higher education in developing countries remains a constant concern for decision makers who must address many organizational and teaching quality issues related to managing large groups of students. A recent study at the University of Lome showed that managing large groups, while taking into account their socioeconomic background and learning environment, requires in-person courses on a campus with well-equipped classrooms similar to smart classrooms, providing better conditions for both teachers and students. According to various studies, smart classrooms are becoming the preferred solution for teachers and learners to address demographic changes. In this paper, we propose a smart classroom interconnection platform for teaching large groups of students. The platform combines videoconferencing, lecture recording, and audience management technologies. It can integrate artificial intelligence resources, which are increasingly discussed in teaching materials. This solution aims to extend a classroom's capacity to other classrooms across a university campus, thereby maintaining teacher-learner and learner-learner interactions. It consists of a main classroom (MC) and several remote classrooms (RC) linked together by a communication medium, with technical staff and tutors operating in two modes (unicast mode and full broadcast mode). It provides educational tools and learning spaces to allow numerous learners to access high-quality higher education and helps teachers effectively use pre-recorded video materials and improve them.

Keywords

Large-group, Teaching Platform, Smart Classroom, Full Broadcast Mode, Synchronous Unicast Mode, Face-to-face Learning

1. Context and Issues

Training large groups, with over 1,000 students per session, has become an urgent and unavoidable reality for public universities in developing countries, in response to the growing demand for executive education in these nations [1]. There is a need to find an effective way to teach these large

student groups. This issue was the focus of a recent study at Togo's public universities, especially at the University of Lomé

The results of this study pointed to the need to find an appropriate or complementary solution to existing solutions,

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such as:

- 1) the multiplication of class sessions taught by different lecturers, with its challenges: the content of courses is never identical (students may have preferences for particular lecturers or revisit the same course from different lecturers in staggered sessions), limitations on how many classes a lecturer can teach in a day efficiently when delivering duplicate contents, and the difficulty to administer the same assessments for the same course when different lecturers are involved.
- 2) the construction of amphitheaters with large seating capacities (over 1,500), despite their size, faces limitations that cannot be ignored: the size of amphitheaters cannot be increased indefinitely without causing additional issues such as audience management, student competition for the best seats, hearing problems, and a teacher-centric vision.
- 3) online courses with challenges for both teachers and students. These challenges include
 - 1) for teachers: some are unable to find their way around the new paradigms demanded by online training, and have difficulty adapting their initial practices to the latest distance learning solutions [1],
 - 2) on the student side: most students have limited access to the tools and technologies needed for online course participation (limits on computer equipment and training, as well as the challenges posed by Internet connection problems). Added to this is the lack of a suitable workspace for distance learning courses. Students with a high level of community life (several students live in a family with shared spaces and variable objectives). This situation often leads to students dropping out, especially in the first year, due to a lack of motivation, organizational problems, inadequate student-teacher communication, and other factors.

The study identified the need for a hybrid solution that combines face-to-face and distance learning approaches, methods using ICT tools to address the needs of both teachers and students. This hybrid approach combines campus-based training with adapted classrooms equipped with all the facilities and technology of smart classrooms, providing a balanced approach to teaching large university groups.

In this paper, we propose an innovative smart classroom platform for teaching large university groups. The platform uses videoconferencing solutions and technologies to provide a promising approach for audience management and access to campus lectures, with the added advantage of recording and replaying sessions, as proposed by [1-3], without requiring extra effort from teachers. Connected classrooms are equipped with the necessary technologies and commercially available tools and equipment, making it a cost-effective and efficient solution.

2. State of the Art

The search for technological solutions to support higher education continues to attract a great deal of interest (all over the world), particularly in developing countries. This research aims to develop pedagogical tools and learning spaces that enable many learners to access quality higher education. In most higher education institutions, information and communication technologies are driving the emergence of pedagogical innovations that impact the methods of disseminating or acquiring knowledge, the diversity and size of target groups, and training costs.

Faced with this technological challenge, academic institutions must incorporate the contributions of the digital revolution (ICT and AI) into new training methods, including smart classrooms that can serve as a bridge to the future [4] and play an essential role in:

- 1) the effective dissemination of knowledge [5], adapting to new learning methods, paradigms, and teaching methods [3, 6, 7],
- 2) obtaining or acquiring learning resources [8],
- 3) improving pedagogical interaction [9, 10], between teachers and learners.

