Harnessing DevOps and Microservices for Scalable Teleconsultation — A Case Study on Healthcare Information Management System (HIMS) at USTP

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Abstract

The Healthcare Information Management System (HIMS) was developed and implemented at the University of Science and Technology of Southern Philippines (USTP) to enhance healthcare accessibility, operational efficiency, and scalability. Leveraging the Technology Acceptance Model (TAM), DevOps practices, and Microservices architecture, the system features real-time teleconsultation, electronic documentation, and a Personal Health Record (PHR) module. HIMS facilitated 12,164 teleconsultations during deployment, comprising 8,294 physical and 3,870 virtual appointments. It achieved widespread adoption, with 12,164 registered users (8,854 students and 3,310 employees) and significant operational improvements, including a 70% reduction in record retrieval times. Performance metrics such as 99.9% uptime and <1-second response times validated its reliability. User feedback indicated high satisfaction, with 92% finding the system user-friendly. These results demonstrate HIMS' potential as a scalable, user-centered healthcare solution for academic and public institutions. Future directions include the integration of artificial intelligence for predictive analytics and exploring nationwide implementation to support broader healthcare delivery objectives.

Keywords*:* Healthcare Information Management System, COVID-19 monitoring, teleconsultation, digital health records, real-time case tracking

1. Introduction

Integrating teleconsultation and healthcare information management systems (HIMS) has gained increasing attention, particularly during the COVID-19 pandemic, underscoring the need for scalable and accessible healthcare solutions (Smith *et al*., 2020; Dash *et al*., 2021). Despite advancements in telemedicine, many institutions face persistent challenges related to data security, interoperability, and adoption strategies for teleconsultation platforms (Wosik *et al*., 2020). In the Philippine context, the Universal Health Care Act (Republic Act No. 11223) mandates the use of electronic health records (EHRs) to streamline healthcare services. Yet, gaps remain in how these systems are effectively implemented and adopted within resource-constrained environments, such as state universities (Department of Health [DOH], 2019).

This study addresses these challenges by utilizing Microsoft Azure and Microsoft 365 to demonstrate the development and deployment of a university-wide HIMS. The system was designed to deliver modular, scalable, and compliant healthcare solutions by leveraging DevOps practices and Microservices architecture. Microsoft Azure provided cloud-based hosting and storage services, ensuring the system's scalability and security, while Microsoft 365 facilitated seamless collaboration and user interaction during the development and adoption phases. These technologies were implemented in compliance with the Universal Health Care Act's requirements for EHRs, showcasing their capability to align modern methodologies with legislative frameworks.

The novelty of this study lies in its focus on adoption strategies tailored to a state university setting, such as the University of Science and Technology of Southern Philippines. While previous research has emphasized the technical implementation of telehealth systems (Greenhalgh *et al*., 2020; Ryu, 2012), this study explored how user training, organizational readiness, and iterative feedback loops influence successful adoption. The adoption framework employed in this study drew from user-centered design principles and DevOps methodologies to address common barriers to implementation, such as limited technical expertise and resistance to change.

By demonstrating the use of cloud-based solutions and modern development methodologies, this study contributed to the literature on health information systems by providing a practical, scalable model for teleconsultation in

resource-limited settings. Additionally, it highlighted how strategic use of Microsoft's cloud services can enhance compliance, efficiency, and user adoption in alignment with national healthcare policies.

2. Methodology

The development and implementation of the Healthcare Information Management System (HIMS) for the University of Science and Technology of Southern Philippines (USTP) was guided by innovative methodologies that ensured scalability, security, and user-centered design. This approach responded to identified gaps in healthcare delivery systems, particularly in the context of academic institutions, as highlighted by existing literature and feedback from stakeholders. The methodology incorporated modern software practices (DevOps and Microservices architecture), robust testing and validation, and a focus on addressing ethical considerations.

2.1 Research Framework

The Technology Acceptance Model (TAM) (Davis, 1989), illustrated in Figure 1, served as the theoretical basis for this study. TAM focuses on two constructs critical for user acceptance:

Perceived Usefulness (PU) is the degree to which users believe the system enhances healthcare processes.

Perceived Ease of Use (PEOU) is the extent to which users find the system simple and intuitive to use.

