Real-Time Surgical Education in Hybrid Learning Environments: Connecting HEI Communities and Advancing Medical Training

Georgios Roussos[1*], Dimos Charidimou[1†],
Anastasios Petalotis[1], Angeliki Agorogianni[1]

[1] Digital Governance Unit (DGU) - Aristotle University of Thessaloniki (AUTh), Greece
grou@it.auth.gr
dharidimou@it.auth.gr,
petalotis@it.auth.gr
aagorogi@it.auth.gr

Abstract

This paper explores the design and implementation of a real-time surgery broadcasting initiative at AHEPA University General Hospital, affiliated with Aristotle University of Thessaloniki (AUTh). Two surgical clinics, the General Surgery Clinic and the Cardiothoracic Surgery Clinic, were transformed into advanced hybrid educational spaces equipped with state-of-the-art audiovisual systems. These enhancements allow students, educators, and medical professionals to remotely observe and interact during live surgical procedures through seamless videoconferencing and secure live streaming. This capability significantly enriches the medical curriculum, benefiting Greek and international students and enabling broader community engagement. By detailing technological improvements, addressing ethical concerns around patient privacy, and evaluating initial educational outcomes, the paper positions this initiative within AUTh's broader digital transformation strategy. The findings underline the transformative potential of real-time surgical education to bridge traditional hands-on experience with modern digital accessibility, ultimately strengthening AUTh's role as a leader in medical training and innovation.

* https://orcid.org/0000-0003-2311-5196
† https://orcid.org/0000-0002-7602-3650

1   Introduction

Advancements in digital technology through digital transformation have already transformed medical education, particularly in surgical training. The COVID-19 pandemic accelerated this transformation by forcing medical institutions worldwide to adopt remote learning solutions (Brown & others, 2020). In response, the Digital Governance Unit (DGU) at the Aristotle University of Thessaloniki initiated a project [PRJ_02SUR_AUTH][‡] that equipped a) the General Surgery Clinic and b) the Cardiothoracic Surgery Clinic—with advanced audiovisual (AV) systems and IT infrastructure. This project was designed to facilitate remote surgical education for students both locally in Thessaloniki, Greece and globally (Figure 1).

Figure 1 - Remote surgical education for students both locally in Thessaloniki and globally

This effort is especially pertinent in the context of hybrid medical education at AUTh as a HEI, which—like many institutions worldwide—expanded the adoption of remote learning tools during the COVID-19 pandemic (Kähkipuro, 2022; Roussos et al., 2025). Globally, live surgical broadcasting has gained popularity in medical education over the past decades, aided by rapid advances in AV technology and networking. Pioneering programs (such as the Liberty Science Center's Live From Surgery in the U.S. or live-streamed surgical conferences in Europe) demonstrate the growing trend of integrating real-time surgery videos into medical curricula. At the same time, these trends raise important considerations regarding patient consent, privacy, and technical reliability, which this project had to address from the outset (American Academy of Allergy Asthma and Immunology, 2023; Alkhnbashi et al., 2024). This introduction outlines the purpose of the PRJ_02SUR_AUTH project, situating it within global trends and underscoring its significance as a step toward modernizing medical education with live surgical telepresence (Abu-Rmaileh et al., 2022; Latif & others, 2023)

[‡] refers to the Aristotle University of Thessaloniki (AUTh) project, which equipped two surgical clinics—the General Surgery Clinic, Operating Room 3 (OR3) and the Cardiothoracic Surgery Clinic, Operating Room (OR2)—with advanced audiovisual (AV) technology to enable real-time surgical broadcasting and enhance hybrid medical education.

2   Background

The COVID-19 pandemic significantly disrupted medical education by suspending in-person clinical training and limiting access to operating rooms (ORs). Medical students faced greatly reduced opportunities for hands-on surgical experience, which is essential for developing clinical skills and decision-making abilities (Miller & others, 2020). Studies reported that nearly 96% of medical students experienced a substantial decrease in OR attendance, with many expressing concerns about their preparedness for surgical residency (Brown & others, 2020; World Health Organization, 2022). Traditional surgical education relies heavily on direct observation and participation in the OR, which was severely curtailed during the pandemic (Figure 2). The absence of live surgical experience led to notable knowledge gaps and reduced confidence among trainees. Surveys indicated that over 70% of medical students felt inadequately prepared for surgical practice due to the loss of hands-on training (Miller & others, 2020; Lee & Park, 2021).