A Smart Classroom is a face-to-face learning environment that combines advanced educational technologies with traditional or formal teaching methods to enhance not only teachers' ability to promote learning but also students' access to formal higher education. The Smart Classroom enables the implementation of teaching approaches and learning experiences that exceed the capabilities of a traditional classroom [11, 12].

Several research studies on smart classroom approaches have been recently published and implemented. One example is the EDUCAUSE Center for Analysis and Research of Technology Solutions in Higher Education, which has identified since 2017 that a technology-supported learning environment is a strategic investment for universities [13-15]. The EDUCAUSE Center continues to seek the best technological solutions and implications to improve the quality of higher education, with contributions from around the world.

Other researchers have studied the key technical features of various types of smart classrooms, which often include interactive whiteboards, digital display interfaces like touch screens [16, 17], large projection screens [18], wireless displays, and shared screens [19]. Smart classrooms can also feature cameras, recording and broadcasting equipment that support both synchronous and asynchronous video transmission, such as the field communication system (NFC) [11]. Others are considering the integration of Internet of Things equipment (collecting data on climate, environment, carbon dioxide, temperature, humidity, and noise, etc.) [20]

Much research has explored the relationship between learning skills, learning outcomes, and learning environments [21-24]. This research has demonstrated that the higher education learning environment must be rich in pedagogi-

cal resources and mediated by technology that meets students' learning needs, with the introduction of modern learning methods that promote social interaction among students and between students and teachers. This environment must facilitate learning motivation and enhance pedagogical and academic outcomes, [24-26].

In a study on learning environments, [27] Li Baoping explored the relationship between intelligent learning environments and learners' learning skills, which the authors believed were essential in the 21st century. This research has demonstrated that smart classrooms are evolving into spaces where teachers and students can engage in rich, immersive teaching and learning experiences that incorporate innovative elements never seen before. The classroom must be equipped with the necessary technologies to meet the needs of the stakeholders.

Finally, studies have shown that well-designed smart classrooms are becoming the preferred solution for teachers and students to adapt to demographic changes in some countries [15]. Others even believe they are the key to a sustainable campus in an evolving learning environment [3].

In conclusion, the classroom has evolved from a basic space to a smart classroom with multiple devices integrated and interconnected in a networked environment, and even to the Internet [27], offering to users, easy access to training and educational tools with minimal user constraints.

Today's smart classroom will be able to integrate not only Internet of Things resources, but also artificial intelligence, which is increasingly being discussed in educational resources by higher education stakeholders.

Several large-scale international and national projects have been proposed to improve the capacity of African universities to meet the growing demand for higher education. These projects, generally based on ICT tools, aim to overcome the lack of infrastructure, teaching resources, and qualified teachers in specific fields. Most of these projects have not produced the expected results, and new pedagogical methodologies for mass training are being sought all over the world [1, 28-31].

Many mass training models centered on ICT have been investigated by researchers with result as E-learning and MOOCs (Massive Open Online Courses) offer training courses to a target audience that can follow the course individually or collectively. Several prestigious universities have adopted these new educational technologies to offer online, fee-based training courses equivalent to the degree courses offered by these institutions in initial training [1, 32-34]. The International Institute of Online Education uses new technologies to provide learning platforms for higher education teachers. IIOE (www.IIOE.org) is a global initiative created by UNESCO-ICHEI in collaboration with higher education partner institutions in China and other developing countries in Asia-Pacific and Africa as well as corporate partners. It aims to build the capacity of the partner institutions and expand access to higher quality education. No research have proposed a learning platform for face-to face courses to deal with large

group of student issue.

To capitalize on advancements in the field of intelligent classrooms, our work addresses the challenge of managing large groups in higher education in developing countries. It focuses on the socio-economic and personal workspace challenges faced by learners, which are significant issues in distance learning and training, as identified by some studies as a key factor in tackling the problem of large groups [1].

