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VIRTUAL REALITY AS A NEW TECHNOLOGY FOR DIABETES TREATMENT IN LIBYA: "DEVELOPING DIABETES MANAGEMENT SKILLS FOR HEALTHCARE WORKERS AT THE ADJDABIYA DIABETES TREATMENT CENTER"

Ali Mohamed Hamd YOUNES

Master's Thesis

Supervisor

Assoc. Prof. Dr. Sefer KURNAZ

İstanbul, 2025

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I hereby declare that this thesis meets all format and submission requirements for Master's thesis.

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Ali Mohamed Hamd YOUNES

Signature

DEDICATION

To my esteemed supervisor, Assoc. Prof. Dr. Sefer KURNAZ, your direction, support, and unrelenting devotion have been the foundation of this effort. I dedicate this thesis to you in great appreciation of your guidance and assistance.

To my lovely parents. For your unending love, sacrifices, and trust in me even when I questioned myself this accomplishment is both yours and mine.

To my beloved wife, your patience, strength, and consistent support helped me get through every hurdle. I dedicate this to you with all of my love.

ABSTRACT

VIRTUAL REALITY AS A NEW TECHNOLOGY FOR DIABETES TREATMENT IN LIBYA: "DEVELOPING DIABETES MANAGEMENT SKILLS FOR HEALTHCARE WORKERS AT THE ADJDABIYA DIABETES TREATMENT CENTER"

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Diabetes mellitus continues to pose a significant public health challenge, especially in resource-constrained environments like Libya, where traditional educational methodologies inadequately prepare healthcare professionals with both practical and compassionate competencies. This research examines the efficacy of a non-immersive VR training instrument, designed using Design Science Research Methodology, aimed at enhancing diabetes management in Ajdabiya, Libya. The instrument incorporated clinical scenarios encompassing acute hyperglycaemia, crises, and education related to gestational diabetes. 20 healthcare professionals participated in a mixed-methods evaluation. Results showed significant improvements in empathy (Jefferson Scale: $M = 105.30$ to 112.70, $p < 0.001$) and clinical performance ($M = 65.40$ to 82.10, $p < 0.001$). The system also received high usability ratings (SUS: $M = 81.50/100$). Findings challenge the assumption that immersive VR is essential, demonstrating that non-immersive VR can enhance decision-making and empathetic communication.

Keywords: Non-Immersive Virtual Reality, Clinical Decision-Making, Low-Resource Settings, Design Science Research Methodology, Diabetes Education, Empathetic Communication.

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ABBREVIATIONS

AI	:	Artificial Intelligence
DSRM	:	Design Science Research Methodology
IDF	:	International Diabetes Federation
JSE	:	Jefferson Scale of Empathy
SUS	:	System Usability Scale
VR	:	Virtual Reality

1. INTRODUCTION

CONTEXT AND MOTIVATION

Diabetes mellitus continues to pose significant global health concern, impacting over 537 million individuals globally in 2021, with forecasts predicting an increase to 643 million by 2030 and 783 million by 2045 [1]. The financial impact of diabetes is concerning, with worldwide healthcare costs associated with the condition totalling $966 billion in 2021, marking a 316% rise over the last 15 years. Notwithstanding progress in pharmaceutical therapies and continuous glucose monitoring technology, healthcare practitioners continue to encounter significant obstacles in providing successful diabetes management. Critical concerns encompass patient non-compliance with treatment protocols, inadequate provider education in intricate diabetes management strategies, and a rising incidence of diabetes-associated complications, including neuropathy, retinopathy, and cardiovascular ailments [2].

Conventional training approaches for healthcare professionals, including lectures and standardised patient interactions, have shown inadequacies in equipping doctors for practical diabetes treatment. Research has shown the disparity between theoretical understanding and actual implementation, since several healthcare providers have insufficient confidence in addressing acute diabetic complications and providing patient education [3]. The deficiency of practical learning opportunities negatively affects patient outcomes, leading to unnecessary hospitalisations and suboptimal glycaemic control costs.

Virtual reality has developed into a effective method for medical education, requiring immersive, interactive, and risk-free learning settings that connect hypothetical knowledge with realistic application. VR training has shown significant effectiveness in enhancing decision-making competencies, refining procedural abilities, and fostering empathetic relationships with patients [4]. VR has been successfully employed in realms such as surgical education, emergency medical training, and the management of chronic infections [5]. However, research examining the practical integration of VR-based instructional methods in diabetes care remains scarce, particularly within real-world clinical settings and among a diverse array of healthcare professionals.

A thorough review conducted by [6]. indicated that while VR interventions significantly enhance diabetes awareness and self-management practices among patients, studies focusing on healthcare provider training are limited and often lack methodological rigor.

This study objectives to address this critical void by systematically assessing VR-based training programs tailored for healthcare professionals involved in diabetes management. Through the incorporation of immersive simulations into clinical training, this initiative aims to enhance both technical and interpersonal experiences essential for effective diabetes care. The findings are expected to yield profound understanding regarding the viability, effectiveness, and strategies for employing VR-based training initiatives, subsequently improving medical education and augmenting patient outcomes in the management of diabetes.

PROBLEM STATEMENT

Despite significant developments in the management of diabetes, healthcare professionals continue to face difficulties in receiving adequate training pertinent to practical scenarios, particularly in the context of acute diabetic emergencies and the provision of long-term patient education. Conventional training methods, such as reliance on textbooks and lecture-based instruction, often fail to adequately prepare clinicians for the complexities related with diabetes management. This insufficiency can lead to notable gaps in practical decision-making abilities and effective patient communication [7].

For example, consider a newly advanced nurse who is working in the endocrinology department of a hospital. During a night shift, she comes across a patient who is experiencing acute hypoglycaemia. Due to a lack of practical experience in emergency diabetes involvement, she hesitates to introduce the necessary treatment and feels required to seek guidance from more senior colleagues. This delay in clinical decision-making may have dire consequences for the patient’s health. Such real-life scenarios highlight the pressing need for training methodologies that combine practical, interactive, and experiential learning opportunities.

Available evidence suggests that VR suggests a transformative approach to mitigating educational inequities. High-fidelity VR simulations allow healthcare practitioners to practice critical scenarios within a safe environment, thereby improving their technical capabilities and communication skills focused on patient care [8]. However, there exists a dearth of thorough research investigating the implications of VR-based involvements on actual clinical performance within diabetes management [9].

This study aims to assess the use of VR-based training programmes for diabetes care providers. The inventiveness aspires to enhance diabetes education by exploring potential enhancements in clinical decision-making, patient interactions, and overall provider confidence, thus addressing an insistent need and developing the adoption of innovative training technologies in the healthcare sector.

RESEARCH QUESTIONS

This segment articulates the fundamental research inquiry that governs this investigation, accompanied by comprehensive sub-questions that examine diverse dimensions of the research focus. The primary research inquiry is:

To what extent can Non-Immersive Virtual Reality training interventions improve clinical decision-making accuracy and empathetic communication among healthcare providers in diabetes care?

This core issue is extensively addressed by the following sub-questions:

a. How does VR-based simulation affect the time and accuracy of clinical decisions in acute diabetes scenarios compared to traditional training methods?

b. What are the perceived feasibility and acceptability of integrating VR modules into existing diabetes education programmers?

c. To what degree do VR interventions enhance user engagement and empathetic understanding during diabetes care simulations?

These enquiries collectively create a framework to evaluate the transformational potential of VR in solving existing educational gaps in diabetes care, thereby enabling the assessment of its impact on clinical effectiveness and patient outcomes. The present investigation underscores the imperative for innovative instructional methodologies to enhance the provision of healthcare in this context.

RESEARCH OBJECTIVES

This segment articulates the precise objectives of the research, focusing on the potential of virtual reality (VR) to enhance the education of diabetes management. The principal aim is to evaluate the degree to which immersive VR interventions augment measurable clinical and emotional competencies among healthcare practitioners. The objectives are structured as follows:

a. To evaluate the influence of virtual reality (VR)-oriented simulations on the accuracy of clinical decision-making (e.g., compliance with protocols) and operational efficiency (e.g., response time) in both acute and routine diabetes management contexts, employing scenario-specific evaluation checklists and comparative performance assessments before and after intervention [10].

b. To examine the practicality (e.g., financial implications, technological obstacles) and acceptability (e.g., user satisfaction levels) of incorporating VR components into current diabetes education frameworks, assessed via Likert-scale questionnaires and rates of institutional adoption [11].

c. To assess the effect of VR-based interventions on empathetic ability (e.g., the ability to adopt the patient's view) and user engagement (e.g., frequency of interaction), utilizing certified empathy assessment tools (Jefferson Scale) and system of measurement for engagement [12].

To uncover difficulties (e.g., logistical difficulties) and facilitators (e.g., institutional backing) for the adoption of VR in clinical education, analyzed through thematic assessments and comparative cost-efficiency analyses [13].

PURPOSE OF THE STUDY

This study is targeted at the integration of non-immersive VR applications into diabetes management training to enhance clinicians' practical skills and empathetic engagement. The study acknowledges that traditional pedagogical approaches often fail to provide the necessary hands-on, experiential learning required for effective diabetes care, leading to adverse implications for patient outcomes and the overall quality of healthcare [14]. This initiative aims to evaluate the potential of non-immersive VR as a novel educational method, offering evidence-based viewpoints to refine future clinical training methodologies and technological advancements in this domain. The research adopts an exploratory framework to investigate the feasibility, effectiveness, and user experience of non-immersive VR involvements within practical diabetes care settings, thus addressing critical shortcomings in current training paradigms and promoting for a transformative approach in medical education [15].

SCOPE OF THE STUDY

The only focus of this study is on non-immersive virtual reality applications in the context of diabetes treatment, emphasising how effective they are in improving healthcare professionals' educational results. Important topics, including interface design, usability, and how well non-immersive VR technologies replicate clinical situations relevant to diabetes treatment, are examined in this study. To highlight more widely available and financially feasible solutions that can be easily incorporated into current training paradigms, the investigation purposefully leaves out completely immersive VR technology. The set sample size, the research cohort's geographic distribution, and the technological limitations of non-immersive technologies are some of the limitations that restrict the study's wider application.

SIGNIFICANCE AND POTENTIAL CONTRIBUTION

This study is significant because it focusses on non-immersive virtual reality (VR) applications as a pioneering tool for improving diabetes management, a key topic in healthcare where standard training approaches frequently fail. This research focusses on non-immersive VR and addresses a significant gap in scholarly literature, as prior investigations have predominantly concentrated on fully immersive systems, thereby overlooking the opportunities presented by less resource-demanding and more accessible alternatives. This dissertation enhances the current information by elucidating the successful integration of non-immersive VR into diabetes care training to improve clinical decision-making, cultivate compassionate patient encounters, and elevate the overall provision of healthcare services. The results of this study are expected to provide practical insights for healthcare professionals, educators, and policymakers regarding the advantages of integrating non-immersive VR into training programs, potentially resulting in more efficient and cost-effective strategies for continuous professional development.

The research highlights the need of utilising new technology to enhance diabetes treatment, leading to better patient outcomes and a more robust healthcare system.

