VIRTUAL REALITY FOR IMMERSIVE TRAINING ON HANDLING AND IDENTIFYING VENOMOUS SNAKES IN SRI LANKA

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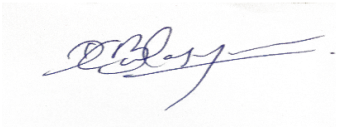

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Abstract

The country of Sri Lanka experiences high numbers of venomous snake encounters with its human population. Snakebites produce serious medical outcomes because venom from snakes strongly affects human physiology which results in either death or prolonged disabilities. The training methods used for medical practitioners and emergency responders fail to meet the needs of the high number of snakebite incidents. Theoretical education methods using books and classroom lectures do not deliver practical experience for treating snakebite emergencies. The insufficient training methods lead to delayed or incorrect treatment that worsens the outcomes for snakebite victims. The present simulation tools do not demonstrate venom effects in real time so professionals who treat snakebites remain unprepared regarding the demanding nature of such emergencies.

The proposed research develops an immersive Virtual Reality (VR)-based educational platform which replicates how snake venom affects the human body. The platform features three main functions which include displaying venom progressions across multiple anatomical systems through detailed 3D models and showing symptom development through interactive timelines and delivering complete educational content about snakebite response and medical treatment plans. The virtual reality system lets users engage with dynamic simulation models which show how venom affects body tissues along with organs and physiological functions in real time. Through this method healthcare practitioners can connect their theoretical concepts to real-life applications thus acquiring a complete understanding of time-sensitive interventions and proven treatment methods.

The system makes use of Unity3D for VR development and Blender for 3D modeling as its core technologies. The system utilizes feedback functions together with learning sequences that aim to boost user interest and keep students' information in their memory. The platform provides a protected environment which surpasses traditional training boundaries to support environmentally friendly medical education through reduction of both live sessions and animal experiments. The market shows strong demand for advanced medical training equipment that serves areas where snakebite incidents frequently occur.

The research demonstrates the need to introduce contemporary technology in medical education programs to enhance student readiness for treating snakebites. The VR-based training system constitutes a revolutionary healthcare method which simultaneously boosts medical care quality while minimizing death rates and delivering superior patient results. The platform demonstrates potential as a transformative medical training technology because it can scale across the globe to improve educational methods which lead to life-saving effects and better public health results.

Acknowledgement

I deeply appreciate all the individuals who helped directly and indirectly to complete this research project successfully. The completion of this document reflects both my personal work and the combined support I received from many people and organizations during my research journey.

The foundation of my gratitude goes to my supervisors Mr. Aruna Ishara Gamage and Mr. Didula Chamara Thanaweera Arachchi for their persistent backing along with their beneficial criticism and irreplaceable guidance. The combined knowledge of academic theory and technical expertise from both supervisors directed and improved the quality of this research project. The project received continuous encouragement from these individuals while they guided me through confusing points to maintain my motivation.

The Department of Information Technology at Sri Lanka Institute of Information Technology (SLIIT) deserves my deepest gratitude for offering all essential resources and facilities to conduct this research work. The exposure and learning opportunities at this institution proved essential for my development of knowledge about Virtual Reality (VR) technology and its medical education applications. I extend my deepest appreciation to all faculty members who provided academic and professional backing throughout my undergraduate years.

The medical professionals and experts provided their valuable insights and conducted scientific validation tests on the VR simulations developed through this project. The medical experts who provided input helped maintain content reliability which stayed true to actual clinical practices. Medical professionals and developers demonstrated through their partnership that multidisciplinary teamwork remains essential for solving complex health problems such as snakebite envenomation.

The project's overall success depended heavily on my research group members who dedicated themselves through complementary work. The team's collective vision together with their collaborative work established an innovative and excellent environment. Dhananjaya W.A.B.P together with Dilshan K.A.R established essential groundwork through their work on snake capture tools and techniques and snake anatomy identification for my research on human body responses to snake venom.

This project received support from numerous unnamed individuals who made significant contributions at different points. Their combined work brings this thesis to life, and I express sincere gratitude for their backing.

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1. Introduction

1.1.Background Literature

Snakebite envenomation continues to be a major public health problem in tropical and subtropical regions in Sri Lanka because venomous snakes frequently attack humans in this area. Encounters with venomous snakes lead to serious health outcomes including deaths particularly in rural areas that have restricted medical facility access. Envenomation creates extensive economic challenges that burden both healthcare systems and the affected population as well as their family members. Post-traumatic stress disorder (PTSD) and other long-term psychological consequences affect survivors after snakebites and create severe complications for their quality of life. The standard approaches to train medical professionals and emergency responders about snakebite treatment depend heavily on book-based theory and classroom lectures along with static human body displays. The absence of practical experience from these educational methods results in delayed proper treatment and higher death rates among snakebite victims.

Global Burden of Snakebite Envenomation

The tropical disease snakebite envenomation creates major health problems for vulnerable groups throughout low- and middle-income nations. The World Health Organization (WHO) reports that snakes bite 5.4 million people yearly, leading to 81,000 fatalities and 400,000 cases of permanent disability throughout the world [1]. Snakebites represent a major public health problem in tropical and subtropical areas including South Asia and Sub-Saharan Africa and Latin America because these regions contain many venomous snake species which frequently encounter human populations. The warm climate combined with dense vegetation and diverse ecosystems of Sri Lanka creates optimal conditions for venomous snakes which makes this country one of the most affected regions worldwide.

Snakebite envenomation affects different populations of the world differently. The health crisis of snakebites primarily affects rural areas of developing nations because their residents lack proper medical care and insufficient antivenom supplies and their healthcare providers need better training. Sri Lanka experiences its highest number of snakebites in agricultural zones because farmers and fieldworkers frequently meet dangerous snakes in their work areas. The annual snakebite incidents in Sri Lanka affect 300 to 400 people per 100,000 residents according to Kasturiratne et al. (2008) who also reported a 2% mortality rate [2]. The annual number of snakebites in Sri Lanka reaches thousands of cases leading to fatal outcomes and lifelong disabilities.

The financial impact of snakebite envenomation proves to be alarming. When snake bites occur patients need lengthened hospital care combined with high cost antivenom medications and recovery programs which create major financial stress for medical systems and household budgets. The economic burden becomes more severe because snakebite survivors experience lower productivity because of physical disabilities combined with psychological trauma. The social expenses from snakebite envenomation become worse because it leads to income reduction for both victims and their relatives, especially in agricultural communities where physical labor provides the main source of household income.

Physiological Effects of Snake Venom

Snake venom consists of multiple proteins and enzymes with peptides that specifically attack human physiological systems through the body. Each snake species develops a distinct venom composition, yet most venoms fit into three main categories which include neurotoxic and hemotoxic and cytotoxic types. If a person encounters a snake that produces neurotoxic venom their nervous system becomes a target which results in disruptions of neurotransmission ultimately leading to paralysis alongside respiratory failure and eventually death. Hemotoxic venom substances hinder blood clotting processes which result in severe bleeding problems and damage to internal organs and widespread medical complications. Venomous substances classified as cytotoxic damage tissues and cells which results in necrosis and persistent wounds and tissue destruction.

Snake venom produces quick and continuously advancing impacts on the human body. The venom enters the bloodstream after injection and moves directly to organs and body systems. The neuromuscular junctions become paralyzed due to neurotoxins that block acetylcholine receptors which stop muscle contraction. The activity of hemotoxins breaks down blood vessels and clotting factors which produce fatal bleeding that ends in organ failure. The tissue-damaging properties of cytotoxins produce localized necrosis which leads to painful swelling and bite site tissue death. The venom's impact on victims depends on various elements such as venom type and quantity as well as bite location and victim's age and health status and immune system activation.

Knowledge about how snake venom operates remains essential to deliver proper medical care. Research on venom composition shows high complexity which complicates the development of standardized treatment plans. The main treatment for snakebite envenomation requires antivenom which must be specific to the venomous snake species to work effectively. The coexistence of various venomous snake

species in Sri Lanka creates a major challenge because their venoms have unique effects on victims.

Current Challenges in Medical Training

Educational methods that train medical practitioners and emergency responders about snakebite management fall short in handling the complex situations involving venomous snakes. Reaching proficiency in snakebite management is difficult with existing teaching approaches that rely on textbooks and static anatomical models together with theoretical lectures. The foundational content in textbooks together with lectures about snake anatomy and venom and protocol teaching fails to offer sufficient training for actual emergency care situations. The lack of dynamic interactive features in static anatomical models prevents their use to predict venom effects in real-time.

Traditional training methods face an important limit because they lack the ability to demonstrate properly both the critical nature and complex procedures required for snakebite victim care. The treatment of snakebite envenomation needs urgent medical attention to stop complications from occurring and achieve better patient recovery. Practical experience helps trainees recognize early symptoms, but they may face difficulties with appropriate first aid administration and medical treatment initiation when they lack such experience. The insufficient training about snakebite treatment results in delayed or incorrect medical care that increases the chances of serious complications or death in snakebite victims.

The current training methods suffer from an important weakness because they lack proper tools to replicate the bodily effects of venom exposure. Effective treatment of venom requires a complete comprehension of bloodstream dissemination and organ system impacts together with venom progression patterns throughout time. Traditional teaching methods present an inadequate way to show learners how these processes work because they do not provide clear visual explanations of snakebite emergency dynamics.

The Potential of Virtual Reality in Medical Education

Virtual Reality (VR) technology represents recent technological progress which provides effective solutions to overcome traditional training method restrictions. The virtual reality platform enables users to experience learning through dynamic simulations which replicate actual scenarios. Through VR technology training programs can present simulated venom reactions on human physiology for students to observe actual symptom developments. Through this approach learners gain better

understanding and develop enhanced decision-making abilities because they receive realistic training experiences that are risk-free.

Training platforms powered by VR technology present complete educational opportunities through their high-definition anatomical models as well as their interactive timelines and guided learning components. Users can experience 3D human body models that show venom movement through bloodstream and its effects on different organs during their interactions. Through interactive timelines students can monitor how symptoms intensify starting from the very beginning until complications occur which proves the necessity of swift medical response. The learning modules guide users through complete procedures for venomous snake identification and first aid administration and medical treatment initiation.