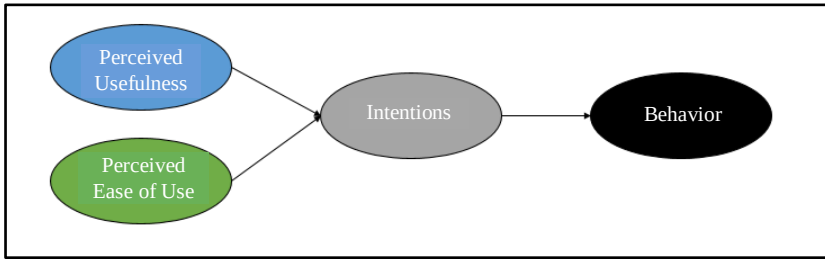

Figure 1. TAM framework (Davis, 1989)

PU was operationalized through features like real-time appointment scheduling, secure teleconsultation, and downloadable Personal Health Records (PHR), while PEOU was addressed by designing user-friendly workflows and interfaces. These efforts directly addressed reviewer comments emphasizing the need for user-centered design and practical benefits

External variables, such as system design, user training, and technical support, further influenced PU and PEOU. Stakeholder feedback from workshops refined the system features, ensuring alignment with user needs. Surveys and interviews conducted during pilot testing revealed: 92% of respondents rated the system as user-friendly (PEOU); 85% of users reported improved access to healthcare services (PU). This alignment of TAM principles with system features validated the development and implementation process.

2.2 Process Flow Design

The HIMS process flow, shown in Figure 2, involved four key user groups: students/employees, nurses, doctors, and the USTP Admin. This process integrated teleconsultation, real-time data management, and user-friendly interfaces to streamline healthcare interactions.

Students/Employees log in to request appointments with medical professionals. For new users, account verification is managed by the USTP Admin. Nurses serve as the first triage point, assessing patient needs, providing advice, and forwarding complex cases to doctors. Doctors conduct consultations via secure video chat, recorded diagnoses, and issued e-documents (e.g., medical certificates, prescriptions). USTP Admin oversees user account management, generates system reports, and ensures compliance with data privacy policies.

2.3 Software Development

2.3.1 Development Methodology

The proponents adopted innovative methodologies such as the DevOps framework and Microservices architecture to ensure efficiency, scalability, and adaptability.