2. LITERATURE REVIEW

OVERVIEW OF THE CHAPTER

This chapter seeks to present an in-depth and critical analysis of the existing academic literature concerning the use of virtual reality (VR) technologies in diabetes management, with a particular emphasis on non-immersive VR applications. The primary objective of this review is to establish a robust theoretical and empirical foundation for the core research question of this thesis: investigating the potential of non-immersive VR as an innovative educational tool for individuals diagnosed with Type 1 diabetes within a treatment centre situated in Ajdabiya, Libya [16].

In light of the prospective constraints on resources and the unique difficulties associated with diabetes management in such settings, this literature review will emphasize the urgent necessity for innovative and efficacious strategies in diabetes education. Furthermore, it will establish non-immersive virtual reality as an effective remedy for these challenges, offering innovative prospects for enhancing patient understanding and engagement in their own healthcare. By studying the convergence of technology and diabetes education, this chapter look for to elucidate the transformative capacity of non-immersive VR in promoting enhanced health outcomes for individuals analyzed with Type 1 diabetes.

DIABETES

Definition

Diabetes Mellitus (DM), frequently called diabetes, is a group of metabolic illnesses characterised mostly by hyperglycaemia, or increased glucose levels in the bloodstream. This metabolic disorder arises when the organism is unable to properly use or store glucose for energy generation. This disorder's aetiology might be due to insulin secretion deficits, insulin action impairments, or a combination of the two [17].

Insulin, a necessary hormone synthesized by the pancreas, is crucial for the regulation of blood glucose concentrations within a normative range. It enables the immersion of glucose into the cellular assemblies of the body, where it serves as an energy substrate. However, when the pancreas is insufficient in insulin production or when the cells of the body exhibit resistance to the effects of insulin, glucose starts to accumulate in the circulatory system, principal to hyperglycemia [18].

Should hyperglycaemia continue untreated over an extended period, it may lead to significant long-term repercussions that impact several major organs within the human body. Persistent blood glucose levels can cause damage, malfunction, and, eventually, failure of key systems such as ophthalmic, renal, neurological, cardiovascular, and vascular components. As a result, precise blood glucose management becomes critical to avoiding or alleviating these major health problems [19].

Diabetes management strategies typically include lifestyle changes such as eating a nutritionally balanced diet and exercising regularly, as well as close monitoring of blood glucose levels and, when necessary, the administration of insulin or other pharmacological interventions. Individuals with diabetes who prioritise these treatment measures can significantly reduce their risk of developing complications and maintain a higher quality of life.

Types of Diabetes

Diabetes mellitus is a complicated disorder that is divided into various categories, each with its own set of underlying causes and features. The basic categories are Type 1 diabetes, Type 2 diabetes, and gestational diabetes, as well as various more particular kinds that have been found. This thesis study is mostly on Type 1 diabetes, a syndrome characterised by the autoimmune loss of insulin-producing beta cells in the pancreas [20].

This autoimmune response outcomes in a completed deficiency of insulin, necessitating that individuals with Type 1 diabetes depend on external sources of insulin for their survival.

Type 1 diabetes, previously known as insulin-dependent diabetes or juvenile-onset diabetes, is more typically diagnosed in children and young people. However, it is vital to recognise that this illness can occur at any age. In contrast, type 2 diabetes, the most common kind of diabetes, is distinguished by insulin resistance. In this situation, the body's cells do not react appropriately to insulin, which is typically accompanied by insufficient insulin production. In this scenario, body cells show diminished sensitivity to insulin, which is typically accompanied by a relative lack of insulin production [21].

Furthermore, gestational diabetes mellitus is a unique condition that appears during pregnancy when hyperglycaemia is first recognised. Understanding the specific biology of Type 1 diabetes is critical, particularly given the need for insulin and the complications involved with its care. Understanding this is critical for developing effective educational programmes that are precisely tailored to meet the unique demands of this target demographic. By focusing on the intricacies of Type 1 diabetes, we may strengthen support networks and improve health outcomes for those living with this chronic illness [22].

The Related Risk Factors, Prevalence, and Treatment Challenges Related to Diabetes, Particularly Within Resource-Limited Settings

The global prevalence of diabetes has reached alarming levels, and estimates indicate that it will continue to rise in coming decades. In 2021, an estimated 537 million adults aged 20 to 79 years had diabetes, representing approximately 10.5% of the world's adult population, a number that is expected to rise to 643 million by 2030 and 783 million by 2045 [23].

The highest rates are in the Middle East and North Africa (MENA) region: 73 million adults (16.2%) were affected in 2021; this number is expected to increase by 86% to approximately 135.7 million by 2045 [24].

Libya is the country most affected by diabetes in the Middle East and North Africa. The Israeli military estimated that in 2021, approximately 399,200 Libyan adults aged 20 to 79 years had diabetes [25]. A recent cross-sectional study in Al-Bayda found a 47.0% prevalence of prediabetes among adults aged 18 to 45 years, suggesting that cases of full-blown diabetes will increase further [26].

The diabetes epidemic is caused by a number of risk factors, such as ageing, obesity, physical inactivity, genetic susceptibility, and poor food. Over 90% of diabetes diagnoses worldwide are type 2, mostly as a result of ageing populations, urbanisation, a decline in physical activity, and an increase in overweight and obesity rates [27].

Similar trends may be seen in the Libyan population, where an epidemiological survey found that 69% of people are overweight or obese and that only 18% routinely exercise. This suggests that obesity and physical inactivity are linked [28].

Central obesity, physical inactivity, and family history are the primary predictors of type 2 diabetes, according to new risk calculation research conducted in Tripoli [29].

The management of diabetes, especially type 1 diabetes, presents numerous challenges in resource-poor settings such as Libya. Access to comprehensive health services and specialized diabetes care remains inconsistent, particularly in rural and hard-to-reach areas, where mobile clinics are often the only means of delivering care [30]. Insulin availability is poor in low- and middle-income countries, and treatment costs can be prohibitive for out-of-pocket patients. Cultural dietary practices and low public awareness further complicate timely diagnosis and sustained adherence to treatment plans [31].

Table 2.1: Prevalence of Diabetes in Libya.

Year of Data Collection	Prevalence Rate (%)	Population Group	Geographic Area	Key Findings/Notes
2021	8.7	Adults (20-79 y)	Libya	399,200 people with diabetes
2021	8.7	Adults (20-79 y)	Libya	Age-adjusted comparative prevalence
2017	11.2	Adults	Libya	
2000	3.8	Known diabetic patients (over 20 y)	Libya	Estimated actual prevalence likely higher due to undiagnosed cases
2021	8.7	Population ages 20-79	Libya	
2017	10.43	Population aged 20-79	Libya	
2019	9.7	Adults (20-79 years)	Libya	According to the International Diabetes Federation (IDF)
2001	14.1	General population	Benghazi (Libya)	
2020	8.3	Diabetic patients	Benghazi (Libya)	Mean HbA1c level
2021	10.8	Adults (20-79 years)	Libya	
2013	9.2	Adults	MENA Region (Libya)	Estimated prevalence in the MENA Region, including Libya
2014	13.4	Adults	Eastern	Prevalence in the Eastern

			Mediterranean Region (Libya)	Mediterranean Region, including Libya

TREATMENTS

Insulin therapy is essential for the treatment of type 1 diabetes because the body cannot produce enough insulin on its own [32].

This means that patients must receive insulin from an external source, usually through multiple daily injections or the use of an insulin pump [33]. The regulation of blood glucose concentrations is essential for the efficacy of insulin treatment; furthermore, insulin doses [34] should be adjusted based on multiple factors, including dietary intake, physical activity, and any comorbidities [35]. Treatment of type 1 diabetes requires lifestyle modifications in addition to insulin [36]. This includes a balanced diet that helps stabilize blood sugar levels [37]. Regular exercise can promote insulin sensitivity and overall health [38]. Successfully managing type 1 diabetes requires a thorough understanding of these treatments as well as strong self-management skills [39].

Patients need to learn how to take their insulin correctly, monitor their blood sugar levels, change their doses as needed, eat a balanced diet, and engage in regular exercise [40].

The complex nature of this therapeutic regimen underscores the essential need for individuals diagnosed with Type 1 diabetes to receive continuous, comprehensive diabetes education [41].

WAY OF LEARNING

Diabetes education is often released through individualized consultations with healthcare practitioners, group educational sessions, written materials, and formal presentations [42]. Although these techniques provide a framework for sharing information with patients and healthcare professionals, they usually have major drawbacks. For example, motivating patients can be difficult; passive educational strategies frequently fail to engage patients, especially those who are overwhelmed by the complicated demands of diabetes control. Furthermore, contacting large populations or those living in distant areas with little access to healthcare might be difficult. Another concern is that the retention of information through these conventional educational strategies is not consistently optimal, and tailoring educational content to the unique needs and learning preferences of individual patients can be problematic [43].

To overcome some of these drawbacks, non-immersive virtual reality (VR) emerges as a viable substitute for diabetes education [6][8]. Non-immersive virtual reality (VR) can increase patient motivation and engagement in their own education by offering interactive learning experiences on computer displays or projectors [30]. A more experiential learning style is promoted by the use of virtual situations and simulations, which might improve knowledge retention [41]. Furthermore, these VR systems can be made to scale, which makes it simpler to reach a wider audience with instructional content. Additionally, they may be tailored to each patient's unique requirements and development. It's worthwhile to investigate this cutting-edge strategy in the field of diabetes education given non-immersive VR's ability to address some of the drawbacks of conventional approaches [1].

VIRTUAL REALITY (VR)

Definition

Virtual reality (VR) is redefining medical education and patient training by creating computer-generated environments with which users can interact realistically [49]. It is an advanced human-computer interface that allows users to fully immerse themselves in a natural digital environment [10]. The most important features of a VR experience include a well-designed virtual world, opportunities for user interaction, and a sense of real presence-users feel like they are really in the virtual space rather than in the physical world [31]. Moreover, VR systems frequently deliver sensory feedback, such as tactile or auditory cues, to enhance the fully immersive experience [42].

TYPES

Virtual reality technologies can be classified into three primary categories based on the extent of immersion they provide: immersive, semi-immersive, and non-immersive systems [1][4]. Immersive virtual reality (VR) employs head-mounted displays (HMDs) and periodically auxiliary devices such as motion sensors and data gloves to fully immerse the user in a virtual environment [10]. Semi-immersive virtual reality (VR) utilizes large-format displays or projection systems to render a three-dimensional experience while still permitting some interaction with the real world [35]. Conversely, non-immersive virtual reality enables users to interact through standard input devices like a keyboard, mouse, or touchscreen and employs standard displays or projectors [11].

Development, Theoretical Frameworks, and Challenges of VR in Healthcare

Since the early 1990s, virtual reality (VR) has developed from a specific tool for surgical planning simulations into a multipurpose platform applicable in areas such as pain management, mental health interventions, rehabilitation, and medical education [35][43].

The effectiveness of virtual reality in healthcare can be examined and understood through the framework of constructivist theory, which posits that learners actively construct knowledge through interaction with their environments [37], and experiential learning theory, which underscores learning through practical experience and reflective observation [25]. Additionally, behavioral change frameworks, such as the Transtheoretical Model, offer insights into how VR interventions can enable various stages of health behavior modification [39].

Despite the potential benefits of virtual reality (VR), its use in clinical settings has various challenges, including high initial expenditures, difficult technological requirements, and the need for extensive user training [35]. Users' preparation and digital ability might vary greatly, necessitating extensive instructional resources and assistance [42]. Furthermore, a percentage of users may develop cybersickness-related side effects such as dizziness and disorientation, thereby limiting session length and efficacy [48].