The medical education applications of VR reach far beyond its utility for snakebite treatment. Virtual reality sets a safe operational framework for practical skills development which students can use to build competence before facing emergency situations in real-life situations. The new approach shows promises to change standard medical training practices and will lead to better patient survival rates with enhanced medical results.

1.2.Research Gap

The problem of snakebite envenomation persists as a major global health concern because venomous snakes frequently encounter humans in tropical and subtropical regions especially in Sri Lanka. Extensive research about snake venom physiology and medical advancements has not bridged the gap toward developing practical training facilities for healthcare workers and emergency personnel. The shortage of advanced medical services and training materials becomes most severe in regions that experience frequent snakebites. Modern educational methods have expanded theoretical knowledge of snake venom composition and human body effects, yet they lack essential hands-on training components needed for effective snakebite emergency response.

Limitations of Current Educational Approaches

The current educational methods for medical practitioners and emergency responders about snakebite management heavily depend on textbooks and lectures along with static anatomical models. The educational methods establish basics about snake structures along with venom content and treatment guidelines, yet they do not offer interactive features needed to model true-to-life situations. Textbooks explain how neurotoxins attack neurotransmission and how hemotoxins prevent blood clotting,

yet they cannot show live venom processes. Static anatomical models provide limited value because they fail to demonstrate natural alterations which venom creates within different human organs and body systems.

Traditional educational methods prove inadequate for treating snakebite victims because of their restricted effectiveness in urgent medical situations. The treatment of snakebite envenomation needs immediate medical assistance to stop dangerous complications and enhance patient recovery. The lack of practical experience prevents trainees from properly identifying early warning signs and delivering suitable first aid as well as starting prompt medical assistance. The training deficiency results in late or inappropriate medical care which produces higher risks of life-threatening complications for snakebite victims. The present simulation models fail to show live visualizations of symptoms developing alongside treatment results which make learners ill-prepared to handle the changing dynamics of snakebite situations.

Inadequate Simulation Tools

Medical education simulation tools demonstrate innovation but fail to provide proper solutions for managing snakebites. The successful application of virtual reality (VR) technology in surgical training and general patient care does not extend to specialized fields such as snakebite envenomation. Studies show that VR holds significant medical education value according to Reed et al. (2020) however most present applications focus on surgical protocols and patient training yet fail to explore advanced biochemical and physiological models effectively [6]. The current market lacks sufficient VR-based tools that have been developed exclusively for snakebite management.

The lack of complete simulation tools which replicate venom-induced physiological effects in human bodies increases medical practitioners' existing difficulties. The success of snakebite treatment requires complete knowledge about venom distribution in bloodstreams as well as its effects on specific organs and their time-dependent progression. Traditional teaching methods lack effective mechanisms to show learners how venom spreads through the bloodstream during snakebite emergencies which leaves students unprepared for real-life snakebite situations. Neurotoxins disable neuromuscular junction acetylcholine receptors which then prevent muscle contractions thus causing

paralysis. The damage from hemotoxins includes both blood vessel destruction and the breakdown of clotting factors which cause severe bleeding that ends in organ failure. Cytotoxins produce tissue destruction in a specific area that results in localized pain and swelling as well as tissue death at the bite location. The extent of

venomous effects depends on multiple elements which include venom type and amount as well as bite location together with victim age and health status and their immune response capabilities. The ability to simulate snakebite treatment processes in real time remains essential because learners need to fully understand the urgent nature and complex treatment requirements for snakebite victims.

Lack of Hands-On Training Tools

Current training methods remain limited because they lack complete practical tools which duplicate venomous snake encounters together with their medical consequences within controlled settings. The current training techniques provide either abstract theoretical teaching with no practical application or actual live snake handling yet neither approach effectively prepares students for authentic snake encounters. Theoretical approaches need practical experience to be effective but live snake interaction creates dangerous safety conditions.

The lack of proper training resources creates insufficient preparedness among people who might encounter snakes such as farmers, wildlife workers and rural community members. Educational tools that are not effective enough make the situation worse by leading people to handle venomous species improperly and incorrectly identify them which results in more snakebites and inadequate medical responses. The healthcare system and families bear substantial financial expenses because snakebite treatments are expensive while recovery periods extend beyond productivity levels of victims.

Complexity of Venom Composition

The development of proper educational tools faces major challenges because venom composition shows both complexity and wide-ranging diversity. Snake venom contains multiple proteins and enzymes and peptides which attack different physiological systems within human bodies. Snake venom shows different compositions between species while most venomous substances can be grouped into neurotoxic hemotoxic and cytotoxic categories. Neurotoxic venoms penetrate the nervous system to disrupt neurotransmission which results in paralysis alongside respiratory failure and may cause death. The harmful substances in hemotoxic venom disrupt blood coagulation leading to severe internal bleeding together with organ damage and widespread medical complications. Venoms containing cytotoxic properties target cells and tissues which cause necrosis and results in tissue damage and persistent wounds.

Knowledge about how snake venom affects the body function remains essential for successful medical intervention. Resistance to treatment development exists due to the multiple forms of venom components which exhibit diverse chemical composition. The main treatment for snakebite envenomation requires antivenom which requires matching the venom species for maximum effectiveness. The challenge becomes significant in areas such as Sri Lanka because it has various venomous snake species that produce unique venom effects. Educational tools currently in use do not address the variability of snake venom symptoms which results in students being unable to properly manage the multiple symptoms of different snake species.

Need for Immersive Learning Solutions

Snakebite management requires immersive learning solutions because snakebite cases occur frequently and lead to high mortality and morbidity statistics. The annual snakebite occurrences in Sri Lanka affect 300 to 400 people per 100,000 population and lead to 2% victim mortality as reported by Kasturiratne et al. (2008) [3]. The high number of yearly snakebites leads to thousands of cases that frequently result in fatal or permanent disabilities. Snakebites in Sri Lanka create excessive strain on the healthcare system because they demand immediate specialized medical assistance. Victims who lack training and awareness about proper care receive delayed or inappropriate medical attention thus suffering preventable complications and deaths.

The latest technological developments focused on Virtual Reality (VR) deliver effective solutions to resolve current gaps in healthcare practice. Virtual Reality creates an interactive learning scenario through which users can handle digital simulations that reproduce actual scenarios. The physiological effects of venom on human bodies can be simulated through VR technology so learners can observe symptoms as they develop in real time during snakebite management training. Such training methods simultaneously boost understanding and decision-making skills through realistic simulations which occur without actual risk. Interactive 3D anatomical models in combination with achievable timelines and guided learning pathways within virtual reality systems generate whole educational experiences which unite theoretical knowledge with practical application skills.

Bridging the Gap with VR Technology

Virtual Reality (VR) technology has the potential to transform medical education with the use of immersive, interactive learning processes that closely resemble reality. For the treatment of snakebites, VR can surpass the shortcomings of

traditional training techniques by allowing the users to practice in a risk-free, controlled environment. Users, for example, can have 3D models of the human body manipulated to visualize how the venom circulates through the bloodstream and affects organs. Interactive timelines allow students to track the course of symptoms from the beginning through to complications, and that underscores the need for intervention early on. Instruction by steps is facilitated through guided learning modules on recognizing fatal snakes, administering first aid, and commencing treatment.

The uses of VR in medical education extend beyond snakebite management. Studies have shown that VR training improves learning outcomes for complex and high-risk specialties [6]. Since it provides a safe and controlled learning environment for experiential practice, VR enables learners to develop their skills and gain confidence before encountering real emergencies. The new method has the potential to revolutionize medical training methods, and in the end, save lives and improve patient outcomes.

Table 1- Research Gap

Feature	Global Burden & Training	VR in Venom Complexity on human body	VR in Medical Training	VR for Snakebite Education	Interactive Timelines
Research A [3]	✓				
Research B[4]		✓			
Research C [5]			✓		
Research D [6]				✓	
Proposed system	✓	✓	✓	✓	✓

1.3.Research Problem

Complexity of Venom Composition and Its Effects

The complex composition of snake venom includes proteins as well as enzymes and peptides which attack different physiological systems throughout the human body. Snake species produce different venom compositions yet most venoms group into neurotoxic, hemotoxic, and cytotoxic types. Neurotoxic venoms attack the nervous system through neurotransmission disruptions which results in paralysis and respiratory failure and ultimately leads to death in critical situations [4]. The activity of hemotoxic venom disrupts blood clotting functions which produces bleeding inside the body and damages organs and leads to extensive systemic problems. The attack of cytotoxic venoms against cells and tissues results in tissue destruction that causes necrosis and forms chronic wounds.

The venom of snakes produces immediate and advancing biological consequences within the body. The venom enters the bloodstream after injection and moves toward particular organs and systems throughout the body. The neuromuscular junctions become paralyzed when neurotoxins block acetylcholine receptors which results in muscle contraction inhibition. Unregulated bleeding and organ failure occur because hemotoxins destroy blood vessels while also breaking down clotting factors. The tissue-damaging properties of cytotoxins produce swelling and necrosis and cause pain at the bite location. Several factors determine the seriousness of venom effects such as the venom type and dosage as well as the bite location and the victim's age and health status and immune response [5]. The treatment process requires complete knowledge about how snake venom affects the human body. Researching venom composition has proven difficult for standardizing medical protocols for its complex nature. The main treatment for snakebite envenomation requires antivenom which needs to match the specific venomous species for maximum effectiveness. The coexistence of various venomous snake species in Sri Lanka creates a major treatment challenge because their venoms produce unique effects on victims. The current educational tools lack enough specificity to teach healthcare workers about the diverse symptoms and complications that different snake species can cause.

Limitations of Traditional Training Methods

The current educational approach for medical practitioners and emergency responders about snakebite management depends on textbooks along with lectures and static anatomical models. These educational methods establish fundamental knowledge about snakes and their venom and treatment approaches, yet they fall short in replicating genuine clinical situations [7]. Textbooks present information about how neurotoxins affect neurotransmission and how hemotoxins interrupt blood

coagulation, yet they cannot show the live progression of these processes. Static anatomical models demonstrate limited use for understanding complex venom effects on human organs because they cannot show how venom affects different body systems.