3. Study Methodology

The methodology used is based on:

- 1) analysis of how Togo's public universities manage large groups,
- 2) using the results of surveys carried out at the University of Lomé among stakeholders in large group training, to identify existing and possible new solutions,
- 3) technological solutions for interconnecting intelligent classrooms to provide seamless audio and video streaming,
- 4) automated course recording solutions, with no additional effort on the part of the teacher, for rebroadcasting in staggered sessions.

3.1. Scope of the Study

This work is a case study that uses Togo to illustrate the challenges faced by developing countries in managing large groups of students in university courses, particularly in public universities.

For several years now, Togo's universities have faced a growing demand for access to post-baccalaureate higher education from first-time students coming from secondary schools. This situation remains a constant concern for university administrators, who must address numerous organizational and teaching quality challenges related to managing large student groups.

This is the case for the Faculty of Letters, Languages, and Arts at the University of Lomé which had 2,919 students in AY2012 and 5,933 in AY2024 [1].

To train this large number of students, the University of Lomé authorities have taken several steps to facilitate large-group teaching. They are based on the reinforcement of material infrastructures and human resources, such as:

- 1) The construction of several large amphitheatres seating 1,000 and 1,500 students,
- 2) The organization of courses in parallel sessions for teaching units with very high demand,
- 3) Online course delivery, enabling not only continuity of students' personal work, but also remote course management by teachers on an online course platform accessible on a local network on campus or remotely off-campus,

The current solutions are inadequate, and surveys of university education stakeholders indicate that existing methods

need improvement [1]. Implementing a smart classroom solution is essential for providing face-to-face teaching on university campuses.

3.2. Surveys Carried out in the Target Area

Surveys using Google Forms, including questionnaires and open-ended interviews, were used to collect data from higher education stakeholders.

The questionnaires were distributed to 1,800 undergraduate students, most of whom work in large groups, and to 106 teachers involved in teaching various large-group courses. We received 86 responses from teachers and 1,702 from students, and these results were used to suggest improvements for current practices. In addition to the questionnaires, 70 open interviews were conducted with teachers from different teaching teams involved in bachelor's and master's degree programs.

The teacher surveys aimed to understand how they felt about teaching large groups (interactions, fair treatment, working comfort, number of training sessions in a day, etc.). [1]

Student surveys mainly focused on the transition from high school to college, specifically regarding working conditions such as group size, teacher-student relationships, and personalized student follow-up. A key part of the questionnaire examined their prior mastery of working tools before college, including computer equipment for courses, computer facilities,

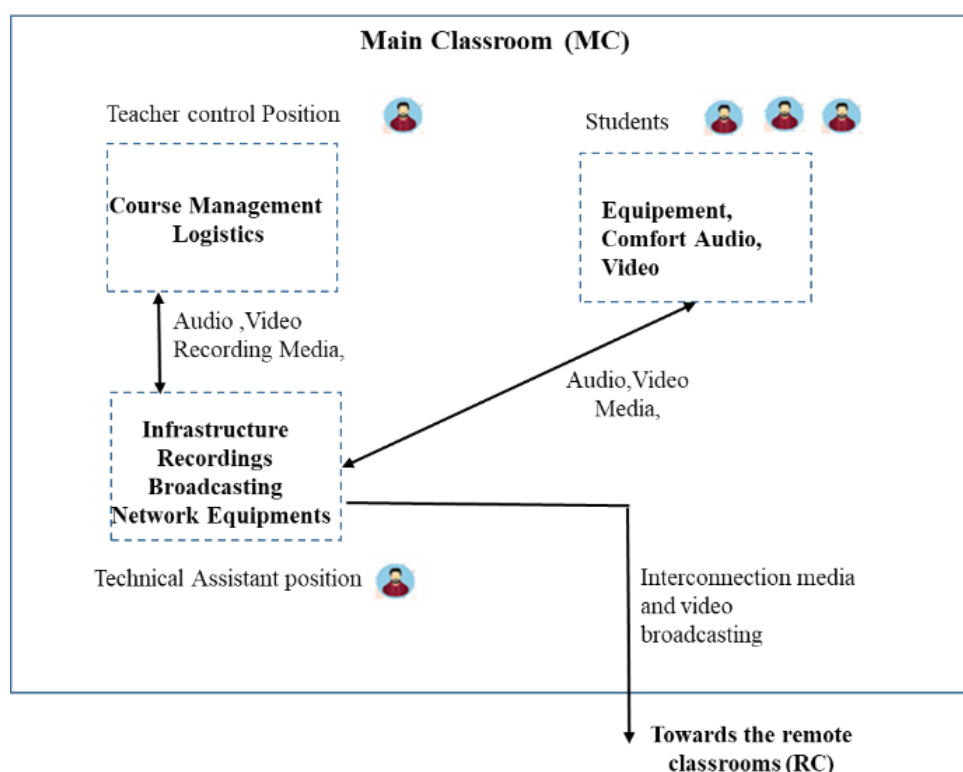
network availability and quality for remote courses, and their ability to have an appropriate workspace for distance learning.