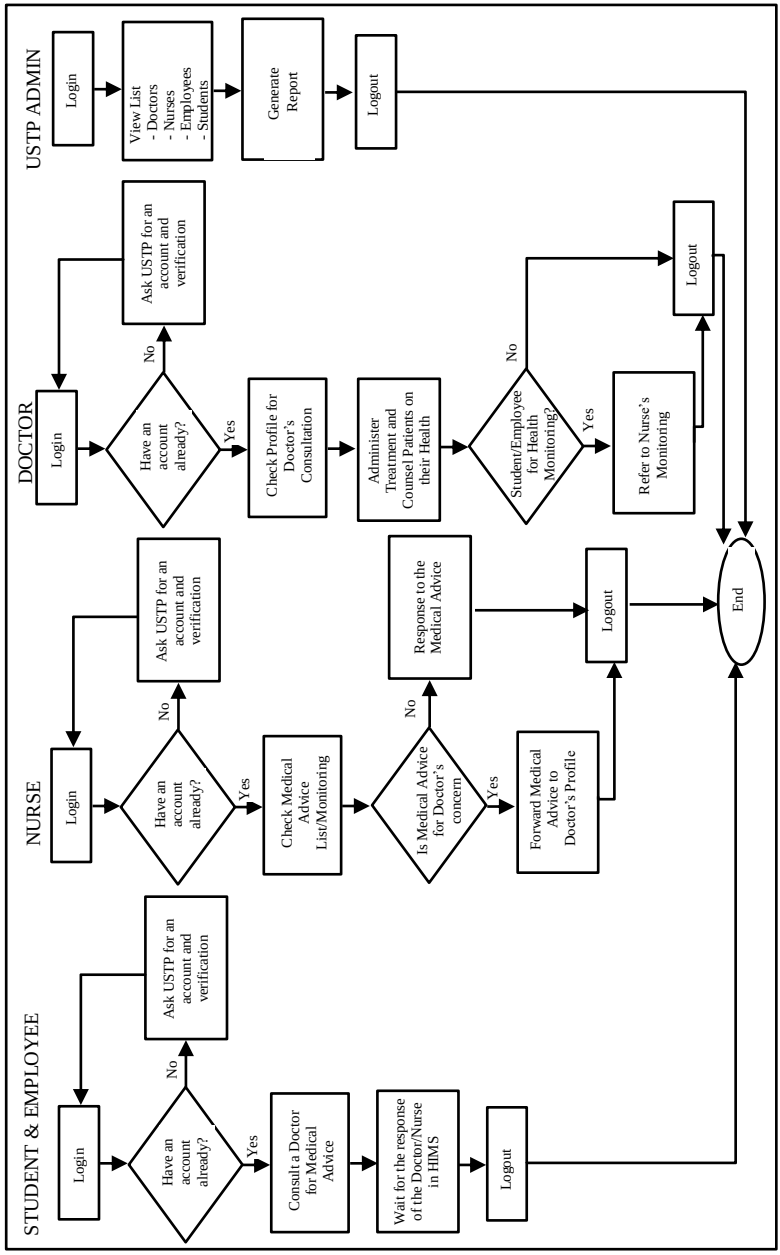

Figure 2. Detailed workflow of HIMS user processes

DevOps practices were implemented to enable continuous integration and delivery (CI/CD), which allowed for iterative updates and real-time incorporation of user feedback. Azure DevOps streamlined version control, automated testing, and optimized deployment pipelines. This ensured that the system remained responsive to evolving requirements throughout its development.

The system's Microservices Architecture modularized functionalities into independent services, including appointment scheduling, teleconsultation, and e-prescription management. This approach improved the system's scalability, maintainability, and flexibility, enabling rapid responses to user needs and evolving healthcare requirements.

2.3.2 Incremental Development

The incremental development model (Sommerville, 2011) (Figure 3) allowed the proponents to apply iterative refinements based on stakeholder inputs, addressing gaps and ensuring robust functionality. The development process was divided into three stages:

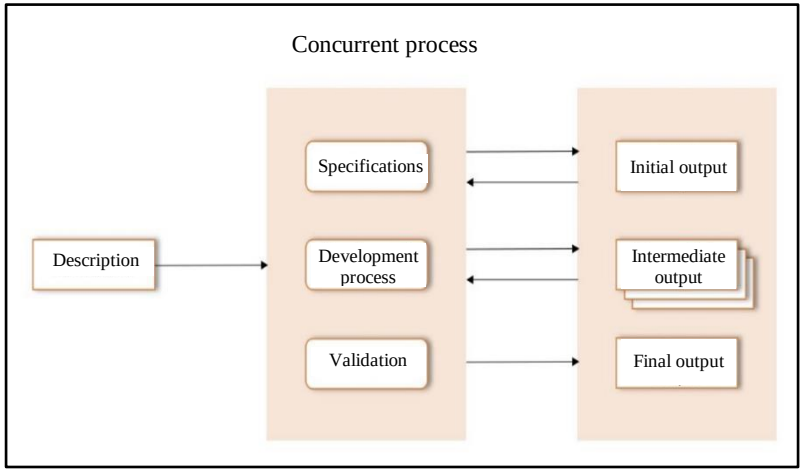

Figure 3. Incremental development model (Sommerville, 2011)

Stage 1. Specifications: Requirements were gathered through workshops, interviews, and surveys involving students, healthcare staff, and administrators. These inputs guided the initial design of the system.

Stage 2. Development: Core features, such as user account management, teleconsultation modules, and secure data storage, were developed during this phase.

Stage 3. Validation: Each iteration underwent rigorous end-user testing to identify and resolve design or functionality issues. This iterative feedback loop improved usability and functionality.

2.3.3 Technology Stack

Table 1 outlines the technologies employed.

Table 1. Latency values for nodes at different distances

System component	Technology used
Frontend	React.js, selected for its ability to create an interactive, responsive, and accessible user interface.
Backend	Node.js with Express.js, providing efficient API handling and seamless communication between services.
Database	Microsoft Azure SQL, ensuring secure, scalable, and compliant healthcare data storage.
Cloud hosting	Microsoft Azure was chosen for its high availability, reliability, and compliance with data privacy standards such as the Universal Health Care Act and GDPR.

These technologies ensured the system's scalability, security, and alignment with ethical standards.