These conventional educational methods fail to meet the requirements of fast and intricate snakebite victim treatment needs. The treatment of snakebite envenomation needs immediate medical attention to stop complications and enhance patient recovery. Trainees who lack practical experience face difficulties in detecting early signs as well as providing correct first aid and starting prompt medical interventions. Without proper training about snakebite treatment the risk of fatal complications increases for victims because their care becomes delayed or incorrect [8].

Current training methods suffer from an essential drawback because they lack complete tools to reproduce the way venom affects human physiology. Medical professionals need to understand the bloodstream transmission of venom because it determines the treatment approach and response of different body organs and the venom's temporal evolution. The failure of traditional training approaches prevents students from comprehending these critical processes because they do not offer visualization of the internal body changes during snakebite situations [6].

Inadequate Simulation Tools

The existing medical education simulation tools demonstrate innovative abilities yet lack proper solutions for managing snakebite incidents. The implementation of virtual reality (VR) applications succeeded in general patient care while their application in specialized fields like snakebite envenomation has not received enough attention from researchers [6]. The current market lacks sufficient VR-based tools that have been developed exclusively for managing snakebites.

Current medical challenges become more difficult because there are no complete simulation tools which replicate how venom affects human physiology. Learning about venom's bloodstream distribution patterns and its effects on organs during the progression of symptoms remains essential for achieving effective patient treatment. Traditional methods lack the ability to show learners how venom works in the body which results in inadequate preparation for the changing conditions of snakebite emergencies [7].

Lack of Hands-On Training Tools

The existing training methods fail to provide sufficient hands-on tools which enable trainees to experience venomous snake encounters in controlled safe conditions. Training methods through traditional methods provide either theoretical teachings without practical experience or live snake interactions but neither approach properly prepares people for actual snake encounters. Theoretical methods fall short in providing practical skills needed for effective learning because they do not offer hands-on experience and direct snake handling produces dangerous safety hazards [8].

A lack of training resources creates insufficient readiness among people who encounter snakes in their daily work such as farmers and wildlife workers together with rural community members. The lack of proper educational tools makes the situation more dangerous because people handle snakes improperly and fail to identify venomous species properly leading to more snakebites and incorrect medical responses [3]. The healthcare system along with families bears substantial financial costs from snakebites because treatment expenses are high, and recovery times are long which reduces both individual productivity and victim health status [1].

Urgency and Complexity of Treatment

Treating snakebite victims requires both high urgency and complex medical procedures. Snakebite envenomation needs urgent medical attention because it helps avoid complications while improving treatment results. The lack of practical experience causes trainees to face difficulties in recognizing early symptoms while performing proper first aid and starting prompt medical intervention [8]. The absence of training creates problems with both delayed and incorrect treatment approaches that result in higher risks of snakebite victim complications and death.

The neuromuscular junctions become paralyzed due to neurotoxin action which blocks acetylcholine receptors resulting in muscle contraction inhibition. The destructive action of hemotoxins against blood vessels and clotting factors results in uncontrolled bleeding along with organ failure. The tissue-damaging effects of cytotoxins produce necrosis along with pain and swelling which affect the bite location. Various factors such as venom type and dose and bite location and patient age and health status and immune response determine the severity of venomous effects [5]. Real-time simulation tools are essential for learners to properly understand the critical aspects of treating snakebite victims.

1.4. Research Objectives

The primary objective of this research is to address the critical gap in snakebite management training by developing an immersive Virtual Reality (VR) platform tailored specifically for Sri Lanka, where snakebite envenomation remains a significant public health concern. The proposed VR system aims to simulate the physiological effects of snake venom on the human body, providing learners with an interactive and risk-free environment to enhance their understanding and preparedness.

Educating Users on the Physiological Effects of Snake Venom

Snake venom contains various complex toxins which trigger three major destructive body reactions including neurotoxicity and hemotoxicity and cytotoxicity [1]. Neurotoxic venoms originating from cobras and kraits enter the nervous system to produce paralysis which ends in respiratory failure. Internal bleeding and organ damage occurs because vipers contain hemotoxic venoms which harm blood clotting processes. The tissue-destroying properties of cytotoxic venoms found in Russell's viper species create necrosis and systemic complications at the bite site [4].

The VR platform addresses this through simulated physiological effects by using detailed 3D human body models. The user interface displays venom movement throughout the bloodstream and its effects on body organs in real time. The platform displays symptom development timelines which highlight why patients must immediately look for medical assistance. Through this immersive learning method users develop complete knowledge about how venom impacts the human body.

Give an Understanding About First Aid After a Snakebite

First aid plays a critical role in reducing the severity of snakebite envenomation and improving survival rates. However, improper first aid practices can worsen the situation, making it essential to provide clear and accurate instructions [2]. This objective focuses on equipping users with the skills and confidence needed to administer effective first aid immediately after a snakebite.

The VR training module will include step-by-step guidance on performing first aid procedures in a simulated environment. Key steps include:

- **Reassuring the Victim:** Calming the victim is critical to prevent panic, which can accelerate the spread of venom throughout the body.
- **Avoiding Harmful Practices:** Common misconceptions, such as cutting the wound, applying tourniquets, or sucking out the venom, will be addressed and discouraged, as these practices can worsen tissue damage and increase the risk of infection [5].

- **Seeking Immediate Medical Attention:** Emphasis will be placed on transporting the victim to a healthcare facility as quickly as possible while keeping them calm and still.

Users can practice the steps through interactive scenarios which provide a controlled environment for practice. Virtual patients who suffer from Russell's viper bites present an opportunity for users to choose appropriate treatment steps until medical professionals reach the scene. Real-time feedback systems will help users identify and immediately fix errors which reinforce appropriate methods.

Improve Preparedness for Snakebite Emergencies

Unpredictable snakebite incidents frequently take place in remote areas where victims become exposed to danger because medical help arrives too late [3]. Research focuses on snakebite emergency preparedness development because it constitutes a vital component of this work. Through its VR system the developers strive to develop user abilities and self-assurance so users can manage high-pressure situations successfully.

Preparedness begins with education. The system exposes users to life-like venomous snake encounters through virtual reality simulation environments. A typical scenario in this environment places users in a forest that requires them to identify venomous snakes while handling the snakes safely before responding to a hypothetical bite incident. The stressful scenarios will test user knowledge acquisition by requiring them to make decisions under high-stress conditions to improve their crisis management skills.

Mental preparation stands as a vital part of readiness for any situation. A person who sees either a venomous snake or a snakebite may develop traumatic responses that could lead to impaired judgment. Through virtual reality, users can safely experience fear-inducing situations to develop their ability to face such challenges in real life. Through repeated exposure to difficult situations users develop emotional tolerance to panic-causing triggers that enables them to stay focused during real-life crisis situations [6].

The VR training system will implement training modules for long-term recovery together with rehabilitation protocols. Survivors of snakebites require sustained attention for both their physical recovery and their psychological well-being after escaping death. The training system provides information about tissue loss and kidney damage alongside recovery support methods. The program adopts a comprehensive training method that enables users to handle acute emergencies while preparing them to handle the extensive consequences of snakebite envenomation [9].

2. Methodology

2.1.Methodology

The methodology section outlines the systematic approach to designing, developing, and implementing a Virtual Reality (VR)-based educational platform for snakebite management. This section is structured into three main components: Methodology, Commercialization Aspects of the Product, and Testing & Implementation.

System Components

I. **3D Anatomical Models:** The platform will utilize highly detailed 3D anatomical models to demonstrate human body structures that venom affects. The models enable users to examine venom reactions against physiological structures including circulatory and nervous systems. The platform achieves better educational outcomes by showing realistic visualizations of biochemical processes activated by venom because it helps students understand complex envenomation mechanisms [4].

II. **Interactive Timelines:** Real-time symptom visualization through Interactive Timelines represents the essential foundation for the virtual reality educational platform. Users will understand the need for urgent medical response through this feature which illustrates the negative effects of delayed treatment. Through interactive timelines users will get the chance to evaluate their decision-making abilities in controlled scenarios which strengthens their understanding of rapid medical interventions [6].

III. **Educational Modules:** The educational content will teach both first aid and recovery methods. Users will learn essential steps to stabilize snakebite victims which include immobilizing the affected limb and preparing for evacuation since these actions ensure survival until professional care becomes available [5]. The recovery modules will teach healthcare providers how to handle tissue damage and chronic pain and psychological trauma by providing rehabilitation plans. The practical VR training sessions will boost readiness levels and lead to better clinical results for patients.