Figure 2 - COVID-19 pandemic disrupted medical education by suspending in-person clinical training

2.1   The Issue and the Need

In response to these challenges, educational institutions rapidly adopted telemedicine and digital learning tools, such as pre-recorded surgical videos, virtual simulations, and real-time streaming of surgeries (Lee & Park, 2021). Real-time surgery broadcasting soon emerged as a promising approach to provide medical students with access to live surgical procedures remotely, allowing them to observe, interact, and ask questions in real time (Williams et al., 2011).

This model aligns with the broader trend towards hybrid medical education, which seeks to combine the advantages of both in-person and remote learning (Latif & others, 2023). Early evidence suggests that hybrid learning models can effectively deliver medical education, particularly for theoretical knowledge, while maintaining or even boosting student engagement. However, HEIs also recognized the need to support practical skill development and address technical and training challenges to make such hybrid models successful (Waqar-Un-Nisa et al., 2024).

2.2   Significance of the Study

This study aims to contribute to the development of best practices for hybrid surgical education for HEIs by evaluating the impact, challenges, and ethical implications of implementing a real-time surgery broadcasting system across multiple surgical clinics. By documenting the aspects of the project, the paper provides a blueprint for other HEIs aiming to adopt similar digital transformation and leadership strategies (Roussos et al., 2025). The findings can inform institutional policies and international guidelines for integrating live surgical broadcasts into medical curricula, ensuring that surgical education remains resilient and adaptive in a rapidly changing digital landscape (World Health Organization, 2022). In the long term, insights from the AUTh project may guide how academic medical centers worldwide blend in-person surgical training with remote learning, maximizing educational value while safeguarding patient welfare.

3   Case Studies: Transforming University's Hospital Surgical Spaces into AV-Enabled Educational Spaces Using Digital Technologies

HEIs are putting more funding into high-tech tools and green practices for their buildings inside and outside the cammpus. By adding digital and hands-on tech like live audio-video systems virtual reality spaces, and mixed in-person and online classrooms, these schools are creating learning environments that are more open to everyone easier to use, and more interesting for students (Roussos G. et al., 2023).

The DGU at AUTh, recognizing the need for digital transformation in medical education, supported the deployment of advanced AV systems at both ORs[§] at the AHEPA University General Hospital. This dual-clinic approach provides comprehensive surgical exposure, encompassing a wide range of procedures and specialties. By equipping these two clinics with state-of-the-art technology, the project aimed to enhance the reach and quality of surgical education, making it accessible to students in Greece and internationally and allowing students to gain practical insights from diverse surgical cases even when they cannot be physically present. The project responded to the immediate pandemic-induced educational gaps and also laid the groundwork for a long-term hybrid learning infrastructure in surgical education.

3.1   Objectives and Functionalities

The project commenced in early 2023 and was successfully completed by early 2024. The primary objective of the project was to integrate digital tools and AV equipment to restore and enhance surgical education for students both locally and globally via a hybrid format. This goal was pursued through several key functionalities:

- **Teleconference Integration:** The system supports real-time teleconferencing on platforms, allowing medical students and even international experts to participate in live surgical broadcasts from either the General Surgery or Cardiothoracic Surgery Clinic. This feature enables synchronous interaction with operating surgeons, recreating a teaching dynamic remotely (Butt & Augestad, 2021). Remote participants can ask questions and receive immediate answers, closely mirroring the interactivity of being in the OR.
- **Live Streaming to Auditoriums:** High-definition live streaming capabilities enable automated connections between the two surgical clinics and lecture halls or auditoriums at

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[§] ORs: Operating Room 3 at the General Surgery Clinic and the Operating Room 2 Cardiothoracic Surgery Clinic

the medical school (Roussos G. et al.). This ensures that students can observe a diverse range of surgical procedures in real time without overcrowding the OR. For instance, a surgery can be broadcast directly to a classroom of dozens of students, all viewing the procedure simultaneously on a large screen with instructor moderation .