3.3. Analysis of Survey Results and Proposed Solutions

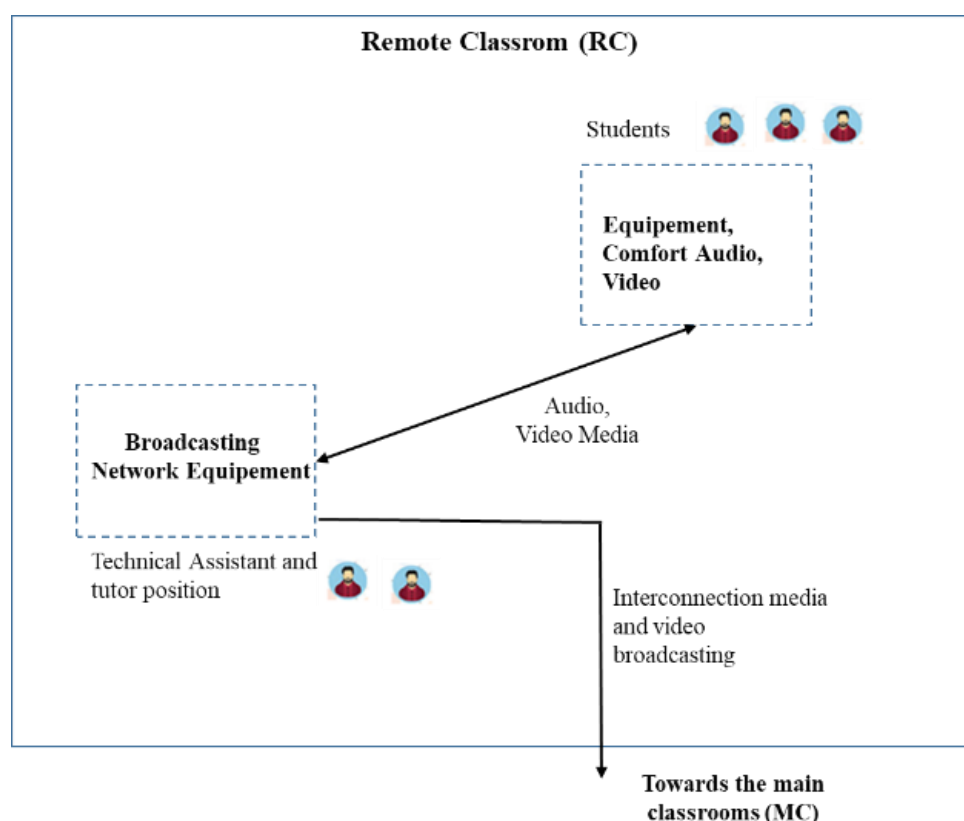
Based on the survey results and proposed solutions for managing university teaching that consider students' social disparities and stakeholder opinions, we have developed a smart classroom interconnection platform for large university groups. This solution allows public universities in developing countries to effectively meet their training goals amid the increasing number of students.

The goal is to combine the benefits of traditional face-to-face training, which encourages interaction between students and teachers, with the advantages of distance learning, which aims to provide quality education to thousands of students at a lower cost. The idea is to use ICT tools to enable an audience spread across two or more connected classrooms to follow face-to-face (in time and space) lectures and tutorials through comfortable audio and video broadcasting conditions.

This solution enables the extension of capacity from one classroom to other classrooms spread across the university campus, while maintaining teacher-learner and learner-learner contact in a conveniently located physical space.



a



b

Figure 1. a. Architecture of the main classroom (MC); b. Architecture of the remote classroom (MC).