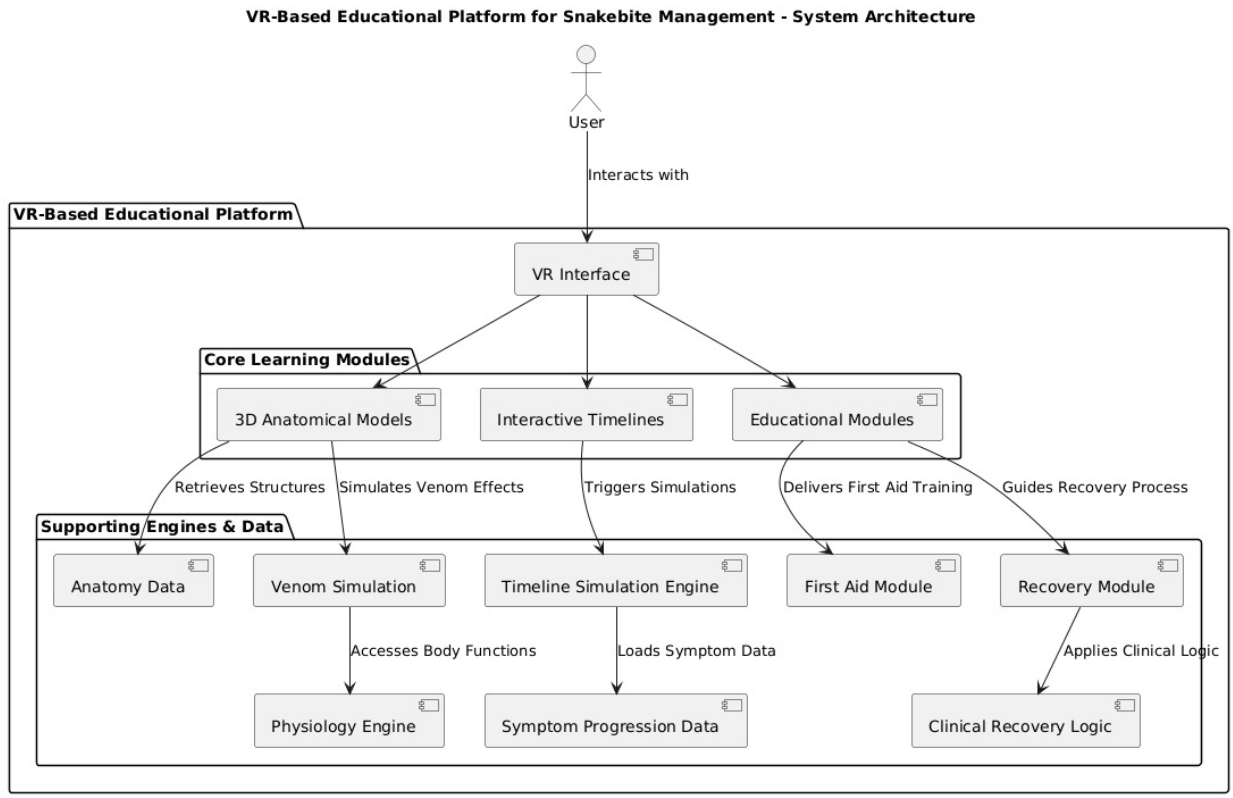

Figure 1- System Architecture Diagram

While drawing inspiration from existing VR platforms used in medical education [6], this project introduces novel features tailored specifically for snakebite management. The implementation of interactive timelines combined with real-time symptom progression marks an important development in VR-based training tools. Through these features users can observe how venom affects the human body dynamically as well as grasp the significance of quick medical intervention. Through virtual reality demonstrations the platform delivers complete venom knowledge and treatment education to medical personnel and emergency responders and community members who live in snakebite prone areas [8].

System Designs

System Overview Diagram

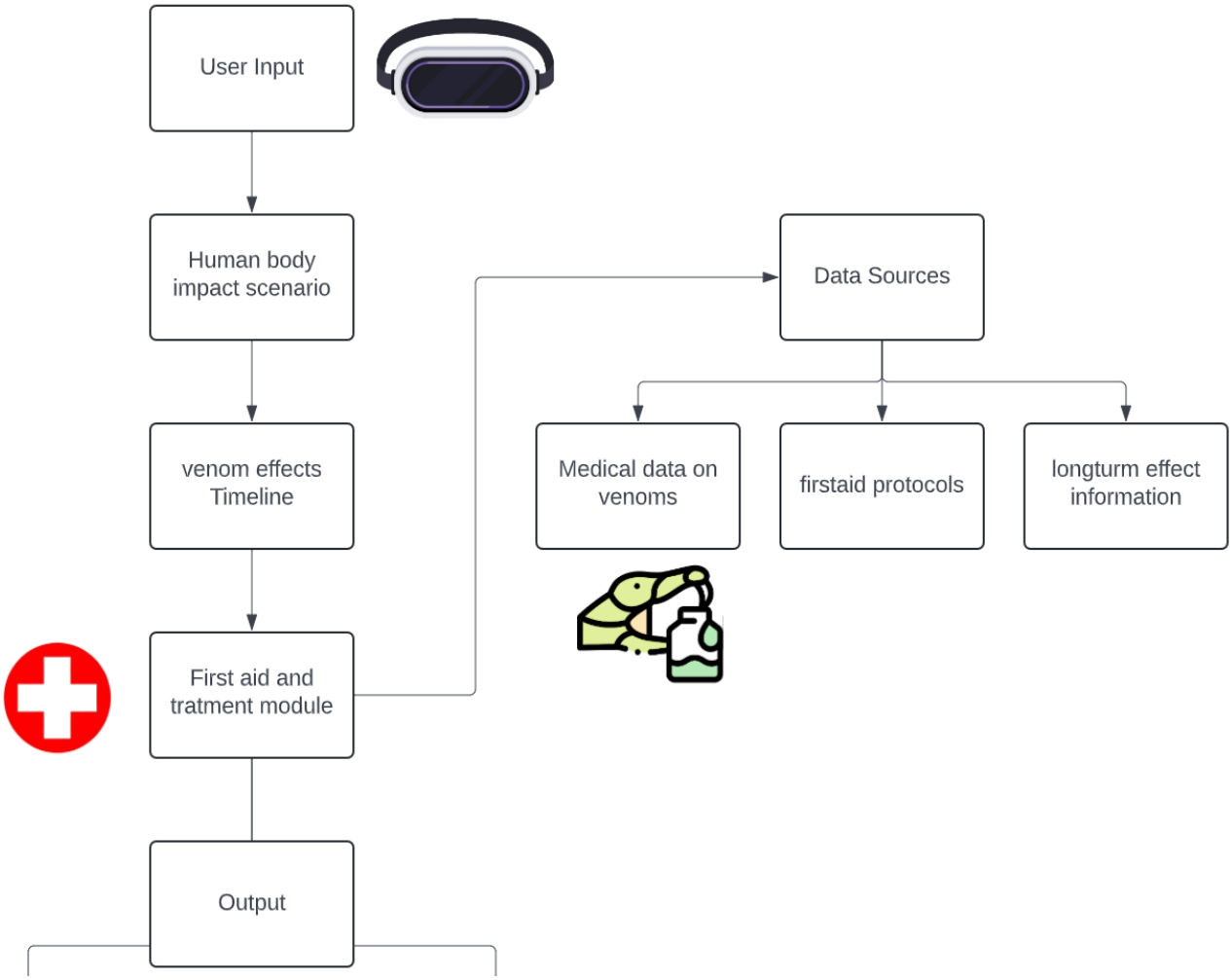

Figure 2 - System Overview Diagram

Sequence diagram

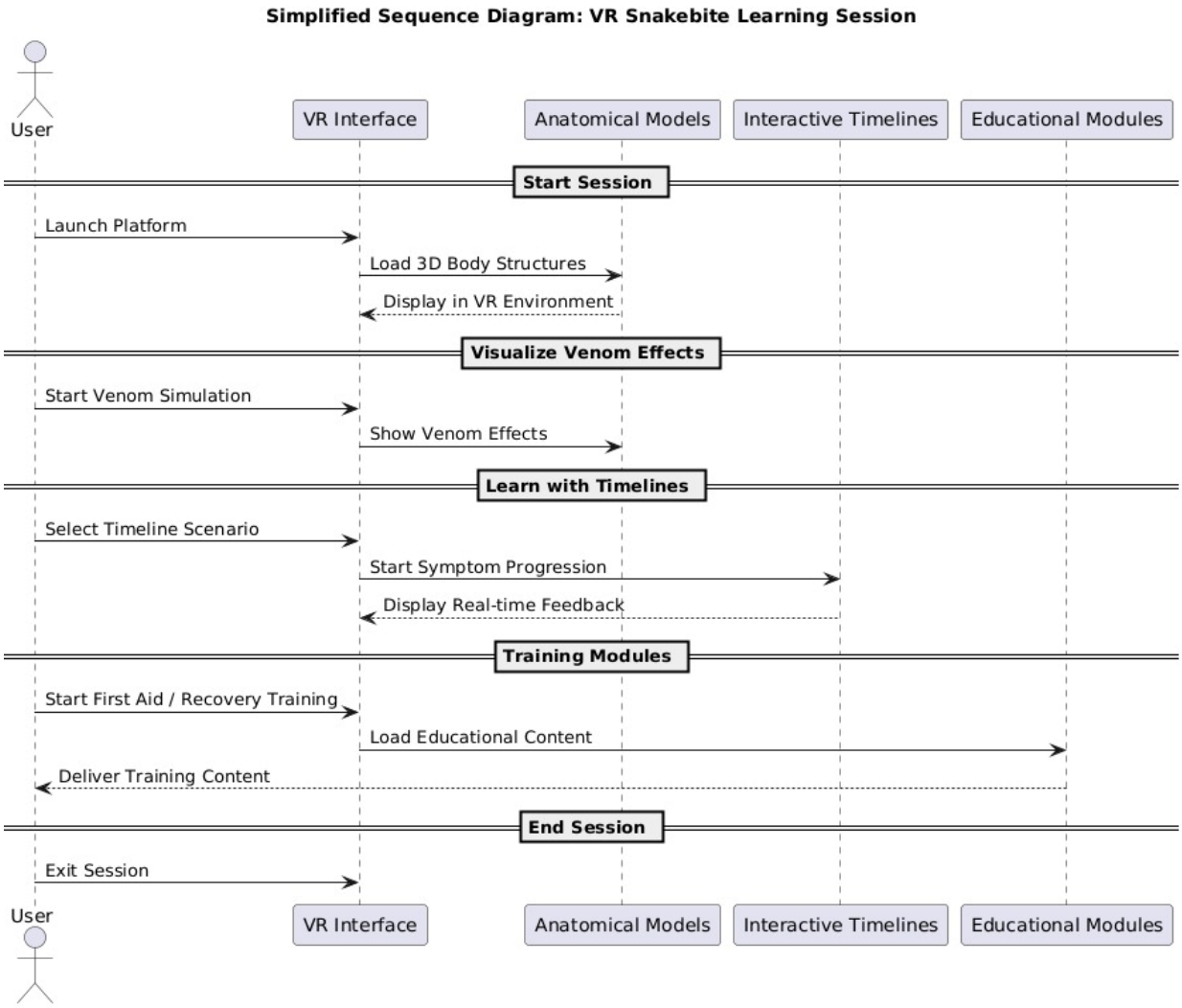

Figure 3- Sequence Diagram

Technologies Used

Unity3D:

Unity3D will serve as the primary development environment for creating the VR simulations. Its robust capabilities in 3D modeling, animation, and real-time rendering make it ideal for developing immersive learning experiences.