- **On-Premises Recording and Scheduling:** Secure on-premises recording and scheduled recording functionalities allow faculty to plan and capture surgeries from both clinics. These recordings are stored in a protected cloud server and can be used for review, self-paced learning, or integration into the curriculum as case study material (Abu-Rmaileh et al., 2022). This archive of surgical footage builds a valuable repository for students to revisit complex procedures and for faculty to incorporate select clips into lectures or assessments.
- **Integration with Medical Devices:** The AV system interfaces with various medical devices (endoscopic cameras, laparoscopic towers, patient monitors, etc.) in both surgical clinics to share real-time data and visuals. This provides a comprehensive learning experience for remote observers – for example, students can see the vital signs or endoscopic views alongside the external surgical field, enhancing understanding of the procedure (Williams et al., 2011). Such integration ensures that crucial information (like an endoscopic image or ultrasound view) is not lost to those observing remotely.
- **Security and Privacy Measures:** The platform was built with strict compliance to privacy regulations like GDPR. All video streams are encrypted end-to-end, and access to live or recorded videos requires secure login credentials. Only authorized faculty can initiate a broadcast, and each session is protected to prevent any unauthorized viewing. These measures address ethical concerns about patient privacy and data security in live medical broadcasts (Al-Harethi & others, 2022). Patient consent is obtained for any procedure that will be streamed, following international guidelines for live surgical teaching events.

3.2 Before the Project: Challenges and Benefits

Before the project, the General Surgery and Cardiothoracic Surgery Clinics at AHEPA University General Hospital lacked modern AV systems and digital infrastructure, limiting educational potential. Transforming typical surgical spaces into advanced educational environments presented several common challenges:

- Complete Infrastructure Overhaul
- Network Upgrade Complexity
- No Remote Learning Capabilities
- Manual Recording and Limited Educational Material
- Cultural and Operational Change Management
- Ensuring Privacy and Ethical Compliance

Overall, the educational experience for students was fragmented, reliant on physical presence, and significantly constrained by technical limitations.

3.3 Project Timeline and Phases

The project rolled out in several phases over approximately one year, each with distinct milestones:

- **Phase 1 - Planning and Funding (Months 1–4):** The initial phase focused on needs assessment and securing resources. The team conducted thorough assessments of the existing infrastructure in both clinics, identifying the lack of AV equipment and network capacity as critical gaps. Simultaneously, a detailed plan was drafted, including technical

requirements (camera specifications, networking gear, etc.) and compliance protocols (patient consent workflow, data security measures). Funding was secured through a combination of the university budget, a government-supported NSRF [**] grant, and contributions from technology partners. By the end of this phase, the blueprint of the project was clear and resources were allocated.

- **Phase 2 - Equipment Procurement and Installation (Months 5–8):** In this phase, the project moved into action. Procurement orders were placed for 4K cameras, AV control systems, microphones, servers for recording storage, and necessary networking hardware. Upon arrival of equipment, installation took place in stages, first in the General Surgery Clinic and then in the Cardiothoracic Clinic. High-speed network lines were laid and tested. Surgical lights and ceilings were fitted with camera mounts, and operating rooms were wired for new connections. By Month 8, both clinics had the core hardware in place. The Gantt chart highlights overlapping tasks – for example, while waiting for some equipment deliveries, networking teams began wiring, which kept the timeline efficient.

- **Phase 3 - Integration and Testing (Month 9):** With hardware installed, the focus shifted to integrating systems and rigorous testing. AV systems were linked with the hospital's IT infrastructure and tested for compatibility (ensuring, for instance, that firewalls allowed the streaming traffic to the university network). Multiple trial broadcasts were conducted during empty-room run-throughs to ensure that audio, video, and device data feeds all synchronized correctly. These tests identified a few minor issues (like audio levels needing adjustment) which were promptly fixed. By the end of this phase, the system was technically ready to go live, having passed tests for streaming quality, latency and security (test streams were checked to confirm encryption and restricted access).

- **Phase 4 - Training and Deployment (Month 10):** The final phase involved training users and rolling out the system for actual educational use. Training workshops were held with surgeons and OR staff in each clinic—initially guided by the vendor technicians and IT experts, and later practiced internally.

3.4   After the Project: Benefits & Improvements

However, the project transformed both clinics into state-of-the-art, AV-enabled educational spaces, featuring comprehensive improvements that included:

- **Advanced AV Systems and Equipment:** Multiple high-definition robotic (PTZ) cameras, specialized microphones, and digital control panels to capture detailed surgical procedures are installed. This enhanced visibility and audio clarity provided students and faculty an immersive educational experience comparable to physical attendance in the OR.

- **Robust Network Infrastructure:** Upgraded network capabilities using dedicated high-speed wired (fiber optic) and wireless connections allowed seamless HD video streaming and reliable real-time interactions between surgical spaces and remote viewing areas, such as auditoriums or classrooms.