4. Smart Classroom Interconnection Platform

The interconnected smart classroom platform includes a main classroom (MC) and several remote classrooms (RC), linked by a communication medium, along with technical staff and tutors. A large group lecture takes place in person at the main classroom and is broadcast to the remote classrooms. The quality of teaching in the connected classrooms relies on proper equipment and technical staff to ensure the course is streamed accurately, as well as to provide visual and audio comfort for participants in the remote classrooms.

The large-group management platform consists of two main components:

- 1) The "Interconnection of smart classrooms" component uses a link solution that enables lectures to be broadcast via videoconference from a main classroom where the teacher is located, to remote classrooms under the control of one or more tutors.

Two modes are available:

- 1) Synchronous unicast mode combines equipment and personnel to broadcast events like lectures and question-and-answer (Q&A) sessions from the main classroom to remote classrooms. It does not support

broadcasting Q&A sessions from remote classrooms.

- 2) Full broadcast mode (two-way synchronous): This setup involves equipment and personnel to broadcast events (such as courses or Q&A sessions) from the MC to the RC. It can also be used to broadcast question-and-answer sessions from the RC.
- 2) The "recording infrastructure" component enables course sessions to be recorded and rebroadcast to students in staged sessions.

4.1. Physical Architecture of the Platform

The physical architecture comprises the main classroom (MC), one or more remote classrooms (RC), and the interconnection technology that connects these classrooms. [Figure 1a and 1b](#) illustrate the architecture of the MC and RC classrooms, respectively, along with the equipment and actors used to manage events in these classrooms. The equipment consists of course management, logistics, and multimedia tools for broadcasting and recording lessons. The actors are the primary teachers, the technical assistants, and the tutors (assistant teachers), who ensure the smooth running of course sessions.

[Figure 2](#) illustrates the connections between the classrooms. The MC is connected to the other remote classrooms (RC) by a wired or fiber-optic medium for transporting video streams.

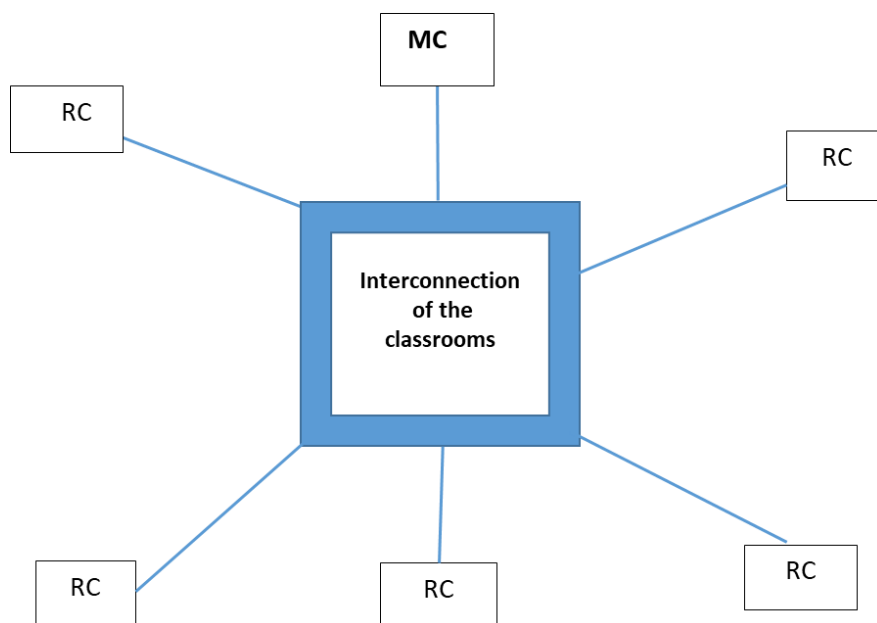


Figure 2. Video cable or single-mode fiber optic cable from the main classroom (MC) to remote classrooms (RC).

4.2. Logical Architecture of the Platform

At the logical level, depending on the solution adopted for interconnecting videoconferencing classrooms, audio-video streams circulate between the connected classrooms. These flows are referred to as single-duplex flows (when a main

classroom is connected to remote rooms RC, with no interaction between the classrooms), as shown in Figure 3, and full-duplex flows (when the main classroom and remote rooms can communicate in both directions), as shown in Figure 4.