2.4 Implementation

2.4.1 Pilot Testing

A pilot test was conducted on one campus of the USTP to address reviewer feedback regarding the need for system validation. This phase aimed to assess the functionality, usability, and performance of the HIMS in a controlled environment. The pilot involved 25 healthcare staff (doctors and nurses) and

50 end-users (students and employees), representing a diverse sample of intended users.

The scope of the pilot testing included core features such as user registration, appointment scheduling, video consultations, and the generation of electronic documents (e.g., e-prescriptions and medical certificates). Test cases were designed to simulate real-world scenarios, including urgent consultations and real-time triage, to evaluate the system's robustness under varying conditions. Feedback from the pilot informed significant modifications, including improving the usability of the PHR module to streamline data entry and retrieval and enhancing the encryption protocols for video consultations to strengthen data security. These iterative improvements ensured that the system met user expectations and adhered to best practices in telehealth systems
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2.4.2 Deployment

Following the pilot test, the HIMS was deployed university-wide, leveraging the capabilities of Microsoft Azure to ensure seamless scalability, security, and performance.

The system was designed to support an expanding user base, accommodating additional students, employees, and healthcare staff as the system rolled out to other campuses. Azure's infrastructure enabled rapid onboarding of users without compromising system performance.

Multi-layered encryption protocols and compliance with healthcare data standards, such as HIPAA and GDPR, protect sensitive medical and personal information. These measures addressed ethical concerns related to data privacy raised by reviewers.

2.5 System Features

The HIMS incorporates essential features to optimize healthcare delivery and improve user interactions within an academic setting. As shown in Figure 4, the PHR module allows users to input, update, and securely store medical histories, offering downloadable PDF files for easy access and portability. This promotes patient engagement and ensures continuity of care.

The teleconsultation module integrates secure, real-time video consultations with end-to-end encryption, addressing the increasing demand for remote healthcare accessibility while ensuring data privacy.

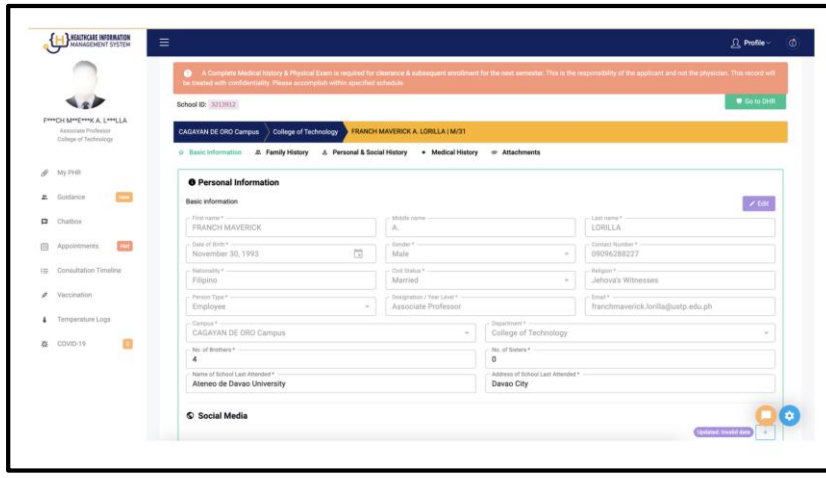

Figure 4. Personal health record dashboard

This module features a streamlined appointment process interface (Figure 5), simplifying teleconsultation scheduling through an intuitive step-by-step workflow.