- **Integrated Teleconferencing and Live Streaming:** Both clinics now support real-time interactive teleconferencing with platforms like Zoom[††], Teams, and Webex, enabling students and international experts to participate actively in live surgical broadcasts. The operating surgeon can provide real-time commentary, and students can engage through moderated Q&A sessions (Roussos et al., Using SaaS in a European University: Protect Your Privacy and Enjoy!, 2023).

[**] ΕΣΠΑ / ESPA / NSRF : Partnership Pact for Regional Development
[††] Aristotle Univeristy of Thessaloniki use Zoom as the primary tool for videoconferences.

- **On-Premises Cloud Recording and Archive:** Secure, automated cloud storage now systematically archives surgical videos, facilitating educational reuse and enabling students to review procedures for enhanced learning. Faculty can plan and schedule recordings of surgeries to build a comprehensive digital library of educational content.
- **Real-Time Integration with Medical Devices:** Both clinics seamlessly integrated real-time data from medical devices (e.g., laparoscopic cameras, patient monitoring systems, heart-lung machines) into the broadcasts, providing comprehensive visual and physiological context for the procedures, significantly enriching student learning.
- **Enhanced Privacy and Security Measures:** Strict compliance with GDPR and related privacy regulations was ensured by encrypting video streams, implementing secure access controls, and establishing clear protocols for patient consent, significantly mitigating privacy risks and promoting responsible educational broadcasting.

To illustrate the implementation of the PRJ_02SUR_AUTH, this section presents the outcome of two case studies of ORs transformation, the OR3 of the General Surgery Clinic (Figure 3) and the OR2 of the Cardiothoracic Surgery Clinic (Figure 4) of University's General Hospital.

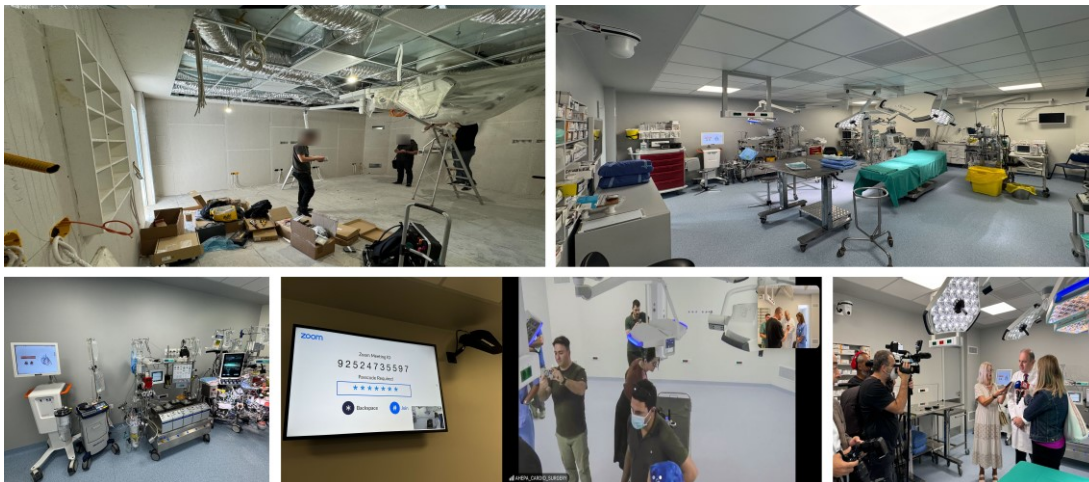**Figure 3 - The General Surgery Clinic: Operating Room 3**

Figure 4 - The Cardiothoracic Surgery Clinic: Operating Room 2

Each case details the state of the surgical education space before the project, the changes implemented by the project, and the situation after the project, including challenges encountered.

4 Comparison with 'Live From Surgery' (USA)

To contextualize the pedagogical significance of AUTh's implementation, comparing it with similar international initiatives, such as the Live From Surgery program developed in the United States, is useful (Liberty Science Center, 2025).

As opposed to the United States Liberty Science Center which offers the Live From Surgery program for secondary students using pre-recorded content, Aristotle University of Thessaloniki (AUTh) differs in the scope of their teaching method orientation, audience, and instructional design. While AUTh's implementation is exclusively designed for externally enrolled medical students, it aims to improve levels of hybrid medical education featuring the live broadcast of actual surgical procedures. The surgery is performed by a surgeon who is also teaching and is a faculty member of the medical college. She provides real-time instructional teaching during the operation, not from a recording. Instruction is done in one or more languages, and multiple lecture halls can be interconnected, enriching the student experience in multiple ways, including facilitating multilingual instruction. This type of construction focuses on didactic teaching and distance learning and ignores public education or general outreach activity.