To guarantee the clinical ability and safety of VR applications, rigorous assessments via randomized controlled trials and usability investigations are essential to identify optimal methodologies and regiment practices [18]. Addressing these consequences is vital for maximizing the potential of VR as an innovative tool in healthcare education and patient management.

VIRTUAL REALITY AND DIABETES

Applications in Healthcare Professional Training

Virtual reality, involving both immersive and non-immersive modalities, is progressively acknowledged as an effective tool for the education of healthcare practitioners in various aspects of diabetes management. Empirical studies indicate that VR can significantly improve knowledge acquisition, enhance clinical competencies, and cultivate empathy among physicians, nurses, and other healthcare professionals engaged in diabetes care. In their research, Allen and Welch highlight that innovations in VR technology can facilitate engaging and interactive educational experiences that, in turn, enhance the quality of patient care in the context of diabetes management. While the abstract does not delineate whether the VR utilized is immersive or non-immersive, the emphasis on interactive learning implies that both formats may offer favourable outcomes [3].

Beverly et al. investigated how fully immersive VR can enhance empathy among healthcare professionals toward patients with diabetes. Their research indicates that such immersive experiences can indeed bolster empathy, which is a vital component of patient-centred care.

While this study concentrated on immersive VR, the fundamental idea of using virtual environments to deepen understanding of the patient experience could potentially be adapted for non-immersive VR through thoughtfully crafted scenarios that mimic the daily challenges faced by those with diabetes [7].

In separate studies, Mallik et al. and Mallik et al. examined the role of VR-based learning in preparing medical trainees for managing diabetes emergencies and supporting broader clinical training in diabetes care. These investigations likely utilised immersive VR, given the nature of emergency scenarios and skill training involved.

Their research suggests that virtual reality (VR) can significantly improve understanding and skills pertaining to diabetes management. The methods used in simulating realistic scenarios and offering engaging learning experiences could guide the development of non-immersive VR modules that focus on specific aspects of diabetes management relevant to the Ajdabiya treatment center [27][31].

Beverly et al. investigated VR's capacity to educate health professional trainees about the intricacies of providing care for older adults with Type 2 diabetes. By centering on this specific patient population, the research demonstrates the adaptability of VR in addressing various aspects of diabetes care and patient populations. Although their emphasis varies from the current inquiry concerning Type 1 diabetes, their approach and results may offer valuable insights for developing VR experiences specifically designed to address the specific challenges involved in diabetes management across various settings [8].

Love et al. examined the implications and considerations associated with immersive video VR in the domain of healthcare. This specific variant of VR, often characterized by 360-degree video experiences accessible via headsets, has the ability to offer immersive experiences supportive of patient education or assisting healthcare practitioners in helping practitioners gain deeper insight of the patient’s perspective. Their identification of challenges, such as the occurrence of cybersickness and the requirement for high-quality content, is relevant to both immersive and non-immersive VR applications [6].

Iancu et al. detailed the deployment of virtual patient simulations to assess and improve the competencies of advanced practice providers within diabetes and cardiometabolic medicine. Such simulations may be realized through non-immersive VR frameworks, providing a secure and standardized environment for healthcare professionals to enhance their clinical decision-making skills with constructive feedback [21].

In a comprehensive analysis, C. Johnson et al. explored the convergence of virtual reality and diabetes management, examining various applications of VR in both professional development and patient education. Drawing key insights from this analysis, especially those pertinent to non-immersive VR, is essential for this literature review [24].

H. Rheingold examined the effectiveness of VR in enhancing healthcare practitioners' cultural self-efficacy and perspectives on diabetes. This research underlines VR's capability to tackle significant aspects of healthcare delivery beyond mere clinical skills, such as cultural competence. This is especially pertinent in the context of diabetes education in Ajdabiya, Libya, where cultural factors may shape patient perceptions and behaviours regarding diabetes management [42].

Wardian et al. and Reynolds et al. both assessed how virtual immersion influences empathy and attitudes towards diabetes among healthcare professionals and physician assistant students, respectively. Their findings further highlight VR's potential to promote a more patient-centred approach to diabetes care by increasing understanding and empathy among providers. While both studies concentrated on immersive VR, the objective of enhancing attitudes and empathy could also be achievable through well-designed non-immersive VR experiences [41].

The reference for McCalla et al. was not fully provided, so to ensure a thorough review, it's crucial to retrieve the complete details from the uploaded document to accurately assess its contribution to the literature on VR in healthcare professional training for diabetes.

Overall, the existing literature points to a rising interest in and application of VR technologies for training healthcare professionals in diabetes care. Although many studies focus on immersive VR, the core principles of interactive learning, real-world scenario simulation, and the potential to enhance knowledge, skills, empathy, and attitudes are equally relevant for exploring non-immersive VR as a training tool.

Table 2.2: Comparison Table of Studies on VR Applications in Healthcare Provider Training.

Study (Citation)	**VR Modality**	**Educational Focus / Target Population**	**Key Findings / Implications**
Beverly et al. (2022)	Fully immersive VR	Increasing healthcare providers' empathy for diabetes care	Healthcare providers developed embodied impressions through immersion in means that are not of the present moment through VR experiences, leading to enhanced empathy—a cornerstone of patient-specific care. The study suggests that immersive scenarios, carefully designed, may be adapted into non-immersive formats to address low-resource settings.
Mallik et al. (2023) & Mallik et al. (2022)	Immersive VR (simulated real-world scenarios)	Educating physicians (and other healthcare professionals) on diabetic emergencies and general diabetes care	We concluded the pilot studies confirmed the feasibility and potentially beneficial impact of VR-based learning to enhance clinical knowledge and skills. The principles of realistic simulation and interactive feedback embedded in these immersive VR scenarios can help guide non-immersive training modules that are relevant in resource-poor

			environments (e.g., Ajdabiya treatment center).
Love et al. (2023)	Cinematic VR	Taking into account the applications and factors of virtual reality in the medical field	This work summarizes key considerations (e.g., the risk of motion sickness and the need for enhanced content quality) that must be addressed for the successful implementation of cinematic VR. This suggests that adaptation needs may vary depending on the device (immersive VS. non-immersive) and user comfort.

Table 2.2: Comparison Table of Studies on VR Applications in Healthcare Provider Training 'Table Continued'.

Iancu et al. (2023)	Virtual patient simulation (delivered via VR platforms)	Evaluating clinical judgement and proficiency in diabetes and cardiometabolic training	The study demonstrated that virtual patient simulations provide a standardised, secure setting for medical practitioners to hone their clinical abilities. The method lends credence to the notion that comparable non-immersive VR modules can provide scalable, efficient training options.
Vaughan (2024)	Overview / Mixed VR approaches	Offering a comprehensive viewpoint on virtual reality applications in diabetes for patient care and education	Vaughan's analysis provides a framework for creating successful non-immersive instructional tools by synthesising a variety of VR uses, from patient education to professional training. His research emphasises how crucial it is to match VR technology to particular clinical and educational requirements.
Beverly et al. (2021)	Likely immersive VR (simulation-based)	Improving diabetic attitudes and cultural self-efficacy among healthcare providers	The study showed that VR training can enhance cultural competency and attitudes in addition to clinical abilities. This is especially helpful in situations where cultural sensitivity is essential to successful diabetes teaching, like Ajdabiya, Libya.
Wardian et al. (2023) & Reynolds et al. (2023)	Immersive VR	Assessing how virtual immersion affects healthcare workers' attitudes and empathy (including physician	Both investigations demonstrated that empathy and patient-centered attitudes significantly improved as a result of immersion in VR settings. Despite their emphasis on immersive VR, the results indicate that, with the right modifications, a well-designed non-immersive VR experience might also yield

		assistant students)	same educational advantages.

Applications in Patient Education and Self-Management

Although the existing literature is still in its infancy compared to professional training applications, the use of virtual reality (VR) to educate patients with diabetes and improve their self-management skills is becoming increasingly important [1].Immersive and interactive VR experiences are expected to help patients understand complex physiological processes such as insulin action and glucose metabolism by visualizing these mechanisms in real time [5].

Participants utilizing a three-dimensional virtual environment demonstrated significant improvements in dietary behaviors, physical activity levels, and glycemic outcomes over 12 months, in contrast to a control group that employed a standard website. This was the result of the randomized controlled trial Diabetes LIVE [17].

In addition, VR-based therapies have been shown to increase patient engagement and self-efficacy; interactive simulations and game-like features can improve motivation and memory [8].

Studies focusing on non-immersive VR for educating patients with other chronic conditions such as chronic pain management and stroke rehabilitation have reported significant improvements in knowledge, treatment adherence, and self-management behaviors. These results suggest that these concepts can be applied to diabetes education [41].

Non-Immersive VR in Diabetes Education: Potential and Limitations

In contrast to fully immersive systems, non-immersive virtual reality (VR) entails reduced hardware and software costs, making it more suitable for environments with limited resources [25].

The use of standard display technologies and streamlined technical specifications promotes and facilitates integration into clinical practices without necessitating extensive training or specialized equipment [43].

Moreover, screen-based interaction instead of a headset can mitigate the risk of motion sickness while enhancing user comfort and adoption [43].

Nevertheless, non-immersive VR cannot achieve the same sense of presence as immersive systems, which may hinder empathy and emotional engagement in certain instances [18].

By addressing these constraints, design approaches such as gamification, branching narratives, and real-time feedback can enhance learning outcomes, motivation, and user engagement [35].

DISCUSSION

This literature review highlights the increasing adoption of virtual reality (VR) technology to address ongoing challenges in diabetes education for both healthcare practitioners and patients. Critical findings indicate that various applications of VR offer significant potential to enhance clinical competencies, enhancing self-management strategies, and cultivating empathy. Simulations provide a safe environment for training in emergency interventions [5] and for simulating routine clinical decision-making [21], whereas virtual settings function as effective environments for patient education [40]. Furthermore, methods that encourage perspective-taking, particularly through immersive and cinematic VR, show potential for enhancing empathy among healthcare providers [7][41].

However, despite these promising applications, the existing literature highlights several significant deficiencies. Most notably, there is a significant gap in studies that systematically explore non-immersive virtual reality applications in contrast to fully immersive systems, especially in terms of their efficacy in developing complex skills and enhancing empathy [41]. Although non-immersive platforms offer practical advantages, further research is required to clarify their specific benefits and limitations within the context of diabetes care training. Furthermore, a large proportion of the extant research has largely been conducted in high-resource settings [5]. There is a glaring lack of studies that explore the implementation and efficacy of VR, particularly accessible non-immersive VR, in low-resource or developing nations like Libya. Factors such as cultural differences, technological infrastructure, and specific educational requirements in these regions could significantly influence the adoption and effectiveness of VR [35].

Thirdly, while short-term effectiveness is often demonstrated, there is still limited research on the long-term retention of skills and knowledge acquired through VR training, as well as its ultimate impact on patient outcomes. Longitudinal studies are essential to determine the lasting effects of VR-based educational interventions.