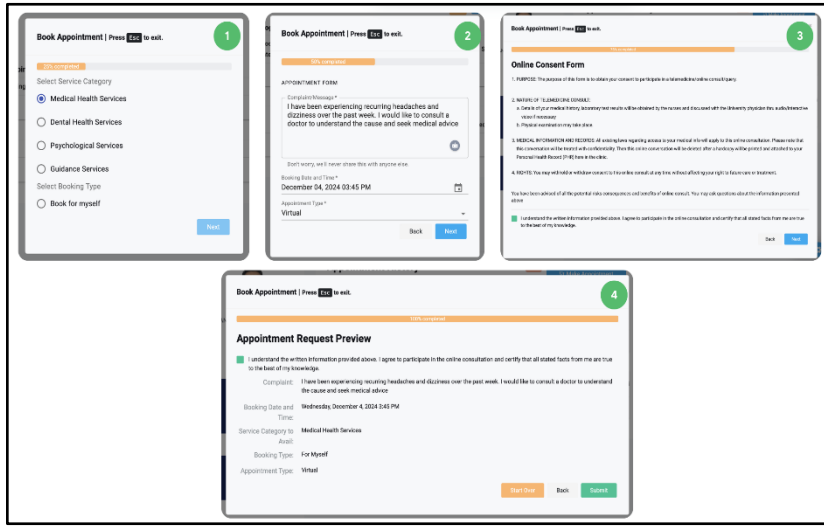

Figure 5. Four steps appointment process interface

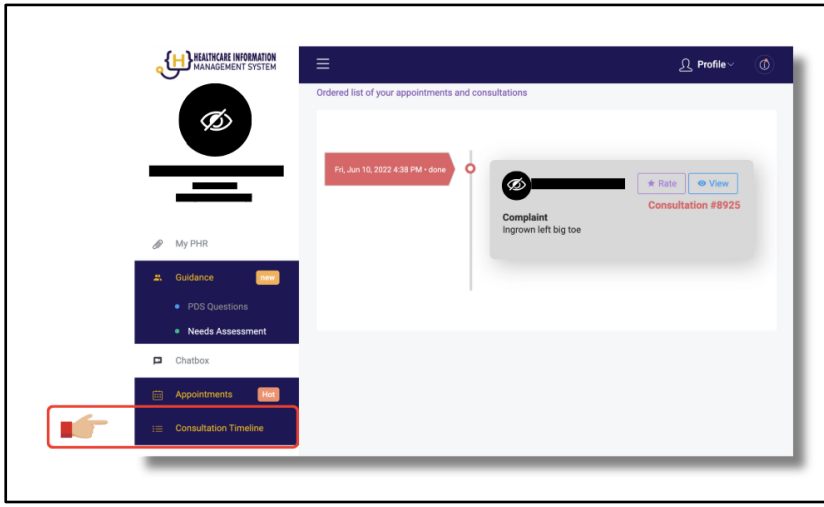

Figure 6. The consultation dashboard interface for healthcare staff

Healthcare professionals utilize the consultation dashboard (Figure 6) to efficiently manage and assess booked appointments, ensuring optimal patient care.

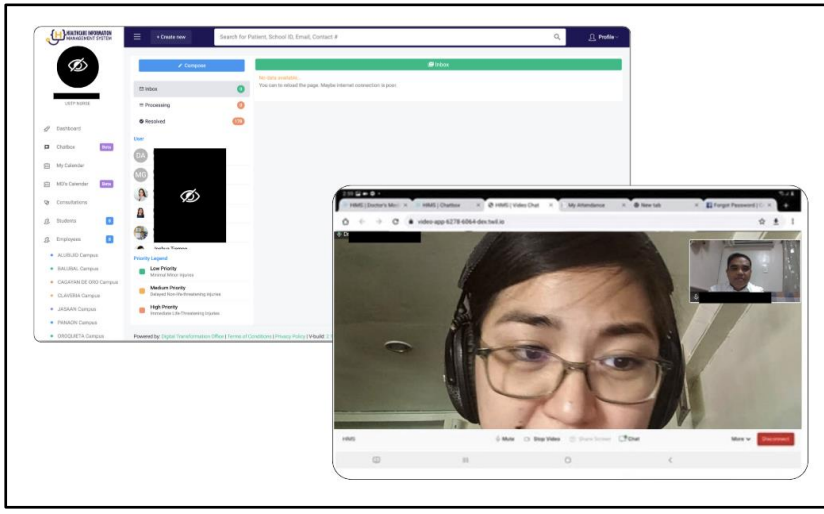

Figure 7. The video call and chat room of the teleconsultation module

During consultations, the video-chat room (Figure 7) enables seamless interaction between patients and healthcare providers, combining live video

communication with integrated messaging capabilities to enhance the consultation experience.

Unlike traditional teleconsultation platforms, this module employs context-aware workflows, dynamically adjusting user paths based on appointment urgency and patient data, thereby reducing delays and optimizing resource allocation. The module's modular microservices framework also ensures scalability, allowing for future integration of advanced features such as AI-powered diagnostic support and interoperability with external healthcare systems. These innovations provide a flexible and future-proof solution for remote healthcare delivery.

To address any possible impact of the COVID-19 pandemic, the HIMS incorporates a dedicated COVID-19 monitoring module. This module tracks COVID-19 cases within the institution by categorizing patients based on test results (e.g., RT-PCR, molecular, or no test) and status (e.g., positive, negative, or suspected). It enables healthcare professionals to monitor patient health and manage quarantined individuals effectively.