5 Limitations and Future Research

A key limitation of the project is its current restriction to two surgical clinics, limiting exposure to a broader range of procedures. Additionally, systematic assessment of long-term learning outcomes has not yet been conducted. Future research should explore expansion to other clinical disciplines and investigate the impact of live surgical broadcasts on student performance over time. Comparative studies with similar international implementations would further contextualize the results.

6 Conclusion

This project has a great impact on the modernization of medical education. This paper has described the aims, design and early impact of the project, and how operating rooms can be transformed to global classrooms. In short, the project shows that surgical education can break through physical barriers with the right technology and planning — dozens of students can now virtually "scrub in" to procedures and gain insights that, until now, were available only to a few. Key takeaways include the importance of high-quality audiovisuals and secure, low-latency networking to truly recreate the immediacy of being there, as well as thoughtful curriculum integration and attention to ethical safeguards (e.g., ensuring patient consent and privacy without hindering patient care).

The project stands as a proof-of-concept for hybrid medical education and integrates irreplaceable real clinical experience with digital access convenience and extensive reach. This alignment with worldwide trends shows how live surgical streaming becomes more accepted as training support while operating inside an academic structure that delivers quantifiable educational results. Through the development of this system AUTh becomes part of the innovative network of institutions which are transforming surgical mentorship practices in this century.

A review of the journey shows that this represents both a technical upgrade and a cultural transformation. The future envisions medical students worldwide learning from top surgeons through

real-time broadcasts on their own campuses which will allow surgical knowledge to spread as quickly and broadly as a live webinar or lecture. Among others, the future undoubtedly lies in surgical simulations since advances in virtual reality, augmented reality, and artificial intelligence have paved the way for highly realistic, risk-free surgical training environments (Park et al., 2022).

Although surgical simulations represent a clear and growing trend in medical training, many experienced surgeons still prefer traditional observation and direct mentorship. For these practitioners, closely watching a skilled surgeon perform procedures in real time offers irreplaceable insights and nuances that digital simulations may not fully replicate. Thus, while simulation technologies are valuable supplements, effective surgical education should integrate both methods—embracing innovative digital tools without overlooking the critical importance of direct, human-centered mentorship.

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Author Biographies

Georgios Roussos is the Head of the Academic Technologies Support at the Digital Learning and Support Department of the Digital Governance Unit (DGU) of the Aristotle University of Thessaloniki (AUTh), Greece. Holding a Bachelor's degree in Informatics and Computer Technology and two Master's degrees in Communication Networks and Systems Security and Intelligent Computer Systems, he manages the university's Audiovisual operations & e-learning operations and centralized projects that enhance educational experiences through emerging technologies. Currently, Georgios is a PhD candidate in the Department of Informatics of AUTh and his research focuses on emerging digital learning technologies based on AI/AR/VR/MR/XR. He is also an Ambassador of the European University Information Systems (EUNIS) organization and actively participates in various European and international technology forums by supporting AUTh's technological initiatives.

Dimos Charidimou is engaged in a wide range of issues in the field of image-audio and eLearning technologies. He has experience in the fields of videoconference services, live event broadcasting and eLearning administration. He graduated from the Department of Electronic Engineering at Alexandreio Technological Educational Institute of Thessaloniki. He holds a Master's Degree in ICT in education and a Master's Degree in Education Administration and Management. He is also a PhD candidate. His main research field is in synchronous/asynchronous distance eLearning services and platforms.

Anastasios Petalotis is the Teleconferencing Administrator in the Academic Technology Support Office at Digital Learning and Support Department of Digital Governance Unit (DGU) of Aristotle University of Thessaloniki (AUTh) with more than 25 years technical experience. He holds a Master's Degree in ICT in education.

Angeliki Agorogianni is the Director of the Digital Governance Unit (formerly the IT Center) at Aristotle University of Thessaloniki. She oversees a team of more than 100 members to deliver end-user services and support effectively in a high-pressure IT environment for a wide range of IT services and infrastructures. She cooperates closely with the Digital Governance Committee in the design and implementation of the University's digital transformation plan. She graduated with an integrated Master's degree from the Department of Electrical Engineering at Aristotle University of Thessaloniki, Greece. She also holds a Master's Degree in Business Administration from the University of Macedonia, Greece. Furthermore, she is involved in various European organizations (EPICUR, EUNIS) in the fields of eLearning, digital transformation, and student mobility.