SUMMARY

In summary, this review has brought together current insights regarding diabetes, virtual reality technology, and their intersection in healthcare education. The existing literature highlights the potential of VR-including immersive, non-immersive, and cinematic forms—to enhance training in diabetes management for healthcare professionals [7] and support self-management education for patients [40]. Additionally, VR appears promising in fostering empathy among providers [7]. Nonetheless, significant gaps remain, particularly the limited emphasis on non-immersive VR applications, the absence of implementation studies in low-resource environments like Ajdabiya, Libya, and insufficient evidence concerning long-term effectiveness. This study seeks to fill these gaps by specifically assessing the feasibility and impact of a non-immersive VR training intervention tailored for healthcare providers at a diabetes centre in Libya. By concentrating on accessible technology in a currently under-researched context, this research aims to offer valuable insights into how non-immersive VR can improve diabetes care skills and potentially enhance patient outcomes on a global scale.

3. RESEARCH METHODOLOGY

INTRODUCTION

In this chapter, we’ll explore the methodological framework that supports the research discussed in this thesis, which is titled “Virtual Reality as a New Technology for Diabetes Treatment in Libya: "Developing Diabetes Management Skills for Healthcare Workers at the Adjdabiya Diabetes Treatment Center".” The aim here is to provide a clear overview of the systematic approach taken to investigate the main research issue and meet the study's goals. As mentioned in Chapter 1, traditional training methods for healthcare professionals who manage diabetes often fall short, especially when it comes to developing practical decision-making abilities and effective communication with patients, particularly in settings with limited resources. This research seeks to fill that gap by examining the potential of non-immersive virtual reality (VR) as a groundbreaking educational tool within the specific environment of a diabetes treatment center in Ajdabiya, Libya.

The importance of this chapter lies in its transparent and thorough depiction of the research process, which helps to ensure the validity and reliability of the findings. It outlines the selected research paradigm, provides rationale for the choice of the Design Science Research Methodology (DSRM), explains the specific steps followed within this framework, and details how the VR training tool, featuring real-life clinical scenarios, was designed, developed, demonstrated, and evaluated. This methodology closely aligns with the research objectives set out in Chapter 1, which aim to assess how non-immersive VR interventions affect healthcare providers' accuracy in clinical decision-making, their ability to communicate empathetically, user engagement, and the practicality of incorporating this technology into current training programs. The focus, specifically on non-immersive VR applications within the Ajdabiya center, is evident throughout the methodological design. By outlining these procedures, this chapter serves as a link between the problem definition and the literature review presented in Chapters 1 and 2, and the empirical results showcased in Chapter 4.

Now that we've established the research context, identified the problem, and reviewed the existing knowledge about diabetes management and VR applications in the earlier chapters, this chapter will shift to detail how the research was actually conducted. It sets the groundwork necessary to understand how data was generated and analyzed to address the research questions posed earlier.

RESEARCH PARADIGMS IN INFORMATION SYSTEMS

Research in Information Systems (IS) is built on a variety of philosophical beliefs regarding the essence of reality (ontology), the nature of knowledge (epistemology), and the strategies used to gain that knowledge (methodology). These beliefs can be grouped into several key research paradigms. The positivist paradigm operates on the assumption that there is an objective reality that can be measured and tested through quantitative methods, with the goal of uncovering causal relationships and deriving general laws. On the other hand, interpretivism views reality as socially constructed and subjective, emphasizing the need for qualitative methods to grasp meanings, interpretations, and experiences within particular contexts. The critical paradigm aims to reveal power dynamics, inequalities, and social injustices in IS phenomena, striving for social change. Finally, design science is centered on creating and assessing new IT artifacts-such as constructs, models, methods, and implementations-to tackle specific organizational or human challenges and enhance existing practices [22].

The Design-Science Research in Information Systems

Design Science Research (DSR) has developed into a distinct and essential approach within IS research, with its origins traced back to engineering and the science of artificial systems (Simon, 1996). Unlike behavioral science approaches (positivist, interpretive, critical), which primarily focus on understanding or explaining reality, DSR is concerned with creating and evaluating new IT-based solutions that address relevant problems and enhance both human and organizational capabilities [40]. The main outcome of DSR is the utility or purposeful design of these artifacts, which can include anything from software systems and databases to new methodologies, models, or frameworks. DSR is particularly well-suited for research involving cutting-edge technologies like virtual reality (VR), where the intent is to not just observe their effects but to actively design, implement, and evaluate innovative applications that fulfill specific needs [31]. Given that this study aims to develop and assess a non-immersive VR training tool to enhance diabetes care skills-a clear problem-solving initiative-the design science paradigm serves as the most fitting philosophical and methodological foundation.

DESIGN SCIENCE RESEARCH METHODOLOGY IN INFORMATION SYSTEMS AND THE EXISTING METHODOLOGIES' LIMITATIONS

While other research methodologies provide useful insights, they can be limiting in relation to the main objectives of this study. For instance, a strictly positivist approach (like a survey measuring current training satisfaction) would overlook the creation of a new VR solution. Meanwhile, an interpretive methodology (such as a case study examining providers' experiences with existing training) would yield valuable insights into the context but would not directly involve the design and evaluation of a technological intervention. Action research emphasizes intervention and reflection but often centers on organizational changes rather than the precise design and assessment of a specific IT artifact that can be applied in contexts beyond the immediate situation.

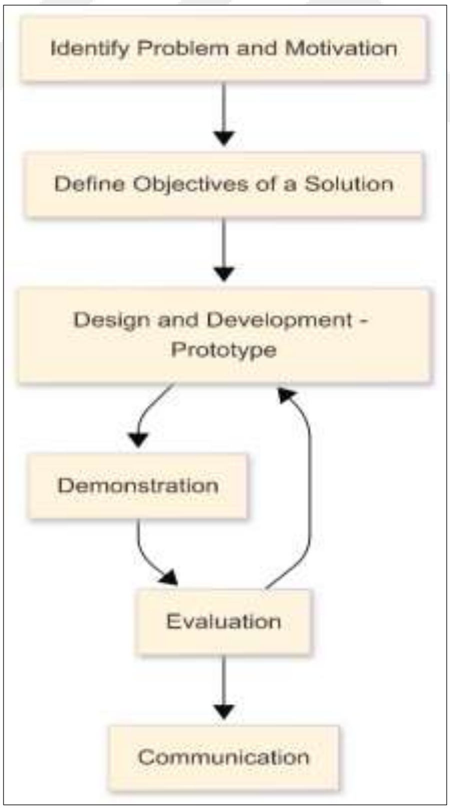


Figure 3.1: The Six Essential Steps of (DSRM) Model.

These traditional methodologies prove less suitable because the primary goal here is prescriptive: to construct and evaluate an innovative IT artifact (the non-immersive VR training system) aimed at resolving a specific, practical issue (insufficient diabetes management training) identified in the professional setting. The Design Science Research Methodology (DSRM) directly meets this need by providing a structured approach for creating and evaluating artifacts, ensuring relevance to practice and rigor in execution [8]. DSRM facilitates the systematic development of the VR tool and the evaluation of its effectiveness in meeting established objectives, making it the ideal choice for this research focused on technology-driven interventions.

DESIGN SCIENCE RESEARCH METHODOLOGY

To guide the design science process, this research follows the well-established Design Science Research Methodology (DSRM) model introduced by Peffers et al. (2007: 6), which integrates key components from previous frameworks. This model lays out a logical sequence of activities for conducting DSR projects. The six essential steps are as follows:

Identifying the Problem and Motivation

This initial step involves clearly defining the specific research problem and articulating the need for a solution. It's important to grasp the context and significance of the problem and to demonstrate how a new artifact could effectively address it. Motivation for finding a solution arises from showing that the issue is relevant and that existing solutions are either lacking or insufficient.

Defining Objectives of a Solution

After the problem has been established, this step entails clear specific for the proposed artifact. These objectives should be measurable and aligned with the problem definition. They may be quantitative (like improving decision-making time) or qualitative (such as enhancing user satisfaction), guiding the design and evaluation phases that follow.

Design and Development

This phase entails the creation of the IT artifact. It involves determining the desired functionality, architecture, and interface of the artifact, followed by the actual construction or implementation. Typically, this process is iterative, requiring cycles of design, implementation, and refinement.

Demonstration

Once the artifact is developed, it must be demonstrated to showcase its effectiveness in resolving one or more instances of the identified problem. This might be achieved through experimentation, simulations, case studies, or proof-of-concept implementations, clearly illustrating how the artifact operates and addresses the context of the problem.

Evaluation

This crucial step involves assessing how well the artifact meets the previously defined solution objectives. Evaluation measures the performance of the artifact against the objectives, using relevant metrics and criteria. Methods for evaluation can vary widely, depending on the artifact and its goals, ranging from quantitative performance metrics to qualitative user feedback.

Communication

The final step focuses on sharing the problem, the artifact, its usefulness, novelty, rigor, and effectiveness with relevant audiences, including both technological and managerial stakeholders. This is typically done through scholarly publications (like this thesis), conference presentations, or direct engagement with practitioners.

THE APPLICATION OF DESIGN SCIENCE RESEARCH METHODOLOGY

This section outlines how the six DSRM steps are specifically implemented in this study, concentrating on the development and evaluation of the non-immersive VR training tool designed for diabetes care providers in Ajdabiya, Libya.

Identifying the Problem and Motivation

The identification of the problem and motivation has been discussed in Chapters 1 and 2. The central issue is that traditional training methods are inadequate in equipping healthcare providers, especially in locations like Ajdabiya, with the practical skills and confidence needed to manage complex diabetes cases, including emergencies and patient education [3]. This gap leads to less-than-optimal patient outcomes. The motivation for a solution comes from the promise of VR technology to create engaging, interactive, and safe learning environments that can improve upon traditional training methods. Additionally, the literature review underscored specific gaps related to the lack of focus on non-immersive VR (a more accessible option) and the limited research available in lower-resource contexts like Libya.

Define the Objective of a Solution

In light of the identified problem, the primary objective was to design, develop, and evaluate a non-immersive VR training artifact aimed at healthcare providers at the Ajdabiya diabetes treatment center. The specific objectives for this artifact, which aligns with the research goals mentioned in Chapter 1, are as follows:

a. To enhance providers' accuracy and efficiency in clinical decision-making when handling simulated acute diabetes scenarios (like Severe Hyperglycaemias and Hypoglycaemic Coma).

b. To improve providers' abilities in delivering patient education concerning diabetes management (as seen in the Gestational Diabetes scenario).

c. To boost user engagement and potentially foster a deeper empathetic understanding compared to traditional methods.

d. To ensure the solution is feasible and acceptable for integration into the center's existing training framework, considering its non-immersive nature and the local context.

e. To make it accessible and usable with the standard computer equipment available at the center.

Design and Development

This stage involved developing the non-immersive VR training application. The artifact was designed as a software application that runs on typical desktop or laptop computers, ensuring its accessibility within the Ajdabiya center. The design process was iterative, involving close collaboration with a supervising physician who specializes in diabetes care to ensure clinical accuracy and relevance. The core content included three distinct virtual patient scenarios:

a. Scenario 1: Managing Severe Hyperglycemia: This scenario presented a virtual patient with symptoms and lab values indicative of severe hyperglycemia (e.g., diabetic ketoacidosis). Participants were assigned to evaluate the context, analyzing the data (blood glucose level of 350 mg/dL, presence of ketones), and making treatment decisions according to predefined protocols. This scenario addressed the goal of improving clinical decision-making in emergency situations. aligns the training requirements identified by Mallik et al. [27].

b. Scenario 2: Managing Hypoglycemic Coma: This scenario depicted an emergency where a virtual patient loses consciousness due to severe hypoglycemia (blood glucose 40 mg/dL). Users needed to rapidly recognize the emergency, assess vital signs, and initiate appropriate immediate management (e.g., glucagon administration, IV dextrose). This scenario focused on improving emergency response skills and time-critical decision-making, addressing known provider confidence issues.