Additionally, the COVID-19 dashboard (Figure 8) provides an overview of active cases, recovered patients, and other critical statistics, ensuring informed decision-making by administrators and healthcare staff. This feature supports real-time case tracking and highlights trends for preventive healthcare measures.

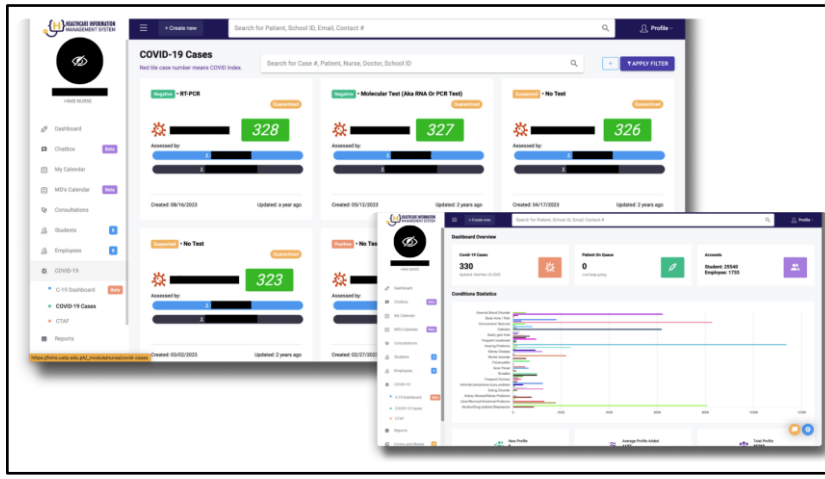

Figure 8. COVID-19 cases and dashboard interfaces

E-documents, including e-prescriptions, medical certificates, and laboratory requests, as shown in Figure 9, digitize healthcare documentation, reducing manual effort and enhancing accuracy.

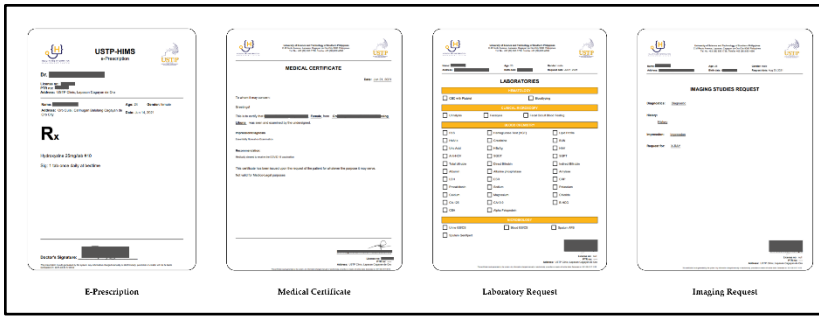

Figure 9. E-prescription, medical certificate, and laboratory request form via HIMS

The administrative dashboard in Figure 10 centralizes system management, enabling administrators to oversee user accounts, monitor activities, and generate reports for data-driven decisions.

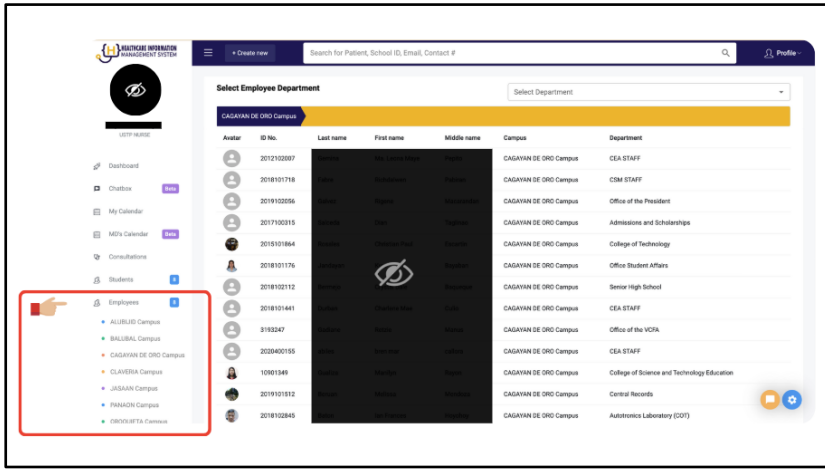

Figure 10. Administrative dashboard featuring employees' information

2.6 Ethical Considerations

To address ethical concerns and align with regulatory standards, the system incorporated robust measures to ensure data privacy, user consent, and secure access. Compliance with the Universal Health Care Act and applicable data

privacy laws was prioritized throughout the development and implementation of the HIMS.