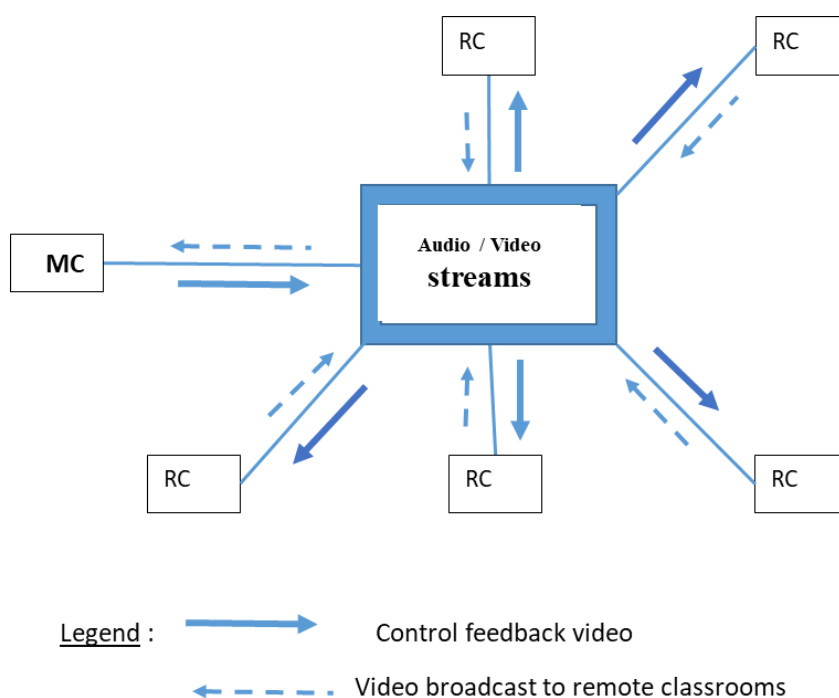


Figure 3. Mono flow modeling with one SC room and remote SD rooms.