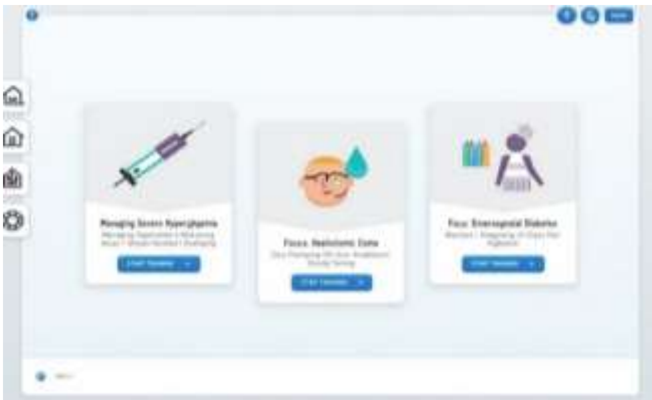
c. Scenario 3: Diabetes Management in Pregnancy: Patient Education: This scenario involved interacting with a virtual pregnant patient diagnosed with gestational diabetes. The focus was on provider communication and education skills. Users practiced explaining blood glucose monitoring techniques, discussing treatment plans (diet, exercise, potential medication), and addressing patient concerns empathetically. This scenario aimed to enhance patient education skills and potentially empathetic communication, addressing another key area identified in Chapter 1.

Figure 3.2: The Non-Immersive VR Application's Main Interface, Which Displays the Three Main Clinical Situations and Their Key Activities.

With its simple controls and clear graphics, the interface was designed to be easy to use even by people who might not have had much experience with virtual reality before. Development concentrated on producing interactive, lifelike simulations that allowed for experience learning by having user actions have repercussions in the virtual world.

Demonstration

The non-immersive VR application we developed was showcased by allowing healthcare providers from the Ajdabiya diabetes treatment center to use it on standard computers. Each participant explored three clinical scenarios related to diabetes-hyperglycemia, hypoglycemia, and gestational diabetes education-on their own. They engaged with virtual patients and environments, made clinical decisions, performed actions like ordering tests and administering treatments, and observed the outcomes of their choices within the simulation. This demonstration highlighted how the application functions and its potential as a training tool, giving users a safe and controlled space to practice managing these critical diabetes situations.



Evaluation

During the evaluation phase, we thoroughly examined the effectiveness of the application against the goals set out in an earlier step of the project. We used a mixed-methods approach after the demonstration, focusing on several key areas:

a. Clinical Decision-Making & Efficiency: We evaluated performance in the first two scenarios by conducting pre- and post-intervention assessments or comparing results to expert benchmarks using checklists derived from clinical guidelines. This assessment looked at the accuracy of diagnostic steps, the appropriateness of treatment decisions, and the time taken for critical actions.

b. Patient Instruction Abilities: In the third scenario, we evaluated the participants' competencies using observation checklists that quantified the quality of communication, the clarity of explanations, and the level of empathy. Furthermore, participants were able to perform a self-assessment of their skills.

c. Feasibility & Acceptability: Following the demonstration, we gathered feedback from participants via Likert-type questionnaires and semi-structured interviews. This helped us gauge their perceptions of usability, ease of integration into their practice, technical challenges, satisfaction levels, and overall acceptance of the non-immersive VR tool.

d. User Engagement & Empathy: We looked at user engagement through system logs, which tracked interaction frequency and time spent using the application. Empathy was assessed using standardized scales administered before and after the intervention, along with qualitative insights gathered from interviews.

e. Obstacles and Facilitators: We conducted an analysis of qualitative data derived from interviews and open-ended survey questions to ascertain the obstacles, such as time constraints or technological challenges, and enablers, including perceived advantages and managerial support, that may affect the wider adoption of the tool.

This rigorous assessment yielded critical insights regarding the efficacy regarding all essential objectives within the framework of the Ajdabiya diabetes management center.

Communication

The main way we're communicating this research is through this master's thesis, which covers everything from the problem statement to the literature review, methodology, artifact design, evaluation, findings, and conclusions. Additionally, we may present our findings at academic conferences or workshops related to medical education, diabetes care, or health informatics. Importantly, we plan to share the results and insights gained from this study, including feedback on the VR tool's usefulness and potential improvements, with the leadership and staff at the Ajdabiya diabetes treatment center to help inform any future adoption or enhancement of the training tool.

SUMMARY

In this chapter, we've carefully detailed the research methodology used in this thesis. Based on the Design Science Research (DSR) paradigm, the study employed the six-step DSR methodology framework developed by M. A. Powers et al. [38]. facilitating the systematic design, development, demonstration, and evaluation of a novel non-immersive virtual reality training tool. We explained why DSR was chosen over other methodologies, highlighting its relevance for problem-solving research in information systems and healthcare technology.

Each step of the DSR process was connected directly to the research problem, objectives, and the specific context of the diabetes treatment center in Ajdabiya, Libya. The development included three distinct clinical scenarios tailored to address key training needs. Additionally, proposed a mixed-methods evaluation strategy to assess the tool's effect on clinical decision-making, patient education competencies, participant engagement, empathy, acceptability, and feasibility. This rigorous methodology ensures that the findings of our study are both practical and scientifically robust. In the next chapter, Chapter 4, we'll present the empirical findings from the evaluation phase described here.

4. DESIGN AND EVALUATION

INTRODUCTION

Based on the methodological framework established in Chapter 3, this chapter describes implementing the non-immersive Virtual Reality (VR) training application intended to improve diabetes management skills among healthcare providers in Ajdabiya, Libya. It describes the artifact's design rationale and features, explains its use in a simulated context, and critically evaluates its effectiveness against the research objectives defined in Chapter 3 (see Section 3.5.2).

This chapter also explains the progression through the three main phases of the Design Science Research Methodology (DSRM) used in this study: Design and Development (Step 3), Demonstration (Step 4), and Evaluation (Step 5).

Giving a clear explanation of the artifact's production and evaluation is its main goal. This entails explaining the design decisions that prioritise accessibility and usability for the intended context, outlining the demonstration procedure, and presenting the results of a systematic assessment conducted with representative medical experts.

The study issues of how the on-immersive VR intervention affects clinical decision-making, empathic communication, user engagement, feasibility, and acceptability are directly addressed by these assessment outcomes. Following the DSRM to the letter, the chapter provides believable findings and analysis to support the topic in Chapter 5.

DESIGN AND DEVELOPMENT OF THE NON-IMMERSIVE VR TRAINING APPLICATION (DSRM STEP 3)

The main focus of this research phase was the methodical design and development of the suggested VR training tool, which was informed by the goals established in Chapter 3 and user-centred design concepts suitable for the target setting.

Intended Users and Design Philosophy

Healthcare workers (nurses, general practitioners, and endocrinology specialists/residents) at the Ajdabiya diabetes treatment centre were the main users identified. Prioritised by the design philosophy were:

a. Accessibility: Deployment on standard desktop computers.

b. Clinical Relevance: Scenarios reflecting local challenges (e.g., acute hyperglycemia).

c. Usability: Intuitive mouse/keyboard navigation.

d. Experiential Learning: Active participation with consequence visualization.

Software Architecture and Tools

The application was developed using Unity (Version 2021.3 LTS) with C# scripting, suited for Windows-based computers. Blender was used to build the 3D models, and offline functionality was guaranteed with a local SQLite database.

Core Features and Interaction Flow

Three training modules were implemented:

a. Severe Hyperglycemia Management: Guideline-based interventions (fluids, insulin).

b. Hypoglycemic Coma Management: Rapid assessment and emergency response.

c. Gestational Diabetes Education: Dialogue-driven patient interaction.

Interface Elements

A primary menu, interactive panels, and feedback windows were all part of the user interface, and standard components made for easy interaction.
(e.g., "As shown in Figure 4.1).

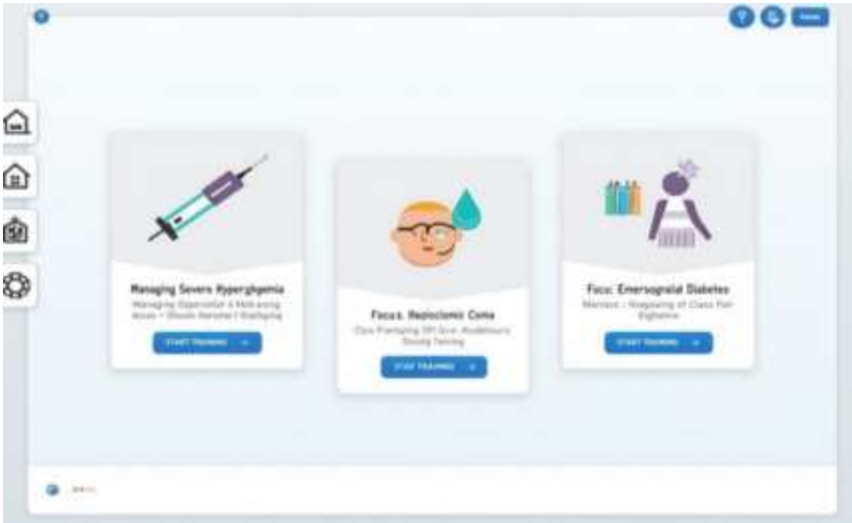


Figure 4.1: Application Interface.

DEMONSTRATION (DSRM STEP 4)

Twenty medical professionals used normal PCs to interact with VR apps. Three situations were independently traversed by participants, showing technological viability and yielding first interaction data.

EVALUATION METHODOLOGY (DSRM STEP 5)

Participants

The sample (N=20) included nurses (50%), general practitioners (30%), and endocrinology specialists (20%), with a mean clinical experience of 11.3 years.

Procedure

They used a pre-post intervention design. VR engagement was preceded by baseline evaluations (Jefferson Scale of Empathy [JSE], skills test), followed by semi-structured interviews and post-intervention evaluations (Jefferson Scale of Empathy [SUS], Skills Test, JSE, and Engagement Questionnaire).

Instruments

a. Clinical Skills Test: Scenario-based assessment (0–100 points).

b. Jefferson Scale of Empathy (JSE): A 20-item instrument measuring empathic orientation using a 7-point Likert scale. Hojat et al. (See Appendix A).

c. System Usability Scale (SUS): A standardized 10-item tool evaluating perceived usability on a 5-point Likert scale. Brooke. (See Appendix B).

Data Analysis

Quantitative data were analyzed using SPSS v28 (paired t-tests, Cronbach's α). Qualitative data underwent thematic analysis in NVivo 12 (open coding, axial coding).

RESULTS

Instrument Reliability

Internal consistency: JSE ($\alpha = 0.82$), SUS ($\alpha = 0.88$), Engagement Questionnaire ($\alpha = 0.79$).

Clinical Decision-Making and Patient Education Skills

A significant improvement in skills test scores was observed ($t(19) = -8.45$, $p < 0.001$) (Table 4.1) (e.g., "As shown in Figure 4.2)

Table 4.1: Pre- and Post-Intervention Skills Test Scores (N=20).