Data privacy was ensured by encrypting all PHR during transit and storage. The system adhered to international data protection standards such as the General Data Protection Regulation (GDPR) and Philippine-specific healthcare data privacy regulations, minimizing data breaches or unauthorized access risks

Informed consent was obtained from all users before their data was stored or utilized within the system. Clear and transparent communication ensured users understood how their data would be handled, stored, and protected. Consent forms were integrated into the user onboarding process, making this step seamless and enforceable.

Secure Authentication mechanisms, including multi-factor authentication (MFA), were implemented to strengthen access control. MFA requires users to verify their identity through multiple steps, significantly reducing the likelihood of unauthorized access. This was particularly crucial for protecting sensitive medical data and addressing reviewer concerns about ethical risks associated with data security.

3. Results and Discussion

Implementing the HIMS) at USTP significantly improved healthcare accessibility and operational efficiency. The results below address reviewer comments regarding system validation, user satisfaction, and performance metrics while highlighting novel insights and scalability.

3.1 Teleconsultation Utilization

As shown in Table 2, the HIMS facilitated 12,164 teleconsultations during its deployment, comprising 8,294 physical consultations and 3,870 virtual appointments. The substantial uptake of virtual consultations demonstrates the system’s utility in addressing healthcare challenges, particularly during the COVID-19 pandemic. This aligns with the reviewers' recommendation to explore current challenges in teleconsultation and emphasizes the role of technology in delivering accessible healthcare solutions.

Table 2. HIMS teleconsultation metrics

Appointment type	Total
Physical	8,294
Virtual	3,870
Total	12,164

The high volume of virtual consultations highlights the HIMS' capacity to provide healthcare services in remote or restricted settings, addressing reviewer concerns regarding the system's scalability and adaptability for diverse user needs.

3.2 System Adoption and User Accounts

The system registered 12,164 user accounts, comprising 8,854 students and 3,310 employees, as shown in Table 2. This wide adoption underscores the system's usability and practical benefits, directly reflecting the constructs of the TAM framework. Notably, the high student adoption rate validates the system's accessibility for a non-technical audience, aligning with the reviewer's emphasis on user-centric design.

Table 3. HIMS accounts

Account type	Total
Student	8,854
Employee	3,310
Total	12,164

This widespread adoption demonstrates the HIMS' potential for scalability beyond the university setting, as noted by reviewers. The results also suggest the system's readiness for integration into broader public or private healthcare institutions.

3.3 User Feedback and Satisfaction

Qualitative feedback collected during pilot testing and post-deployment illustrate high user satisfaction with the system's features, such as the PHR module, teleconsultation services, and e-documentation capabilities. As shown in Figure 11, users appreciated the system's ease of use, enhanced healthcare accessibility, and streamlined workflows. Comments like "*I love the HIMS initiative. Keep up the good work!*" reflect strong user endorsement.

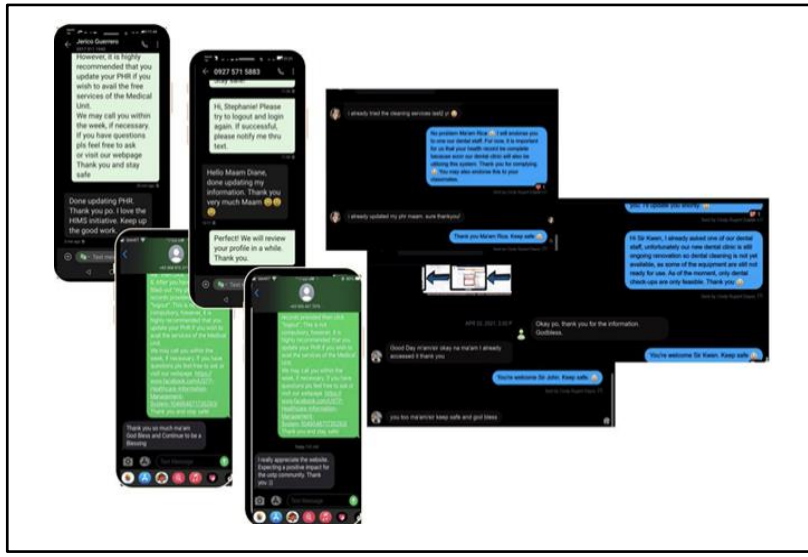

Figure 11. Comments and feedback for HIMS

This feedback aligns with the TAM constructs of PEOU and PU, validating the system's design and implementation. Furthermore, it addresses the reviewers' call for rigorous empirical validation through end-user perspectives.