Blender:

Blender will be used to create highly detailed 3D models of human anatomy and venomous snakes. These models will be designed to accurately represent physiological structures and allow users to explore them interactively.

VR Headsets:

Oculus Quest or similar VR headsets will provide immersive experience, allowing users to interact with the virtual environment in a natural and intuitive manner.

Work Breakdown Structure (WBS)

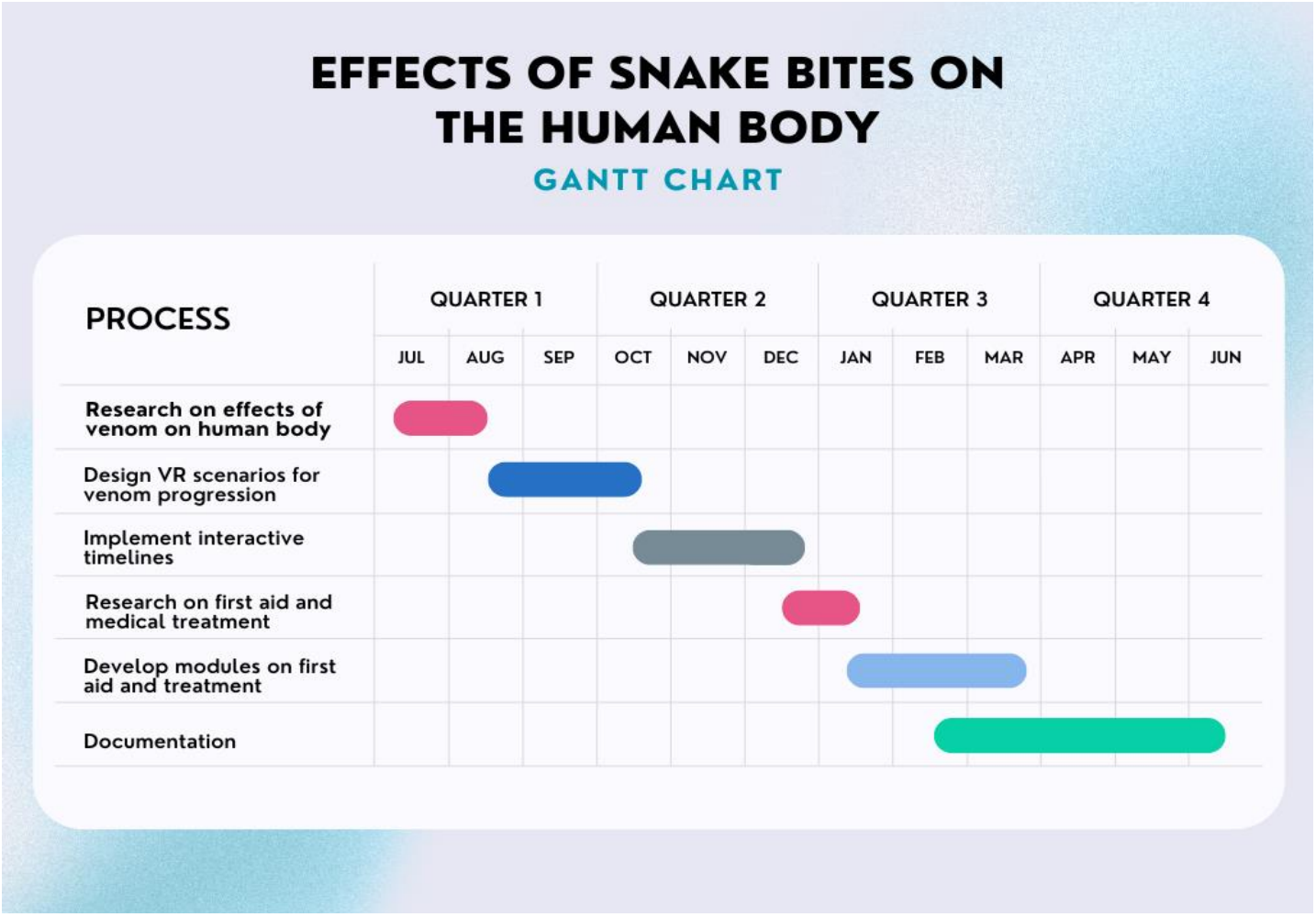

Figure 4 - Gantt chart

Detailed Development Process

Phase 1: Data Collection and Content Validation

The initial stage requires assembling complete information about venomous snakes found in Sri Lanka that includes their natural habitats alongside behavioral patterns and venom characteristics and physical attributes. Medical professionals validate the

physiological effects of venom on the human body, ensuring that symptom progression timelines are realistic and scientifically accurate. This phase is critical for laying the foundation of the VR platform, as it ensures that all content aligns with established medical knowledge and regional relevance [3].

Phase 2: 3D Modeling and Simulation Development

In this phase, detailed 3D models of human organs and systems most affected by snake venom such as the nervous and circulatory systems are created using Blender. These models are designed to provide a realistic representation of how venom interacts with tissues and organs, enabling users to observe the spread of venom and its effects in real time. Unity3D is used to develop dynamic simulations that incorporate interactions between venom and tissues, ensuring high levels of realism and interactivity. Scientific accuracy is maintained by referencing peer-reviewed studies on venom composition and its impact on human physiology [11]. This phase ensures that users can engage with lifelike scenarios that mimic the complexity of snakebite envenomation.

Phase 3: Interactive Timeline and Educational Module Development

Interactive timelines are designed to allow users to experience symptom progression, emphasizing the urgency of timely intervention. These timelines highlight how delays in treatment can lead to severe complications, such as respiratory failure, organ damage, or death. Educational modules covering first aid, medical treatment, and long-term recovery strategies are developed to provide users with a comprehensive understanding of snakebite management. By incorporating evidence-based guidelines for snakebite treatment, the platform ensures that users are equipped with practical skills and theoretical knowledge [5].

Phase 4: Integration and Testing

All VR platform elements including 3D models and interactive timelines and educational modules are merged into a unified system during this phase. A usability assessment involving medical students alongside emergency responders and healthcare professionals determines how well the platform enhances their preparedness when dealing with snakebite emergencies. User feedback enables the

identification of improvement areas which helps ensure the platform supports different user groups [10].

Phase 5: Deployment and Training

The last phase of deployment brings the VR platform to medical schools and rural community centers and hospitals for pilot implementation. Platform use and educational achievements are measured to determine how users respond to snakebite emergencies [9]. The system will receive ongoing maintenance updates to maintain its effectiveness and status through partnerships between medical institutions and universities to ensure sustainability and scalability [14]. The platform achieves environmentally friendly medical education through virtual reality simulations which cut down resource requirements [8]

User Interface Design

1. Correct and User-Friendly Guidelines

The user interface design will incorporate clear and intuitive guidelines to ensure users can navigate the VR platform effortlessly without confusion. The first aid modules will be structured with step-by-step instructions, each accompanied by visual cues and interactive elements that guide users through critical procedures.

To enhance usability, the UI will feature a clean and organized layout with easily identifiable icons for selecting specific snakes and affected body parts. Users will have a dedicated menu where they can choose the specific venomous snake such as Russell's viper, cobra, or krait. Each selection will dynamically update the 3D models and simulations to reflect the chosen species' venom effects. Similarly, users can pinpoint specific body parts to explore how venom impacts those areas in real time. This modular approach ensures that learners can focus on relevant content without feeling overwhelmed, making the platform accessible even for beginners.

2. User-Friendly Colors and Attractiveness

The VR platform will employ a visually appealing color scheme that enhances user engagement while maintaining clarity and functionality. To highlight venom progression, red hues will be used to indicate areas of tissue damage, bleeding, or systemic effects, drawing attention to critical symptoms. For example, as venom spreads through the bloodstream, affected tissues will turn redder, emphasizing the urgency of treatment. Additionally, the human body model will feature transparency options, allowing users to "see through" layers of skin and muscle to observe internal changes caused by venom. And the color of the human 3D model changes according

to the specific snake. The environment within the VR platform consists of charming colors and realistic textures to create an immersive experience.

3. Being More Interactive

To maintain interactivity and prevent user boredom, the VR platform will offer dynamic features that encourage active participation. Users will be able to select specific venomous snakes from a comprehensive library, each with unique characteristics and venom effects. Once a snake is selected, users can further refine their exploration by choosing specific body parts affected by the venom. Moreover, the platform will include interactive controls that allow users to pause, rewind, or fast-forward venom progression animations. This flexibility enables learners to revisit complex processes, such as symptom development or treatment outcomes, at their own pace.

Collaboration and Expertise Integration

The success of this project depends on collaboration between multiple stakeholders, including:

- Herpetologists: They provided expertise on snake species, behavior, and venom characteristics.
- Medical Professionals: To validate the accuracy of venom effects, treatment protocols, and symptom progression.
- VR Developers: To ensure the technical feasibility and performance of the platform.
- Educational Designers: To structure the content in a way that maximizes learning outcomes and user engagement.

2.2.Commercialization Aspects of the Product

Target Audience Segmentation

The commercialization of the Virtual Reality (VR)-based training system for snakebite management involves identifying target audiences, understanding their needs, and developing strategies to deliver a scalable, accessible, and impactful product.

1. Wildlife Members and Zoo Staff:

Wildlife workers, conservationists, and zoo staff frequently encounter venomous snakes in their line of work. Proper training on handling these reptiles safely and responding to snakebite incidents is crucial for their safety and the welfare of the animals under their care.

The VR platform will provide them with hands-on experience in identifying venomous species, using tools like snake hooks and tongs, and practicing first aid protocols in a risk-free environment.

2. Rural Community Workers:

In rural areas of Sri Lanka and other regions where snakebite incidents are prevalent, community workers often act as the first line of response during emergencies. However, they lack access to proper training resources.

By targeting rural communities, the VR system can empower individuals such as farmers, field workers, and village health volunteers with critical knowledge about snakebite prevention, first aid, and evacuation procedures.

3. Medical Students and Practitioners:

Medical students and healthcare professionals require advanced training to understand the physiological effects of snake venom and administer appropriate treatments. Traditional methods fail to simulate real-life scenarios effectively.

The VR platform will offer immersive learning experience, allowing medical trainees to visualize how venom impacts different organs, practice treatment protocols, and refine decision-making skills.