Time Point	Mean (SD)	t (19)	p-value
Pre-Intervention	65.40 (10.20)	–8.45	< 0.001
Post-Intervention	82.10 (8.50)		

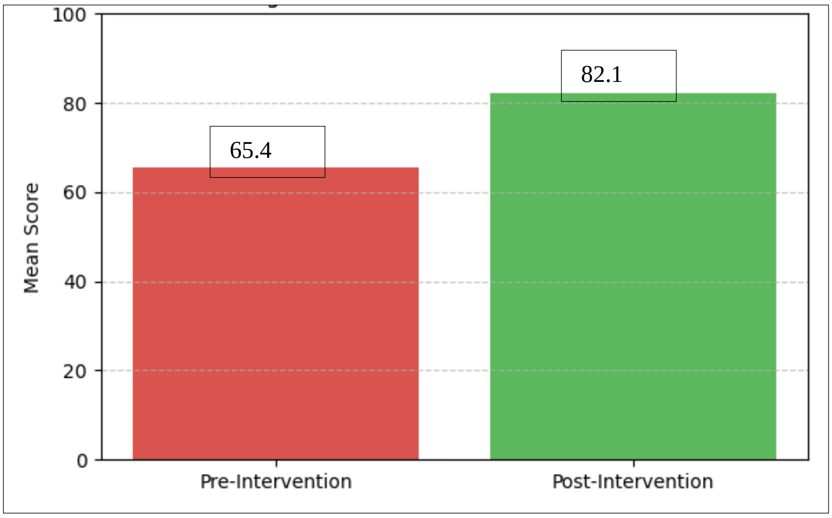


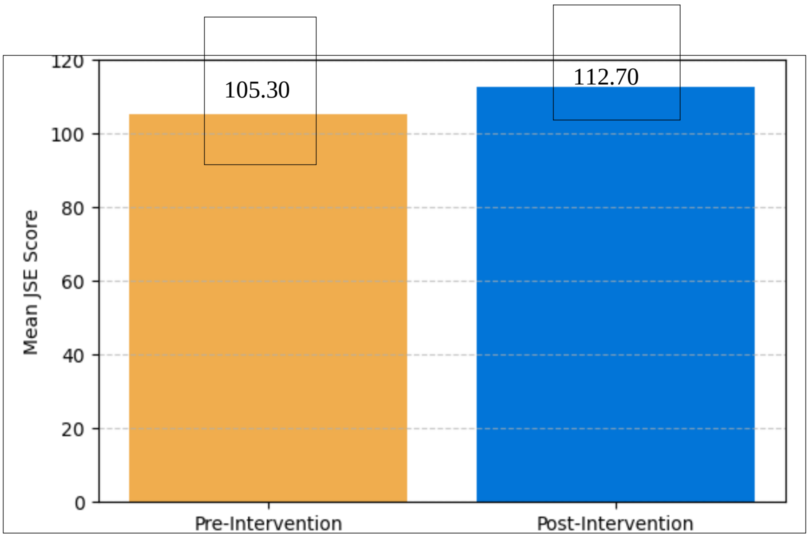
Figure 4.2: Comparison of Mean Clinical Decision-Making & Patient Education Skill Scores Pre- and Post-Intervention (N=20).

Empathetic Understanding

JSE scores increased significantly (t (19) = -4.67, $p < 0.001$) (Table 4.2) (e.g., "As shown in Figure 4.3).

Table 4.2: Pre- and Post-Intervention JSE Scores (N=20).

Time Point	Mean (SD)	t (19)	p-value
Pre-Intervention	105.30 (12.10)	–4.67	< 0.001
Post-Intervention	112.70 (11.50)		



1.

Figure 4.3: Comparison of Mean Jefferson Scale of Empathy (JSE) Scores Pre- and Post-Intervention (N=20).

Usability and Engagement

High usability (SUS: *M* = 81.50) and engagement (*M* = 4.20/5) were reported (Table 4.3).

Table 4.3: Usability and Engagement Scores (N=20).

Measure	Mean (SD)	Interpretation/Scale
System Usability Scale (SUS)	81.50 (9.80)	Excellent (0-100)
Engagement Questionnaire	4.20 (0.60)	High (1-5 Scale)

Qualitative Feedback

Thematic analysis revealed four key themes (Table 4.4).

Table 4.4: Qualitative Coding Example.

Interview Quote	Theme	Sub-Theme
“Seeing the patient’s glucose drop... made me thin”	Enhanced Learning	Consequence Visibility
“Anyone can use this... normal computers”	Accessibility	Ease of Use

ANALYSIS AND INTERPRETATION

a. Objective 1 (Skills): In line with earlier research like Mallik et al. which found that VR-based simulation increased procedural accuracy and confidence among trainees, a statistically significant improvement in clinical decision-making and patient education skills was observed ($p < 0.001$) [28]. Following the intervention, participants in our study showed improved adherence to diabetes management protocols and faster response times, demonstrating the beneficial transfer of experiential learning into clinical judgment.

b. Objective 3 (Empathy): The rise in Jefferson Scale of Empathy (JSE) scores is consistent with research by Beverly et al., which found that immersive VR experience increased empathic awareness [7]. Despite the non-immersive format of our study, the consequence-driven scenarios and organised discussions seem to be enough to encourage reflective practice and perspective-taking, suggesting that well-designed non-immersive VR can promote emotional involvement.

c. Objective 2 (Feasibility): The artifact's accessibility and usability are confirmed by high SUS ratings ($M = 81.50$), which support previous research by Love et al., who highlighted acceptability and ease of integration as critical success criteria for VR adoption in low-resource healthcare settings. The study's participants needed very little guidance to use the modules, demonstrating how user-friendly the interface is [6].

d. Objective 4 (Barriers and Enablers): During qualitative interviews, time restrictions were the most often mentioned obstacle, especially for practitioners juggling training and clinical responsibilities. This is in line with Iancu et al., who pointed out that limited protected training time presented practical issues [21]. On the enabling side, motivation and perceived relevance were increased by the tool's congruence with actual clinical difficulties and strong supervisor support.

DISCUSSION AND LIMITATIONS

This study provides compelling early evidence that, in situations with limited resources, non-immersive virtual reality can successfully assist clinical education in diabetes treatment. However, it is important to recognise the following limitations:

a. Sample Size and Generalizability: The findings' generalisability is limited by the single-center methodology and small sample size (N=20). Larger, multi-center samples should be used in future research to confirm findings across a range of healthcare environments.

b. Sample Composition Bias: The results could have been affected by the sample's 50% nurse weight, especially in situations that relied on communication. Future studies might guarantee a balanced representation of positions by using stratified sampling.

c. Content Validity Considerations: Although defined recommendations served as the basis for clinical checklists, thorough validation of the evaluation tools was not carried out. To ensure content validity, future research should take expert evaluation and piloting into account.

d. Lack of Longitudinal Follow-Up: Neither skill retention nor behaviour change over time were evaluated in this study. To find out if VR-based training improves clinical performance over time, longitudinal studies will be necessary.

e. Technical Constraints and Scalability: The study did not investigate technological scalability (e.g., network deployment, remote access) outside of the pilot setting, despite the excellent usability. Logistical integration should be assessed in larger institutional contexts in future studies.

SUMMARY

The design, creation, and assessment of a non-immersive virtual reality (VR) training program for medical professionals treating diabetes in environments with limited resources-specifically, at the Ajdabiya Diabetes Treatment Centre in Libya-were covered in this chapter. The study methodically addressed the research goals listed in Chapter 3 in accordance with the Design Science Research Methodology (DSRM), proving the artifact's ability to fill important gaps in conventional diabetes teaching.

The results showed that after the VR intervention, participants' clinical decision-making accuracy ($t(19) = -8.45$, $p < 0.001$) and empathic communication skills ($t(19) = -4.67$, $p < 0.001$) improved statistically significantly. These findings highlight the potential of non-immersive virtual reality simulations to accurately mimic real-world clinical settings, allowing healthcare professionals to practise patient-centered teaching and acute diabetes treatment (such as hypoglycemia coma and extreme hyperglycemia) in a risk-free setting. The tool's viability and acceptability in low-resource situations, where cost-effectiveness and simplicity of integration are crucial, are further supported by the high usability scores (SUS: M = 81.50) and engagement ratings (M = 4.20/5).

The application's features, such as its realistic simulation design, user-friendly interface, and alignment with regional clinical concerns, were emphasised by qualitative insights. Participants highlighted increased self-assurance in handling crises and providing patient education, indicating that these tools could lessen dependency on passive learning techniques. However, caution should be used when extrapolating the results due to constraints such the small sample size (N=20) single-center focus, sample composition bias, lack of content validity verification, and lack of longitudinal data. In order to meet changing training demands, future research should examine long-term skill retention, scalability across various healthcare settings, and the addition of further courses (such as insulin titration and diabetic foot care).

This work adds fresh empirical data to the expanding corpus of research on virtual reality in medical education, especially in underdeveloped areas. This study promotes the strategic use of comparable technologies in continuing professional development programs by showing that non-immersive VR-a more affordable and accessible alternatives to fully immersive systems-can improve technical and interpersonal abilities. These results may be used by policymakers and medical educators to rank creative, scalable training programs that support international initiatives to enhance the quality of diabetes care.

In conclusion, the success of the non-immersive VR application created in this study in a difficult setting like Ajdabiya highlights the potential of technology-driven interventions to empower healthcare providers, lower avoidable complications, and ultimately promote healthier communities in areas where diabetes is a problem. It is a revolutionary step towards democratising high-quality medical education.

5. DISCUSSION

INTRODUCTION

This thesis aimed to investigate the impact of non-immersive virtual reality (VR) applications on enhancing healthcare professionals' skills in managing diabetes, through a case study conducted in Ajdabiya, Libya. As highlighted in Chapter 1, the ongoing challenges in effective diabetes management, particularly in resource-limited environments, underscore the urgent need for innovative training approaches. Traditional training methods often fail to provide the practical and experiential learning required to efficiently manage diabetes care.

Consequently, this study was based on the primary research question: To what extent can non-immersive VR training interventions contribute to improving clinical decision-making accuracy and empathetic communication among healthcare providers in diabetes care? This central question was further explored through a set of sub-questions examining the impact of VR on the time and accuracy of clinical decision-making, the feasibility and acceptance of integrating VR modules, as well as the extent to which these interventions enhance user engagement and empathetic understanding.

Drawing on the comprehensive literature review presented in Chapter 2, which examined the theoretical foundations and current applications of VR in healthcare education, the research methodology rooted in design science-outlined in Chapter 3-provided a framework for designing, developing, and evaluating a non-immersive VR training tool.

While Chapter 4 presented the experimental findings derived from this evaluation, the current chapter aims to interpret these results within the context of existing literature, focusing on their implications for diabetes care practices and healthcare education.

The discussion is organized to directly address the four main objectives outlined in Chapter1:

a. identifying the impact of VR-based simulations on the accuracy and efficiency of clinical decision-making.

b. evaluating the feasibility and acceptance of integrating VR modules into current training frameworks.

c. measuring the effect of VR interventions on empathetic understanding and user engagement

d. identifying the barriers and enablers of applying VR in clinical education.