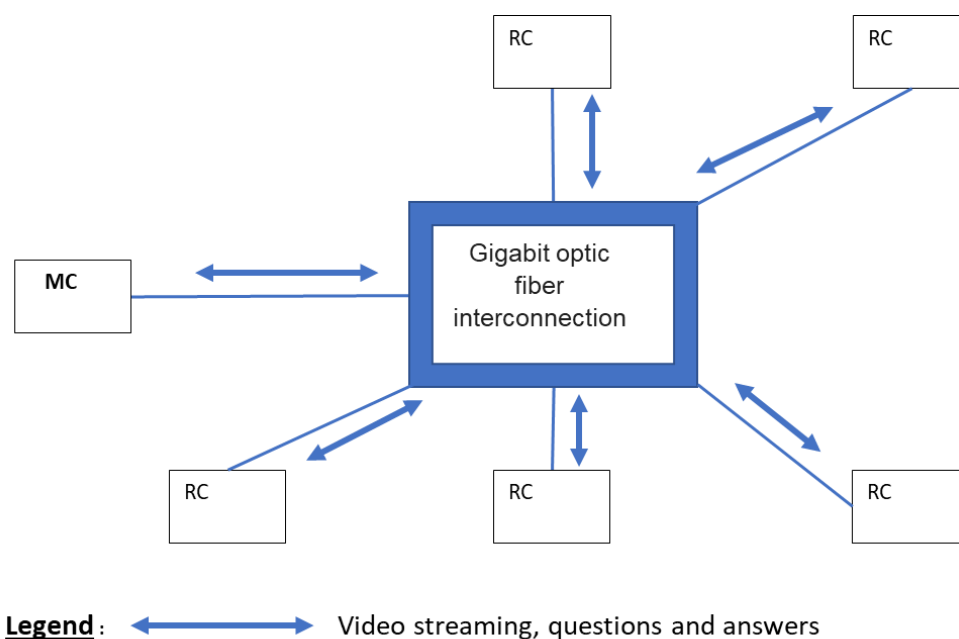
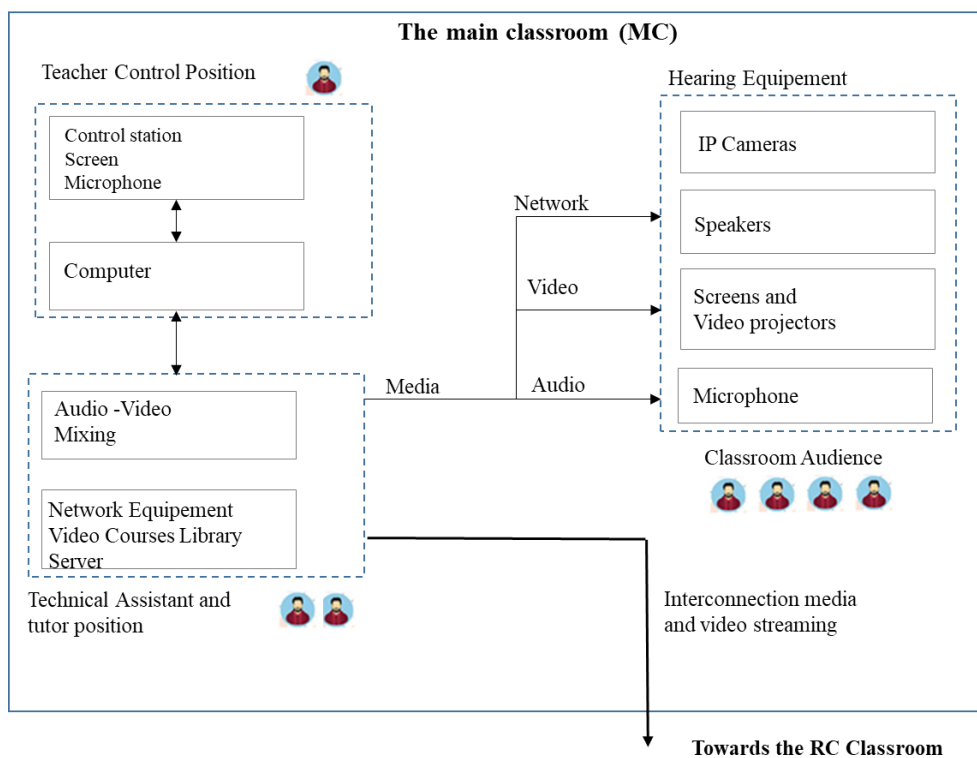


Figure 4. Extended full-duplex flow modeling with MC classroom and RC Classrooms.

5. Experimental Prototype

The functional architecture includes audio, video, video image capture, and broadcast comfort equipment, as shown in Figure 5a and b.