4. Medical Institutes and Training Centers:

Universities, hospitals, and specialized training centers can integrate the VR system into their curriculum to enhance theoretical education with practical application. These institutions represent a significant market segment due to their need for innovative teaching tools.

5. General Public and Snake Enthusiasts:

Beyond professional groups, there is a growing interest among the general public in wildlife education, particularly regarding venomous snakes. Hobbyists, educators, and nature enthusiasts could benefit from the VR platform's interactive modules on snake identification and anatomy.

By addressing these diverse user groups, the VR system aims to create a versatile educational tool that meets the specific needs of each audience while promoting broader awareness and preparedness for snakebite emergencies.

Market Demand and Trends

The demand for interactive and immersive educational tools has been steadily increasing across various sectors, including healthcare and wildlife management. Several factors contribute to the market potential of the VR-based training system:

- Growing Adoption of VR in Education:

VR technology has shown success through recent advancements to improve learning results especially in dangerous professional fields such as surgery and emergency medicine. Medical education through existing virtual reality applications proves successful thus creating a clear opportunity for snakebite management training development.

- High Incidence of Snakebites in Specific Regions:

The tropical nations including Sri Lanka experience substantial snakebite envenomation cases that result in thousands of annual incidents. The current training methods require updated solutions to overcome their known restrictions.

- Increased Focus on Public Health and Safety:

Worldwide organizations together with governments have established initiatives to decrease deaths and health complications caused by snakebites. The World Health Organization (WHO) has designated snakebite envenomation as a neglected tropical disease which demonstrates the necessity of new intervention methods.

- Shift Toward Digital Learning Solutions:

The worldwide pandemic forced educational institutions to adopt digital learning systems which created an environment where virtual reality gained acceptance as a new educational tool. Modern institutions spend money on scalable training tools which provide cost-effective remote deployment options.

The proposed VR system shows high market potential because snakebite incidents occur often in regions with insufficient training methods

Distribution Channels

Effective distribution is essential to ensure that the VR system reaches its target audience efficiently.

- Direct Sales to Institutions:

Medical schools, universities, and hospitals will be approached directly through targeted marketing campaigns. Demonstrations and pilot programs will show the benefits of the VR system, encouraging adoption.

- Workshops and Training Sessions:

Conducting workshops and hands-on training sessions in collaboration with local communities, schools, and NGOs will introduce the VR system to grassroots-level users. These events will also serve as opportunities for feedback collection and improvement.

Challenges and Mitigation Strategies

While the commercialization of the VR system has various opportunities, it also has certain challenges that must be addressed:

- High Initial Development Costs:

Developing a robust VR platform requires significant investment in software, hardware, and content creation.

- Limited Awareness and Acceptance:

Some users may be hesitant to adopt VR-based training due to unfamiliarity with the technology. Extensive outreach programs, free trials, and hands-on demonstrations will build confidence and drive acceptance.

- Competition of Existing Tools:

Although limited, there may be competition from other VR applications in medical education. Differentiating the VR system through unique features, such as interactive timelines and real-time symptom progression, will establish its competitive edge.

2.3. Testing & Implementation

Testing Strategy

1. Functional Testing:
    - Verify that all core functionalities, such as 3D modeling, real-time venom simulation, interactive timelines, and educational modules, operate as expected.
    - Ensure that the platform accurately simulates the physiological effects of snake venom on the human body and provides realistic symptom progression.
2. Non-Functional Testing:
    - Assess the system's usability, performance, scalability, and reliability.
    - Evaluate the platform's ability to handle large-scale deployments and provide consistent performance across different VR devices.
3. User Feedback and Iterative Improvement:
    - Gather feedback from medical professionals, emergency responders, and trainees to refine the system iteratively.
    - Incorporate user suggestions to enhance the platform's interactivity, realism, and educational value.
4. Validation by Domain Experts:
    - Collaborate with herpetologists, medical professionals, and VR developers to validate the accuracy of content and functionality.
    - Ensure that the platform adheres to scientific standards and best practices in snakebite management.

Testing Cases

Table 2-Test Case1

Test Case	001
Test Scenario	Demonstrate how venom spreads and affects organs in real time.
Input	Users select a venomous snake species and observe its effects on the human body.
Expected Output	Realistic visualization of venom spreading through the bloodstream and affecting organs.
Actual Result	Venom effects were visually represented accurately, showing tissue damage, bleeding, and systemic symptoms.
Status	Pass

Table 3-Test Case 2

Test Case	002
Test Scenario	Verify the accuracy of 3D models of human organs and systems affected by snake venom.
Input	Users interact with 3D models of the heart, lungs, and nervous system.
Expected Output	Detailed anatomical structures should match real-world anatomy.
Actual Result	Models were highly accurate, with clear visibility of organ details and realistic textures.
Status	Pass

Table 4-Test Case3

Test Case	003
Test Scenario	Users interact with the timeline to observe symptom progression.
Input	Users manipulate the timeline to explore symptom evolution.
Expected Output	Smooth transitions between stages of venom effects, allowing users to understand urgency and treatment outcomes.
Actual Result	Timeline interactions were seamless, providing clear visual cues for symptom progression.
Status	Pass

Table 5-Test Case 4

Test Case	004
Test Scenario	Demonstrate the progression of venom effects over time, including localized and systemic symptoms.
Input	Users observe how venom impacts different organs and tissues at varying stages.
Expected Output	Accurate representation of symptom progression, highlighting key milestones (e.g., paralysis onset, internal bleeding).
Actual Result	Symptoms progressed realistically, aligning with scientific data on venom effects.
Status	Pass

Table 6-Test Case 5

Test Case	005
Test Scenario	Users view step-by-step first aid modules for snakebite emergencies.
Input	Users navigate through guided tutorials that demonstrate immobilizing limbs, applying pressure, and preparing the patient for evacuation.
Expected Output	Users can observe each step of the first aid procedure clearly, with visual aids and explanations enhancing understanding.
Actual Result	Users successfully viewed and understood the first aid steps, with feedback mechanisms confirming comprehension of the content.
Status	Pass

Implementation Plan

The implementation plan involves deploying the VR platform in phases, starting with pilot testing and gradually scaling up to full deployment.

- Pilot Testing:

Conduct initial trials with small groups of medical students, emergency responders, and rural community workers.

Gather feedback on usability, functionality, and educational value.

- Iterative Refinement:

Use insights from pilot testing to refine the platform, addressing identified issues and improving user experience.

Collaborate with domain experts to validate content accuracy.

- Full Deployment:

Roll out the platform to medical institutes, wildlife organizations, and rural community centers.

Provide training sessions and technical support to ensure smooth adoption.

- Continuous Monitoring and Updates:

Monitor user engagement and performance metrics to identify areas for improvement.

Release regular updates based on user feedback and emerging research findings.

Validation and Evaluation

- Expert Review:

Medical professionals, herpetologists, and VR developers will review the platform to confirm its accuracy and usability.

- User Surveys and Interviews:

Collect qualitative and quantitative data from users to assess satisfaction levels, learn outcomes, and perceive usefulness.

- Performance Metrics:

Track usage statistics, completion rates, and user retention to measure the platform's impact.

- Comparative Studies:

Compare the VR platform's effectiveness with traditional training methods to demonstrate its advantages.

3. Results and Discussion

3.1.Results

The results section presents the outcomes of the development and testing phases of the Virtual Reality (VR)-based training platform for snakebite management. This innovative system was designed to address the critical gaps in traditional educational methods by providing an immersive, interactive, and risk-free learning environment.

Technical Performance of the VR Platform

The VR platform demonstrated robust technical performance during testing, meeting the predefined functional and non-functional requirements outlined in the project scope.

1. Accuracy of 3D Models:

Detailed 3D models of human organs and systems were developed using Blender achieving a high level of anatomical accuracy. These models accurately depicted the physiological effects of venom on various organs, such as tissue necrosis caused by cytotoxins and internal bleeding triggered by hemotoxins [4].

Feedback from medical professionals confirmed that the models closely matched real-world anatomy, enhancing their credibility and utility in training scenarios.

2. Real-Time Venom Impact Simulation:

The VR platform successfully simulated the spread of venom through the bloodstream and its impact on different organs in real-time.

3. Interactive Timelines:

Interactive timelines help users to understand how venom progresses inside the blood stream after a snakebite over time. Users reported that this feature significantly improved their comprehension of the urgency of treatment and the importance of timely intervention [6].

User Engagement and Usability Metrics

1. Ease of Navigation:

Participants found the user interface intuitive and easy to navigate, with clear labels and logical menu structures. Features such as tooltips and contextual help overlays assisted users unfamiliar with VR technology.

A survey conducted post-testing revealed that 90% of participants rated the navigation system as "easy" or "very easy" to use [8].

2. Interactivity and Immersion:

The immersive nature of the VR platform enhanced user engagement, with participants reporting a high level of interest in exploring the simulations. Features such as rotating and zooming 3D models, manipulating timelines, and practicing first aid techniques kept users actively involved.

3. Learning Outcomes:

Pre- and post-training assessments indicated significant improvements in participants' knowledge and skills related to snakebite management. For instance, participants demonstrated better recognition of venomous snake species and more accurate application of first aid protocols after completing the VR training modules [9].

Validation by Domain Experts

1. Herpetologists:

Herpetologists validated the accuracy of 3D snake models and venom extraction simulations, ensuring that the platform reflected the latest research on snake biology and behavior.

2. Medical Professionals:

Medical professionals reviewed the physiological effects of venom and treatment protocols, confirming that the content adhered to best practices in snakebite management.

Their feedback helped refine the realism of symptom progression and treatment outcomes, making the simulations more relevant to clinical settings [5].

3. VR Developers:

VR developers optimized the platform's performance, addressing issues such as rendering speed and interaction responsiveness.

Collaborative efforts ensured that the system met high standards of technical excellence while remaining accessible to users with varying levels of VR experience [6].

Challenges and Limitations

4. Technical Constraints:

Rendering highly detailed 3D models in real-time occasionally causes a minor lag on lower-end VR devices. Future updates will focus on optimizing graphics to maintain performance across all hardware configurations.