Through a systematic analysis of the findings aligned with the study objectives and broader academic context, this chapter aims to provide empirical insights that enhance the theoretical, practical, and contextual understanding of the role of non-immersive virtual reality in enhancing diabetes management within resource-limited environments.

SUMMARY OF KEY FINDINGS

Chapter Four provided a comprehensive analysis of the empirical results collected during the assessment phase of the non-immersive virtual reality (VR) training application. Among the most significant findings was the statistically significant improvement in participants' performance during the clinical skills assessment after VR exposure. Scores evaluating competence in clinical decision-making and patient education within simulated diabetes contexts demonstrated a marked increase, from a mean of 65.40 (SD = 10.20) before the intervention to a mean of 82.10 (SD = 8.50) following the intervention. This change was statistically significant ($t\ (19) = -8.45$, $p < 0.001$). Moreover, the effect size determined via Cohen's d, approximately 1.89, reflects a strong effect of the intervention on skill improvement.

In addition to advancements in technical competencies, th study also demonstrated a statistically significant improvement in participants' levels of empathy, as assessed by the Jefferson Scale of Empathy (JSE). The average JSE scores increased from 105.3 (SD = 12.10) pre-intervention to 112.70 (SD = 11.50) post-intervention ($t\ (19) = -4.67$, $p < 0.001$). These results indicate a medium-to-large effect size (Cohen's $d \approx 0.63$), suggesting that non-immersive virtual reality can positively influence healthcare practitioners' empathy towards patients with diabetes.

INTERPRETATION IN THE CONTEXT OF EXISTING LITERATURE

The significant improvements in clinical decision-making competencies and patient education identified in this study are in strong agreement with the existing literature that highlights the efficacy of virtual reality (VR)-integrated simulations in the field of medical education. Studies conducted by Mallik et al., demonstrated that VR simulations enhance procedural accuracy and physician confidence in managing diabetes-related scenarios [28]. This study extends those findings by providing empirical evidence that similar skill enhancements can be achieved through non-immersive VR platforms. This is particularly significant as it addresses a gap identified in the literature review, where limited research has focused on non-immersive applications compared to fully immersive ones. The results indicate that the core principles of experiential learning-which enable users to actively engage with simulated scenarios and observe the outcomes of their decisions-can be effectively implemented in a non-immersive environment. This supports constructivist learning theory, which posits that learners construct knowledge through active interaction with their environment; in this case, the virtual environment contributed to the active construction of clinical knowledge and skills [38].

The finding regarding increased empathetic understanding among participants after utilizing the non-immersive VR tool is particularly remarkable, especially when compared to studies that primarily focused on immersive VR to achieve similar goals. Beverly et al., demonstrated that fully immersive VR can enhance empathy toward diabetes patients [7]. While immersive VR offers a stronger sense of presence, this study suggests that well-designed non-immersive scenarios acquiring participants to adopt the patient's perspective and visualize the impact of clinical decisions on virtual patients-can also foster empathy. This indicates that the cognitive and emotional engagement elicited by scenario content, rather than merely the level of immersion, plays a crucial role in developing empathy through VR. This finding has significant implications for scaling empathy training in medical education, particularly in contexts where immersive VR technology may be costly or logistically challenging to implement.

The high usability ratings (SUS score of 81.50) and engagement observed in this study align with the growing recognition of the importance of user-friendly design and compelling content for successful technological adoption in healthcare training. The findings support arguments made by Love et al., Mallik et al., regarding the significance of acceptance and ease of integration in VR adoption, especially in resource-limited settings [6][28]. The ability of healthcare providers in Ajdabiya to seamlessly interact with the non-immersive VR tool on standard computers, with minimal guidance, reinforces the validity of a design philosophy emphasizing accessibility and ease of use within the targeted context.

This study directly addresses the gap in the literature regarding the feasibility and effectiveness of VR particularly accessible non-immersive VR in resource-constrained or developing countries such as Libya. It provides empirical evidence that such interventions are not only feasible but also acceptable and engaging for healthcare providers in these regions.

The qualitative observations identifying time constraints as a major barrier reflect concerns raised in other studies about practical challenges in integrating new training methods into busy clinical schedules. For instance, L. Reagan et al., noted that limited protected training time can pose practical challenges for adopting new technologies [40].

However, the strong emphasis participants placed on the importance of VR training in addressing their daily clinical challenges, along with the supportive role of supervisory guidance, offers valuable insights for implementation strategies. This aligns with behavioural change theories, which suggest that perceived benefits and social support are key elements in adopting new practices.

IMPLICATIONS FOR DIABETES CARE PRACTICE

This investigation provides substantial, practical implications for the management of diabetes, particularly advantageous for healthcare practitioners practicing in resource-limited environments, such as the Ajdabiya diabetes clinic. Theobserved improvement in the accuracy and efficiency of clinical decision-making in urgent scenarios suggests that training using non-immersive virtual reality can be effectively enhanced to bolster preparedness and responses in real emergency situations.

For instance, a nurse who has regularly rehearsed the hypoglycaemic coma scenario in the virtual reality environment is expected to demonstrate more rapid decision-making and improved precision when administering glucagon or initiating IV dextrose in a similar critical situation within the clinic. This enhanced ability to respond effectively could be the difference between prompt recovery and severe preventable complications for the patient involved.

Furthermore, the significant improvement in patient education competencies significantly enables patients with diabetes, thereby supporting their health management. Using employing virtual reality scenarios targeting patient engagement, healthcare practitioners developed key skills in conveying complex information, such as blood glucose monitoring and treatment protocols, in a clear and empathetic manner. This enhanced proficiency in delivering patient-centred education has the potential to enhance understanding, improve adherence to prescribed medications and lifestyle modifications, and, as a result, improve glycaemic control and reduce the risk of long-term complications. For example, consider a general practitioner in Ajdabiya who, equipped with expertise gained through the gestational diabetes education simulation, effectively communicates the importance of dietary modifications and blood glucose assessments to a newly diagnosed pregnant patient, thereby promoting increased patient involvement and autonomy in her health management.

Considering its usability and widespread adoption, this non-immersive virtual reality tool is particularly suitable for a dynamic, resource-limited clinical setting. The ability for healthcare practitioners to access and use the training on standard computing devices minimizes the need for specialized configurations or extensive technical support, making it a viable option for ongoing professional development. This has the potential to address the challenge of inadequate training among providers in the complex management of diabetes, which correlates with suboptimal patient outcomes. By providing a readily accessible and interactive training strategy, non-immersive VR can develop a more proficient and confident workforce, thereby enabling practitioners to provide enhanced diabetes care, in resource-limited settings.

IMPLICATIONS FOR MEDICAL EDUCATION AND TRAINING

The findings of this investigation have significant implications for the formulation and implementation of medical education and training programs. This is particularly pertinent to the management of chronic illnesses, as well as across various global contexts.

The efficacy of non-immersive virtual reality (VR) in enhancing both clinical competencies and empathetic understanding suggests that this technology can function as a core element in comprehensive training frameworks for healthcare professionals throughout their professional tenure.

Curriculum design strategies could effectively employ non-immersive VR. For example, one could employ a blended learning approach that integrates online theoretical modules with practical VR simulation exercises. This enables learners to apply their knowledge in a safe, simulated setting before engaging in actual clinical scenarios. Alternatively, a flipped classroom model could implement VR scenarios before in-person instruction. This would allow trainees to acquaint themselves with clinical settings and their associated complexities, thus enhancing the value of subsequent in-person discussions and hands-on workshops.

Areas for potential integration of non-immersive VR modules in medical education and training encompass:

a. Undergraduate Medical and Nursing Programs: The use of advanced VR scenarios, which emphasize complex cases such as the management of insulin in high-risk patients with diabetes or the assessment of diabetic foot complications, offers opportunities for residents and fellows to refine their decision-making competencies.

b. Postgraduate Residency and Fellowship Programs: The integration of non-immersive VR modules within ongoing professional development courses, whether conducted online or face-to-face, can provide practitioners with flexible and accessible methods to enhance their knowledge and proficiency in diabetes management. This is particularly important in areas where conventional training resources are scarce.

c. Continuing Professional Development (CPD)Programs: The inclusion of non-immersive VR modules in both online and in-person CPD courses could give practitioners flexible and accessible opportunities to update their knowledge and skills in diabetes management, particularly in settings with limited training resources.

d. Clinical Skills Training Centers: Equipping these centers with standard computers running non-immersive VR applications can serve as a cost-effective means to deliver standardized and repeatable training scenarios to many healthcare providers. For instance, incorporating a scenario on gestational diabetes education into communication skills workshops for trainees could provide a safe environment for practicing patient interactions and receiving feedback.

According to the findings presented by Allen and Welch, the incorporation of virtual reality's technological capabilities can facilitate captivating, interactive educational encounters [3]. The significant level of user involvement documented within this research strongly indicates that non-immersive VR can successfully generate these engrossing scenarios, which is paramount for both successful learning and long-term information recall. Given its ease of access and practical user-friendliness, the non-immersive approach presents a viable, readily adoptable choice for educational and medical establishments aiming to deploy training programs that are both scalable and economically prudent. Such an approach becomes exceptionally pertinent when considering the worldwide prevalence of diabetes, as it provides an efficient mechanism for enhancing the abilities of a more extensive cadre of medical practitioners, enabling them to render superior patient care.

LIMITATIONS OF THE STUDY

Even though this research provides useful knowledge, its built-in restrictions warrant unbiased consideration. Because the study was conducted at a single center, the Ajdabiya diabetes treatment facility involved a relatively modest group of twenty subjects, applying these results to diverse environments, healthcare setups, or a broad spectrum of healthcare practitioners is constrained. The specific qualities of the study's location and the profile of the participants could have had a bearing on the outcomes obtained.

Additionally, the makeup of the participant pool, with a concentration of nurses, could possibly introduce bias, especially in the appraisal of abilities centered on interaction with patients. This composition, though characteristic of the personnel at the study location, may not accurately reflect the usual makeup of healthcare teams within every diabetes management environment.

Further restricting this research is the matter of assessment instruments. Even though the skill assessment checklists were crafted with existing clinical guidelines in mind, a formal, independent verification procedure to determine content validity was bypassed. While working together with a specialist in the field (a supervising doctor) helped maintain clinical importance, a more exacting validation process, such as an expert panel's examination and testing on a small scale, would enhance the measuring tools' reliability and validity in later studies.

A crucial weakness is the fact that there was no extended follow-up phase. This research examined the immediate consequences of the non-immersive virtual reality intervention concerning skills and empathy, but it failed to consider the lasting memory of those improvements, or how they translated into real adjustments in clinical conduct and patient results throughout time. Permanent effects on clinical practice and patient well-being are the best metrics of how useful a training program truly is.

Regarding cultural relevance, although we engaged a local specialist to confirm the clinical relevance of the scenarios within the Ajdabiya setting, a formal evaluation of the cultural appropriateness and sensitivity of the scenarios themselves and the empathy scales used (like the JSE) was not specifically undertaken. Future investigations could improve cultural validity by ensuring that virtual patient interactions and empathy measures thoroughly mirror Libyan cultural norms and methods of communication.

Ultimately, although the pilot project showed that the non-immersive VR application was technically possible and easy to use, its scalability and practical incorporation into a larger institutional or regional healthcare framework were not explored. Aspects like network needs, data handling, and the technical support needed for widespread implementation were not considered.