a

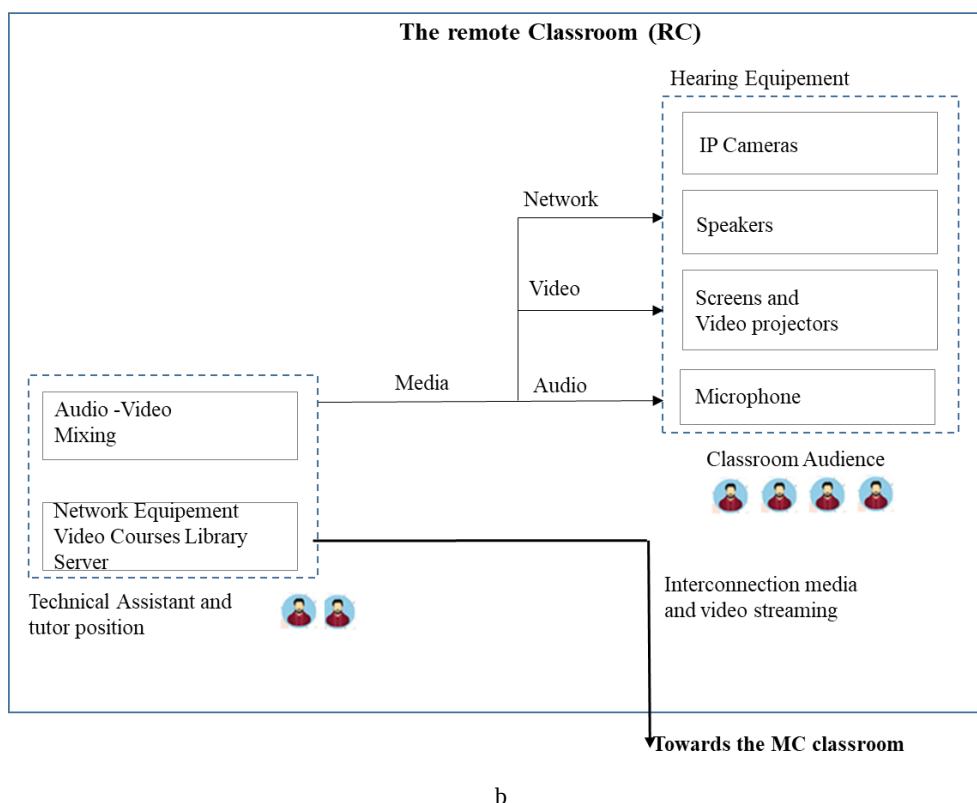


Figure 5. a. Functional architecture of the main Classroom; b. Functional architecture of the remote Classroom.

6. Conclusion

This paper presents an innovative approach to tackling the challenges of managing lectures for large student groups. It is a platform for connecting intelligent classrooms to facilitate teaching large audiences. It includes a main classroom (MC), remote classrooms (RC) linked through a communication medium, technical staff, and tutors. It uses ICT tools to allow more students to participate in face-to-face courses with optimal listening and viewing conditions, and to provide teachers with suitable conditions for engaging an interactive audience. Course sessions are automatically recorded using the proposed platform and made available to the university community as reusable teaching resources for various learning and development purposes.

No research have proposed a learning platform before for in person courses to deal with large group of students issue like our innovative platform interconnecting smart classrooms.

The main benefits of our work include:

- 1) efficient classroom management to provide ideal conditions for large groups of students.
- 2) a technological platform comprising smart classroom equipment, ICT tools, and pedagogical and technical support. It also includes a pedagogical database of video courses that can be stored on servers (media library). This pedagogical database can be continually fed and updated with recordings of courses.

- 3) replay of live recorded lessons: these lessons can be replayed to other groups by the teacher or department at different times. The groups concerned may be a) students who were unable to attend the initial lesson, or b) students who failed their assessment (make-up session).
- 4) use of recorded audio-video lessons to perfect teaching practices (best practices) by first-time teachers or colleagues for input and exploitation, or teacher capacity-building purposes.
- 5) These video materials are much easier for learners to use in a world where video-based learning is becoming increasingly popular, and easier to use with modern reading materials.

Beyond its advantages, the large group management solution raises several questions about the evolution of teaching practice and teachers' careers. These include:

- 1) rebroadcasting lessons recorded in the pedagogical database without the participation of the primary teacher may raise copyright issues (actors recorded in video supports);
- 2) will digital media records in the media library gradually replace live teaching?
- 3) is a replayed lesson considered a completed lesson and counted as part of the teacher's teaching expenses?
- 4) the need for question-and-answer sessions for students following a rebroadcast course. Is this session led by the primary teacher or another?

Abbreviations

AI	Artificial Intelligence
AY	Academic Year
DKIL	Distributed Knowledge and Intelligence Laboratory
EDUCAUSE	A nonprofit Association that Helps Higher Education Elevate the Impact of IT
ICT	Information and Communication Technology
MC	Main Classroom
NFC	Near Field Communication
Q&A	Questions and Answers
RC	Remote Classroom
UNESCO	United Nations Educational, Scientific and Cultural Organization (The Specialized Agency of the United Nations with the Aim of Promoting World Peace and Security Through International Cooperation in Education, Arts, Sciences and Culture)
UNESCO-ICHEI	The International Centre for Higher Education Innovation Under the Auspices of UNESCO

Author Contributions

Kossi Tepe: Conceptualization, Project administration, Resources, Supervision, Validation, Writing – original draft

Yann Verchier: Formal Analysis, Funding acquisition, Investigation, Supervision, Visualization, Writing – review & editing

Kokou Yetongnon: Conceptualization, Formal Analysis, Methodology, Supervision, Validation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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