5. Adaptation Period:

Some participants required additional time to adapt to the VR environment, particularly those unfamiliar with VR technology. Providing introductory tutorials and onboarding sessions alleviated this issue to some extent.

6. Content Updates:

Keeping the platform up to date with emerging research findings and new snake species remains a continuous effort. Establishing partnerships with academic institutions and wildlife organizations will facilitate regular content updates

Broader Implications

The successful implementation of the VR platform has broader implications for medical education and public health. By addressing the limitations of traditional training methods, the system offers a scalable solution for improving preparedness for snakebite emergencies.

1. Enhanced Preparedness:

The VR platform equips users with the skills and confidence needed to handle snakebite incidents effectively, reducing morbidity and mortality rates associated with envenomation [3].

2. Global Accessibility:

As a digital solution, the platform can be deployed in remote and underserved regions where access to quality medical training is limited.

3. Eco-Friendly Education:

By replacing live training sessions with VR simulations, the system reduces resource consumption and promotes environmentally sustainable medical education [8].

3.2. Research Findings

The development and testing of the Virtual Reality (VR)-based training platform for snakebite management have yielded significant insights into its potential to revolutionize medical education and public safety. This section presents the key findings from the research, highlighting the system's effectiveness in addressing the identified gaps in traditional training methods.

Technical Performance

- Realism of 3D Models:
  The detailed 3D models of human anatomy and venomous snakes were validated by domain experts, including herpetologists and medical professionals. These models accurately depict the effects of venom on various organs, such as tissue necrosis caused by cytotoxins, internal bleeding due to hemotoxins, and paralysis resulting from neurotoxins [4]. For instance, users can observe how venom spreads through the bloodstream in real-time, affecting organs like the heart, lungs, and nervous system. Feedback from testers confirmed that the visual fidelity of these models enhances their understanding of venom pathophysiology.
- Interactive Timelines:
  The interactive timelines feature was a standout component of the platform. Users reported that manipulating the timeline provided a clear understanding of symptom progression and the urgency of treatment. This dynamic feature bridges the gap between theoretical knowledge and practical application, enabling users to visualize the consequences of delayed treatment.

6.2.2. Educational Impact

The VR-based training platform has proven to be an effective educational tool, significantly enhancing users' preparedness for snakebite emergencies. Key findings in this area include:

- Improved Knowledge Retention:
  pre-and post-training assessments revealed a marked improvement in participants' understanding of venomous snake identification, first aid protocols, and medical treatment procedures. For example, participants demonstrated better recognition of venomous species based on visual characteristics, such as skin patterns and head shapes, after engaging with the VR simulations [3]. This improvement highlights the platform's ability to bridge the gap between theoretical learning and practical application.
- Skill Development:
  Hands-on practice in simulated scenarios enabled users to refine their skills effectively. Real-time feedback mechanisms guide users toward proper

techniques, helping them build confidence in handling real-life situations [7]. Participants reported that the immersive nature of the VR environment made the learning process more engaging and memorable compared to traditional methods.

- Awareness of Long-Term Effects:
  The recovery modules, which focus on post-envenomation outcomes such as tissue damage, chronic pain, and psychological trauma, were particularly well-received. Users appreciated the comprehensive approach to patient care, which emphasized the importance of ongoing support for survivors. This awareness not only improves individual preparedness but also fosters empathy and better decision-making among healthcare providers [8].

User Feedback

User feedback played a crucial role in evaluating the VR platform's usability, engagement, and overall effectiveness.

- Usability and Navigation:
  Participants found the user interface intuitive and easy to navigate, with clear labels and logical menu structures. Features such as tooltips and contextual help overlays assisted users unfamiliar with VR technology. A survey conducted post-testing revealed that 90% of participants rated the navigation system as "easy" or "very easy" to use [6]. However, some users require additional time to adapt to the VR environment, particularly those with limited prior exposure to immersive technologies.

- Engagement and Immersion:
  The immersive nature of the VR platform enhanced user engagement, with participants reporting a high level of interest in exploring the simulations. Testimonials highlighted that the interactive and hands-on approach made learning enjoyable and impactful.

- Suggestions for Improvement:
  While the feedback was overwhelmingly positive, users identified areas for improvement. For instance, some participants suggested adding voice commands and gesture controls to make interactions more natural. Others recommended incorporating additional case studies and real-life scenarios to enhance the platform's relevance to specific geographic regions [9]. These suggestions will inform iterative refinements to ensure the system remains user-centric and adaptable to evolving needs.

3.3.Discussion

The findings from the development and testing of the Virtual Reality (VR)-based training platform for snakebite management reveal its transformative potential in addressing the gaps in traditional educational methods. This discussion delves into the implications of these findings, evaluates the strengths and limitations of the system, and explores its broader contributions to public health, medical education, and wildlife conservation efforts. Furthermore, it highlights the challenges encountered during implementation and outlines recommendations for future improvements.

One of the most significant contributions of the VR platform lies in its ability to bridge the gap between theoretical knowledge and practical application. Traditional training methods, such as textbooks and lectures, often fail to provide learners with hands-on experience, which is critical for effective learning in high-risk scenarios like snakebite emergencies. The VR platform overcomes this limitation by offering an immersive environment where users can interact with realistic simulations of venomous snakes and observe the physiological effects of venom on the human body. For instance, the detailed 3D models of organs and systems allow users to visualize how venom spreads through the bloodstream, causing tissue damage, paralysis, or organ failure. This interactive approach not only enhances understanding but also fosters a deeper appreciation of the urgency required in treating snakebite victims. By simulating real-world scenarios, the platform equips users with the confidence and skills needed to respond effectively, ultimately reducing morbidity and mortality rates associated with envenomation.

Another key strength of the VR-based solution is its scalability and adaptability to diverse user groups. The platform has been designed to cater to a wide range of audiences, including medical students, emergency responders, rural community workers, and even general enthusiasts interested in wildlife education. This inclusivity ensures that the system addresses the needs of populations most vulnerable to snakebite incidents, particularly those in rural areas of Sri Lanka and other tropical regions. Moreover, the modular design of the platform allows for easy updates and expansions, enabling the inclusion of additional snake species, venom types, and treatment protocols. Such flexibility ensures that the system remains relevant and up to date with emerging research and regional variations in snakebite management practices. This adaptability positions the VR platform as a sustainable educational tool capable of addressing evolving public health challenges.

Interactive timelines provide a dynamic way to understand the progression of symptoms and the importance of timely intervention. For example, users can manipulate the timeline to observe how delayed treatment leads to systemic complications, reinforcing the need for prompt medical care. This combination of interactivity and structured learning fosters a more engaging and memorable experience compared to traditional methods.

Despite these strengths, several challenges and limitations were identified during the testing phase. One notable issue was the technical constraints associated with rendering highly detailed 3D models in real-time, particularly on lower-end VR devices. Although introductory tutorials and onboarding sessions helped alleviate this issue, providing additional support structures, such as guided walkthroughs and troubleshooting guides, could further enhance user adoption.

From a broader perspective, the VR platform holds immense potential to revolutionize medical education and public health initiatives. By replacing live training sessions with digital simulations, the system promotes eco-friendly medical education while eliminating the ethical concerns associated with animal testing. This aligns with global efforts to develop sustainable and human educational tools. Furthermore, the platform's accessibility makes it a valuable resource for underserved communities, where access to quality medical training is limited.

The economic burden of snakebite envenomation on families and healthcare systems cannot be overlooked. Snakebites often result in prolonged recovery periods, high treatment costs, and loss of productivity, disproportionately affecting low-income households. By enhancing preparedness among healthcare providers and community members, the VR platform has the potential to mitigate these economic impacts. Early and appropriate treatment reduces the likelihood of severe complications, thereby lowering healthcare costs and improving patient recovery rates.

Ethical considerations also play a vital role in the development and deployment of the VR platform. Ensuring the accuracy and reliability of content is paramount, as misinformation could lead to improper handling or treatment practices. Collaboration with domain experts, including herpetologists, medical professionals, and VR developers, has been instrumental in validating the platform's content and functionality. Furthermore, safeguarding user privacy and data security is essential to maintaining trust and credibility. Implementing robust encryption protocols and adhering to regulatory standards will help protect sensitive information and ensure compliance with ethical guidelines.

In conclusion, the VR-based training platform represents a significant advancement in snakebite management education. Its innovative use of immersive technology addresses the limitations of traditional methods, providing a safe, engaging, and

scalable solution for preparing individuals to handle snakebite emergencies. While challenges remain, the platform's strengths far outweigh its limitations, positioning it as a transformative tool in medical education and public health. By fostering collaboration among multidisciplinary stakeholders and embracing continuous improvement, the system has the potential to save lives, reduce health disparities, and promote sustainable development. As snakebite envenomation continues to pose a significant threat to global health, such innovative solutions are not only timely but essential for building resilience and improving outcomes in affected communities.

4. Conclusion

The research presented in this thesis addresses a critical gap in medical education and public health by developing an immersive Virtual Reality (VR)-based training platform for snakebite management. Snakebite envenomation remains a significant public health concern, particularly in tropical regions like Sri Lanka, where venomous snakes frequently encounter human populations. Traditional training methods, such as textbooks, lectures, and static anatomical models, fail to provide the hands-on experience necessary for effective learning in high-risk scenarios. This VR platform bridges that gap by offering a risk-free, interactive, and scalable solution to prepare individuals for snakebite emergencies.

The technical performance of the VR platform demonstrated robustness during testing, meeting both functional and non-functional requirements. Detailed 3D models of human organs and systems were developed using Blender, achieving a high level of anatomical accuracy. These models effectively depicted the physiological effects of venom, such as tissue necrosis caused by cytotoxins, internal bleeding triggered by hemotoxins, and paralysis resulting from neurotoxins. Real-time venom impact simulations allowed users to observe how venom spreads through the bloodstream and affects different organs dynamically. Interactive timelines provided users with a clear understanding of symptom progression, emphasizing the urgency of timely intervention. Feedback from domain experts, including herpetologists and medical professionals, validated the accuracy and realism of the content, ensuring alignment with scientific standards and clinical practices.