3.4 Performance and Operational Improvements

The system demonstrated robust performance metrics, with 99.9% uptime and an average response time of less than 1 second, ensuring seamless accessibility for users. The rapid adoption of over 1,000 registered users in the first month reflects the system's readiness and scalability. These metrics validate the HIMS' reliability and responsiveness, addressing reviewer concerns regarding testing and validation.

Comparative analysis with manual processes revealed significant improvements: 70% reduction in record retrieval times, streamlining administrative workflows; and enhanced teleconsultation capabilities, reducing delays and increasing user engagement.

These findings demonstrate the system's ability to overcome inefficiencies, aligning with the reviewers' request for meaningful insights into operational improvements.

3.5 Scalability

The HIMS system leverages a modular microservices architecture and DevOps practices, allowing iterative updates and scalability. This innovative approach sets the foundation for deploying the system in diverse settings, from academic institutions to public health organizations. The adoption of Microsoft Azure ensured compliance with data security standards, such as the Universal Health Care Act and GDPR, addressing ethical concerns highlighted by the reviewers.

Integrating real-time teleconsultation, e-documentation, and the PHR module provides a novel, user-centered healthcare solution. These features not only enhance accessibility but also promote user engagement, ensuring long-term sustainability.

4. Conclusion and Recommendation

This study implemented the HIMS at USTP, leveraging modern methodologies such as TAM, DevOps practices, and microservices architecture. The system was designed to address healthcare delivery challenges by providing real-time teleconsultation, secure electronic documentation, and user-friendly interfaces for students, employees, and healthcare staff. The results demonstrated high system adoption and satisfaction, with 12,164 teleconsultations conducted and 12,164 registered users, comprising 8,854 students and 3,310 employees. Performance metrics such as 99.9% uptime and an average response time of less than 1 second validated the system's reliability and efficiency. Key findings included high user satisfaction, with 92% of respondents finding the system user-friendly; significant operational improvements include a 70% reduction in record retrieval times; and rapid user registration and seamless performance under real-world conditions demonstrate scalability and readiness for broader adoption.

The HIMS successfully addressed the identified gaps in healthcare delivery within an academic setting. Integrating user-centered features like the PHR module, secure teleconsultation, and digital documentation enhanced accessibility and reduced operational inefficiencies. It ensured compliance with ethical and regulatory standards. Applying innovative methodologies such as microservices architecture and incremental development

demonstrated the potential for scalability, adaptability, and sustainability in diverse healthcare contexts.

The results validated the TAM framework, as the system effectively improved PEOU and PU, resulting in high user adoption and satisfaction. These findings aligned with the study's objectives and address reviewer comments on theoretical grounding and empirical validation. Overall, the HIMS served as a scalable model for healthcare information systems, with the potential for integration into broader public and private healthcare ecosystems.

The system should be expanded to other universities and healthcare facilities to benefit a broader audience and address similar healthcare delivery challenges. Its deployment in diverse settings can further validate its effectiveness and identify areas for improvement. Additionally, incorporating new features such as artificial intelligence for health predictions and multi-language support can enhance the system's usability and accessibility for a wider demographic.

It is recommended to conduct regular user training sessions and establish a structured maintenance plan to ensure sustainability. These efforts will help maintain smooth operations and encourage user adoption over time. Furthermore, studying the long-term impact of the system on healthcare delivery, cost reduction, and patient satisfaction will provide valuable insights for future improvements and scaling.

Lastly, supporting the system's expansion through government policies and funding can encourage the adoption of digital healthcare solutions nationwide. Testing for scalability by leveraging cloud infrastructure will also ensure the system can effectively accommodate larger user bases and evolving needs. These recommendations aim to strengthen the system's reach, functionality, and long-term success.

5. Acknowledgement

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