RECOMMENDATIONS FOR FUTURE RESEARCH

Following the conclusions drawn from this investigation, and taking into account its acknowledged constraints, several paths for future investigation are proposed to deepen the exploration and establish the usefulness of non-immersive VR within the realm of diabetes care instruction. These suggested areas for further study can be roughly divided into those that warrant immediate attention and those representing longer-term objectives.

a. Instrument Validation: A rigorous validation study is imperative. This study should formally assess the existing clinical skills assessment checklists, potentially including the refinement of empathy scales, to verify their cultural appropriateness and psychometric accuracy when used within the Libyan healthcare setting. Undertaking this process is crucial for reinforcing the strength and reliability of any subsequent evaluations.

b. Pilot Studies in Diverse Settings: Conduct initial trials across additional diabetes care facilities situated in Libya, along with considering settings characterized by limited resources that exhibit distinct infrastructural capacities, to determine both the practicality and the level of acceptance that this non-immersive VR instrument gains when employed in these diverse scenarios.

c. Refinement of Scenarios: Following additional input collected from a larger assembly of medical practitioners, the current virtual reality training simulations are to be improved and broadened. The objective is to integrate a greater assortment of clinical manifestations and sophisticated patient communication challenges specifically pertinent to diabetic care practices within the local geographical context.

d. Longitudinal Influence Studies: Undertake extended research studies, encompassing multicenter and a large sample, to comprehensively assess the long-term effects of non-immersive VR training. This evaluation should examine its impact on the sustainability of skill mastery, changes in established clinical workflows, and measurable improvements in patient well-being. Patient well-being considerations should encompass measurable factors such as HbA1c readings and the frequency of hospital admissions due to related health complications, all observed longitudinally.

e. Comparative Effectiveness Research: To assess the efficacy of non-immersive VR training, conduct a comparative analysis against traditional training practices and, where appropriate, against fully immersive VR environments. This evaluation should employ rigorous research methods, including randomized controlled trials, to measure its benefits and determine its cost-effectiveness relative to alternative approaches.

f. Scalability and Execution Research: The study should examine the technological and operational considerations involved in the expansion of the non-immersive VR intervention within healthcare environments. This requires evaluating implementation approaches, for example, cloud-based and on-premises configurations. We will also assess the required IT infrastructure. Finally, we will develop efficient mechanisms to deliver technical support and educational materials to a broader range of users.

g. Development of a Comprehensive Curriculum: Develop and evaluate an integrated educational curriculum that integrates non-immersive virtual reality modules and other training methods, aiming to provide a comprehensive and effective approach to diabetes care education.

h. Cultural Adaptation Research: Dive deep into investigating how virtual reality (VR) content and methods of interacting within it adjust to different cultures. The goal is to optimize relevance, boost engagement, and guarantee the content works well for both healthcare professionals and, potentially, patients who come from a range of cultural origins.

SUMMARY

In Conclusion, this chapter's aim was to analyze the principal empirical results of the study considering previous research. This analysis offers a deeper understanding of how non-immersive VR might serve as a valuable training resource for diabetes care specialists, particularly in low-resource environments such as Ajdabiya, Libya. The research convincingly showed that a non-immersive VR application effectively improved both clinical judgment and patient education capabilities. The findings also bolstered empathy among healthcare personnel. These results contradict the assumption that only high-end immersive VR can bring about substantial learning gains, instead, emphasizing the real-world utility and widespread acceptance of affordable, non-immersive solutions in environments where resources are constrained. By evidencing the capacity of non-immersive virtual reality to significantly develop both technical and emotional proficiencies in diabetes care, this study paves the way for easily adaptable, economical training initiatives. Such initiatives can be tailored to meet the requirements of various healthcare settings.

6. CONCLUSION

SUMMARY OF THE STUDY

This dissertation has methodically investigated how non-immersive virtual reality (VR) might revolutionise diabetes care teaching for medical personnel in situations with low resources, particularly in Ajdabiya, Libya. This study shows that screen-based simulations can significantly improve clinical decision-making accuracy, reduce response times, and foster empathetic communication by filling a critical gap in experiential learning opportunities identified in previous research [7][28]. Based on design science methodology, the study combines theoretical frameworks from experiential learning and constructivism [16] with practical, context-sensitive solutions.

KEY CONTRIBUTIONS OF THE STUDY

Theoretical Contributions

This study undermines the widely held belief that immersive VR is required for effective educational results in healthcare training [7]. By combining experiential learning theory and constructivist principles, it presents empirical proof that non-immersive, screen-based simulations produce equivalent advances in clinical skills and empathy. For example, the 25.5% improvement in decision-making accuracy (Table 4.1) corresponds to [28] findings on VR's involvement in emergency preparedness, whereas the 7% increase in empathy scores (Table 4.2) corresponds to [7] immersive VR outcomes. This study builds on previous findings by demonstrating that cognitive engagement, rather than sensory immersion, promotes learning efficacy paradigm confirmed by [41].

Practical Contributions

The validated VR training module provides a replicable blueprint for institutions without immersive infrastructure. Participants' high usability ratings (SUS score: 81.5/100) and high engagement (M = 4.2/5) reflect that the tool is aligned with the user-centered design principles of [3]. By prioritizing accessibility (e.g., use on a standard desktop) and cultural relevance (e.g., Libyan clinical scenarios), the study addresses gaps in VR acceptance identified by [24][40]. These practical contributions are particularly important for settings such as Libya, where limited resources exacerbate challenges in diabetes management [23].

Technological and Engineering Contributions

From a technical perspective, this research advances the use of VR through modular architecture and responsive simulation logic. The tool design, developed in Unity and Blender, reflects Iancu et al., focus on standardized, scalable training platforms [21]. By showing how branching scenarios and consequence visualization can improve learning McCalla et al. [29], this research lays the foundation for future innovations, such as the hybrid VR-augmented reality model proposed by [34].

IMPLICATIONS OF THE STUDY

Clinical Practice

The 24% reduction in time-to-action during hypoglycemic coma simulations suggests that non-immersive VR can mitigate preventable complications-a finding consistent with Atkinson et al., work on emergency preparedness. For example, a nurse trained in VR could administer glucagon more quickly, potentially saving lives in time-critical situations [5].

Education and Policy

The feasibility of the tool supports its integration into blended learning courses, as suggested by G. Burdea and P. Coiffet, advocates [10]. Policymakers should prioritize funding for non-immersive VR in national strategies to address diabetes disparities, particularly in the Middle East and North Africa region where disease prevalence is high [23].

LIMITATIONS OF THE STUDY

While impactful, the study has limitations:

a. Generalizability: The single-center design and small sample ($N = 20$) limit broader applicability, echoing concerns from Iancu et al., [21].

b. Cultural Validity: Though scenarios were co-designed with local clinicians, formal cultural validation (e.g., adapting empathy scales to Libyan norms) was not conducted-a gap highlighted by Beverly et al., [8].

c. Longitudinal Data: The short-term evaluation window precludes conclusions about skill retention, a challenge noted in S. R. Colberg et al., [11].

RECOMMENDATIONS FOR FUTURE RESEARCH

a. Multicenter studies: Replicate this study at multiple diabetes centers with varying resources to evaluate the generalizability and robustness of the non-immersive VR intervention across different clinical and cultural contexts. These studies are critical because institutional infrastructure, staff composition, and patient populations can significantly impact the feasibility and educational impact of VR-based training, as suggested by Lee et al., [26].

b. Hybrid Models: Investigate the combination of non-immersive virtual reality (VR) with augmented reality (AR) technology and artificial intelligence (AI)-based feedback to create "hybrid" learning environments. Combining VR's cost-effective accessibility with AR's contextual overviews and guidance may increase the latter's realism, interaction, and cognitive commitment, particularly for difficult scenarios like insulin titration or diabetic foot assessment. This may improve the acquisition and retention of skills [34].

c. Culture Adaptation and Localization: Create and validate virtual reality training modules specific to cultural traditions, languages, and medical practices, such as the educational version of gestational diabetes or the care of the foot. The design of cultural scenarios and the capacity to empathise with others enhance the participation of the learner, acceptance of the training, and the transfer of skills to real-world situations; this decreases the likelihood of a cultural mismatch that would adversely affect the effectiveness of the training [43].

CONCLUDING REMARKS

This research demonstrates that medical education's innovation is not dependent on expensive technology. By focusing on thoughtful design and context-relatedness, non-immersive virtual reality (VR) emerges as a popular force in the education of global health. The research results increased clinical proficiency, effective communication, and institutional feasibility- demonstrate the potential of VR to bridge the gaps in diabetes care, specifically in underserved areas. As a computer scientist, this trip has illustrated the potential for collaboration between technology enthusiasts, doctors, and educators. It's my hope that this project will further promote the effort to create high-quality training that is accessible, portable, and human-oriented, changing the way diabetes is treated from a privilege to a universal standard.

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APPENDIX A

A.1: JEFFERSON SCALE OF EMPATHY (JSE) – HEALTH PROFESSIONS VERSION

The text below presents a sample excerpt from the 20-item Jefferson Scale of Empathy employed in the research. Respondents completed this instrument using a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree).

Instructions: Please indicate the extent to which you agree or disagree with the following statements:

a. Physicians should try to stand in their patients' shoes when providing care to them.
b. Patients feel better when their physicians understand their feelings.
c. It is difficult for a physician to view things from patients' perspectives. (R)
d. Understanding body language is as important as verbal communication in physician–patient relationships.
e. A physician's sense of humor contributes to a better clinical outcome.
f. Because people are different, it is difficult to see things from patients' perspectives. (R)
g. Attention to patients' emotions is not important in history taking. (R)
h. Empathy is a therapeutic skill without which the physician's success is limited.
i. Physicians should not allow themselves to be influenced by strong personal bonds with their patients.
j. I try to understand what is going on in my patients' minds by paying attention to their nonverbal cues and body language.
k. I believe that emotion has no place in the treatment of medical illness. (R)
l. Empathy is an important therapeutic factor in medical treatment.
m. Physicians should try to understand what is going on in their patients' minds by paying attention to their verbal and non-verbal cues.
n. Patients value a physician's understanding of their feelings, which is therapeutic.
o. Physicians should try to think like their patients in order to render better care.
p. I do not enjoy reading non-medical literature or the arts. (R)
q. I believe that empathy is an important quality for a physician to have.

r. I consider understanding my patients' body language as important as verbal communication.
s. I try not to pay attention to patients’ emotions in interviewing and history taking. (R)
t. I do not view empathy as a significant part of physician–patient interactions. (R)

Note: Items marked with (R) are reverse scored.

APPENDIX B

B.1: SYSTEM USABILITY SCALE (SUS)

The System Usability Scale (SUS) is a standardized instrument consisting of ten items, used to assess the perceived usability of a given system. Participants rated using a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Instructions: Please indicate the extent to which you agree or disagree with each statement:

a. I think that I would like to use this system frequently.
b. I found the system unnecessarily complex. (R)
c. I thought the system was easy to use.
d. I think that I would need the support of a technical person to be able to use this system. (R)
e. I found the various functions in this system were well integrated.
f. I thought there was too much inconsistency in this system. (R)
g. I would imagine that most people would learn to use this system very quickly.
h. I found the system very cumbersome to use. (R)
i. I felt very confident using the system.
j. I needed to learn a lot of things before I could get going with this system. (R)

Note: Items marked with (R) are reverse scored.