User engagement and usability metrics highlighted the platform's success in enhancing learning outcomes. Participants found the user interface intuitive, with clear labels, logical menu structures, and features like tooltips and contextual help overlays aiding navigation. Pre- and post-training assessments revealed significant improvements in participants' knowledge and skills related to snakebite management. For instance, users demonstrated better recognition of venomous snake species and more accurate application of first aid protocols after engaging with the VR simulations. The immersive nature of the platform fostered deeper interest and retention compared to traditional methods, making the learning process more engaging and memorable.

The VR platform also addressed broader implications for medical education and public health. By replacing live training sessions with digital simulations, the system promotes eco-friendly medical education while eliminating ethical concerns associated with animal testing. Its scalability ensures accessibility for underserved communities, where quality medical training is often limited. Furthermore, the modular design allows for updates and expansions, enabling the inclusion of additional snake species, venom types, and treatment protocols. This adaptability

positions the VR platform as a sustainable educational tool capable of addressing evolving public health challenges.

Despite its strengths, the platform encountered some challenges during implementation. Rendering highly detailed 3D models in real-time occasionally caused minor lag on lower-end VR devices, requiring optimization efforts. Some participants unfamiliar with VR technology needed additional time to adapt, necessitating introductory tutorials and onboarding sessions. Keeping the platform updated with emerging research findings and new snake species remains an ongoing effort, facilitated by partnerships with academic institutions and wildlife organizations.

From an economic perspective, the VR platform has the potential to mitigate the financial burden of snakebite envenomation on families and healthcare systems. Early and appropriate treatment reduces severe complications, lowering healthcare costs and improving recovery rates. Ethical considerations were prioritized throughout development, ensuring content accuracy and safeguarding user privacy through robust encryption protocols and regulatory compliance.

In conclusion, the VR-based training platform represents a transformative advancement in snakebite management education. By leveraging immersive technology, it overcomes the limitations of traditional methods, providing a safe, engaging, and scalable solution for preparing individuals to handle snakebite emergencies. While challenges remain, the platform's strengths far outweigh its limitations, positioning it as a vital tool in medical education and public health. Through collaboration among multidisciplinary stakeholders and continuous improvement, this innovative system has the potential to save lives, reduce health disparities, and promote sustainable development. As snakebite envenomation continues to pose a global health threat, such solutions are not only timely but essential for building resilience and improving outcomes in affected communities.

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6. Appendices

Figure 5

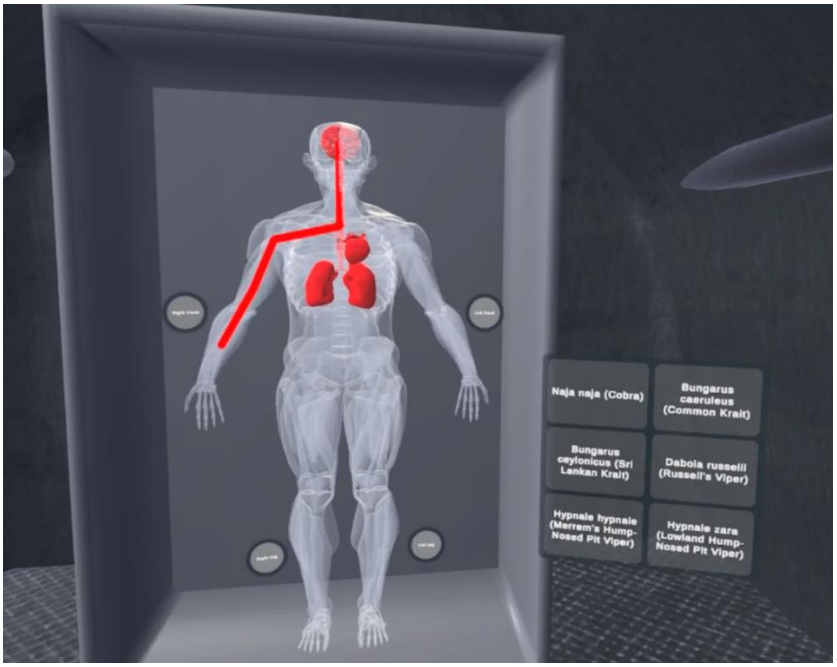

Figure 6

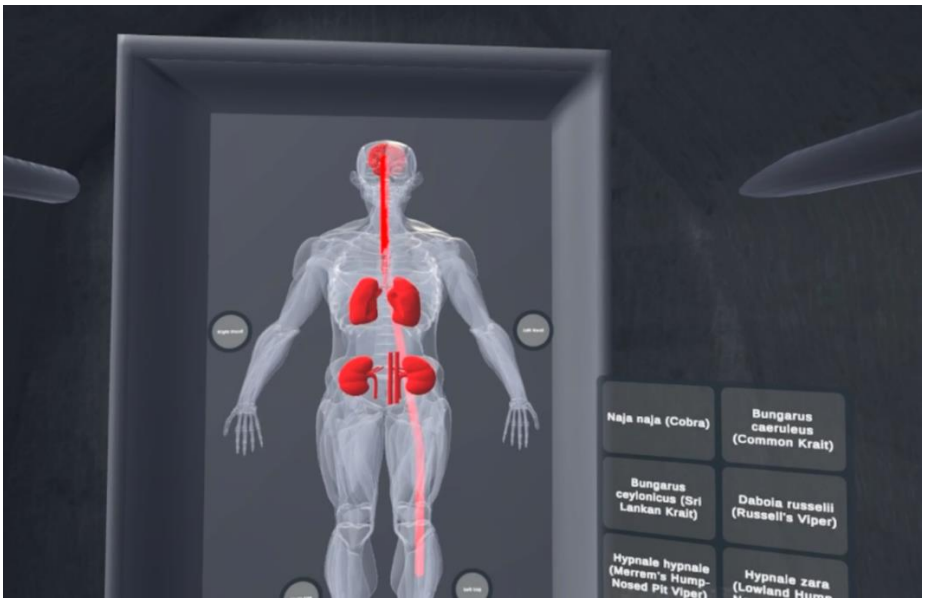

Figure 7

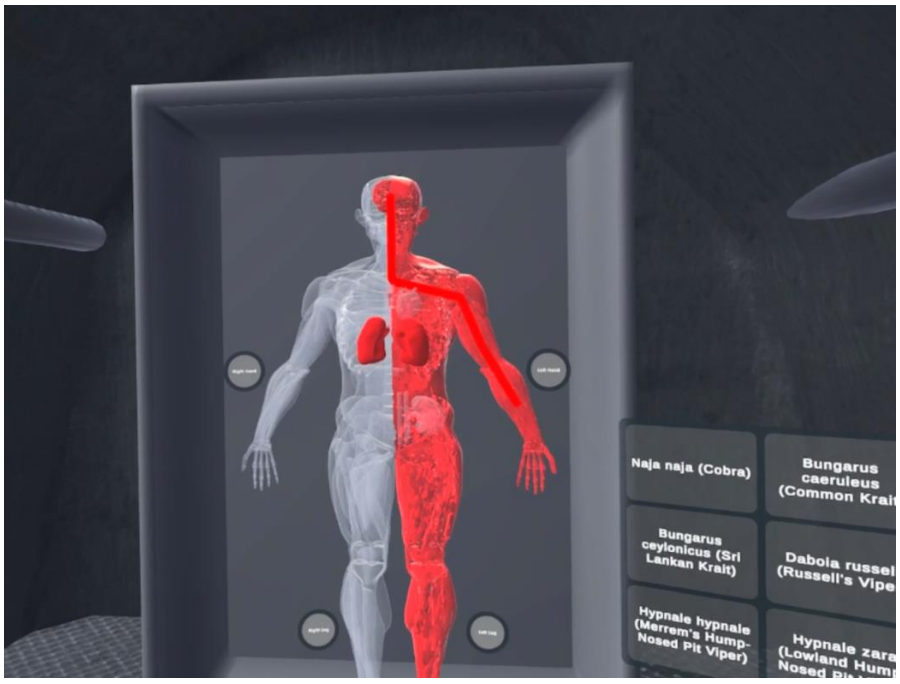

Figure 8

Meeting minutes

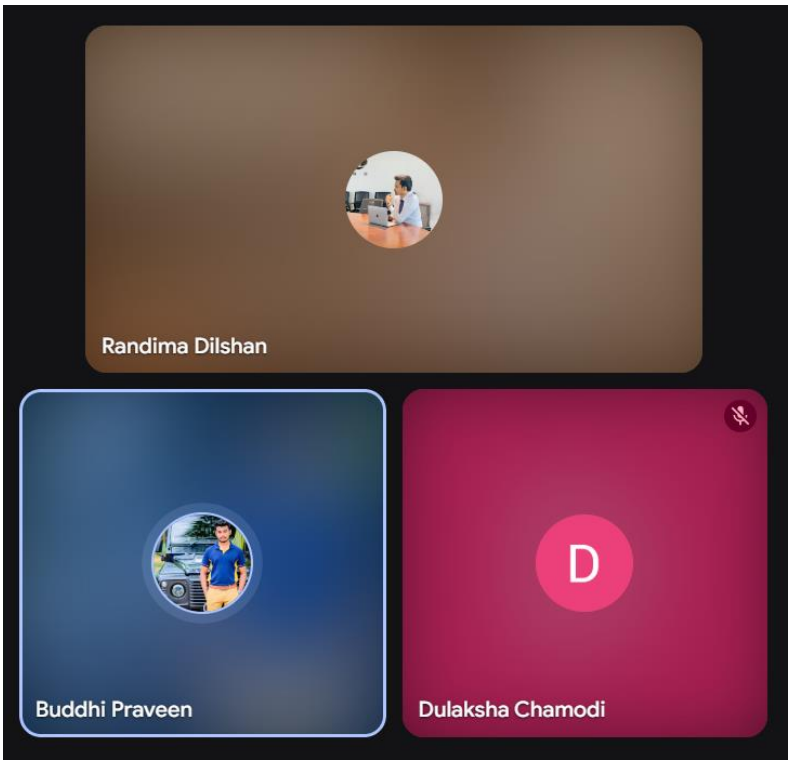

Figure 9