An Adaptive Game-Based Educational Tool for Maternal and Neonatal Health

By

Salome Monthe Chemiat

101169

Submitted as part of the requirement for obtaining a

Master of Science in Information Technology (MSc.IT) Degree at Strathmore University

School of Computing & Engineering Sciences

Strathmore University

Nairobi, Kenya

June 2025

Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Student Name: Salome Monthe Chemiat

Admission Number: 101169

Sign: _______________ Date: 18th May 2025

Approval

The thesis of **Salome Monthe Chemiat** was reviewed and approved for examination by the following:

Professor Ismail Ateya
Professor,
Strathmore University

Dr. Julius Butime,
Dean, School of Computing & Engineering Sciences,
Strathmore University

Prof. Bernard Shibwabo,
Director of Graduate Studies,
Strathmore University

Abstract

Globally, Maternal and Neonatal Health has become a critical topic of discussion due to high mortality rates in different countries. Despite ongoing efforts to handle the situation, preventable challenges persist in contributing to high rates of Infant and Maternal Mortality Rate (IMMR). In Kenya, the Neonatal Mortality Rate (NMR) stands at 21 deaths per 1000 live births, while the Maternal Mortality Rate (MMR) is reported at 530 deaths per 100,000 live births. In contrast, countries like Italy report much lower rates, with 1.76 neonatal deaths per 1,000 live births and only 12 maternal deaths per 100,000 live births. Education emerges as a critical factor in addressing these challenges, with studies indicating substantial differences in mortality rates between educated and uneducated women. One study highlights that Maternal Health Education (MHE) significantly influences child mortality, with uneducated mothers facing higher risks. Currently, MHE is on a need-to-know basis, either in accidental or planned pregnancies, school-based research or in professional setting. This study comes up with a proof-of-concept that utilizes gamification and artificial intelligence in the simplification of MHE delivery. The study designs an adaptive, game-based educational tool that is engaging, interactive, and context-specific. By increasing the accessibility and reducing the complexity of MHE content, the tool seeks to make maternal health education more widely available and easily understandable for the public. The research provides an overview of Maternal Health highlighting the challenges faced in addressing maternal and neonatal health issues. Additionally, the study explores the principles of game-based learning, examining how these strategies are currently being used in education and their potential to enhance MHE delivery. A methodology section has been outlined detailing how the study has been conducted. A design-based research (DBR) approach has been employed. The study focuses on the iterative development of a culturally adaptive, game-based educational tool for Maternal Health Education (MHE). The use of secondary data has been used to inform the design process, followed by prototyping and user testing to refine the solution. The study includes an implementation and analysis section that clearly explains how the pretrained LLaMA model was integrated to support the system. Additionally, the results section presents the outcomes of using FAISS as a Retrieval-Augmented Generation (RAG) methodology, along with an evaluation report where performance metrics such as precision, recall, and F1-score were each recorded as 1.0.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AI	--	Artificial Intelligence
CHV	--	Community Health Volunteer
CHW	--	Community Health Workers
ECG	--	Electrocardiogram
IMR	--	Infant Mortality Rate
IMMR	--	Infant and Maternal Mortality Rates
IoT	--	Internet of Things
KNN	--	K Nearest Neighbor
LMIC	--	Low- and Middle-Income Countries
MMR	--	Maternal Mortality Rate
MCH	--	Maternal and Child Health
MH	--	Maternal Health
MHE	--	Maternal Health Education
MHC	--	Maternal Health Care
mHealth	--	Mobile Health Technologies
MHK	--	Maternal Health Knowledge
MNH	--	Maternal and Newborn Health
MNCH	--	Maternal, Newborn and Child Health Care
NLP	--	Natural Language Processing
NMMR	--	Neonatal and Maternal Mortality Rates
SDG	--	Sustainable Development Goal

SVM -- Support Vector Machine

SSG -- Smart Serious Games

Definition of Terms

Term	Definition
Artificial Intelligence (AI):	Computer Systems that have been constructed to simulate human intelligence. These systems perform tasks that typically require human intelligence, such as learning, problem-solving, and decision-making (Dave & Patel, 2023).
Infant Mortality Rate (IMR):	This is the number of deaths of infants under one year of age per 1,000 live births in each population (Bugelli et al., 2021).
Gamified solution:	This refers to the use of gaming technology and principles for non-gaming context e.g. educational purposes, in this research, in the field of maternal health education (Laine & Lindberg, 2020).
Maternal Mortality Rate (MMR):	MMR is the number of maternal deaths per 100,000 live births from any cause related to or aggravated by pregnancy or its management (excluding accidental or incidental causes) (Maternal mortality rates in the United States, 2021 2023).
Maternal Health (MH):	This is the health of women during pregnancy, when giving birth and after birth ("Maternal Health," 2024).
Morbidity:	This is a condition where one suffers from a disease or has a medical condition ("Maternal Health," 2024).

OB-GYN: This a medical speciality covering obstetrics (childbearing, pregnancy and postmature) as well as gynaecology (the health of the female reproductive organ) (“Obstetrics and Gynaecology,” 2024)

Preventative Health Care: Health care that involves measures that prevent contraction of diseases (“Preventive Healthcare,” 2024).

Postpartum Hemorrhage: This is heavy bleeding of mother associated with birth (“Childbirth,” 2024).

Risk Mitigation in Childbirth: This is the process of identifying, assessing, and implementing strategies to reduce the likelihood or impact of adverse outcomes associated with pregnancy and childbirth (*What Makes a Pregnancy High Risk?*, 2023).

Targeted and Personalized Maternal Health Education: This involves tailoring educational interventions to specific demographics or individual needs of expectant or new mothers (Dave & Patel, 2023) .

Acknowledgements

I would like to express sincere gratitude to God for blessing me with good health, life, and Favor, enabling me to undertake this research thesis with a sound mind and great health. Furthermore, I extend heartfelt appreciation to my supervisor, whose invaluable advice and unwavering support have been instrumental throughout this journey. His willingness to listen to my ideas and provide constructive feedback has significantly enriched this process. I am also deeply thankful to Strathmore University for their dedicated provision of resources and unwavering support, which have facilitated the development of my ideas as I prepare to embark on the actual research. Lastly, I am indebted to my family and friends for their steadfast support, both financially and emotionally. Their encouragement and belief in me have played an integral role in bringing this idea to fruition.

Dedication

I dedicate this research to my beloved family, comprising my mother, Lucy Katilo Chemiat, my sister, Janet Amina Chemiat, and my brother, Nicholas Nasong'o Chemiat. Most significantly, I dedicate this work to the memory of my late father, Andrew Nasong'o Chemiat, whose unwavering support and unconditional encouragement fueled my endeavors. Additionally, I dedicated this work to my colleagues who turned to friends, Noela, Sandra and Faith who continually advised and helped in crafting my research. Their collective support has been the cornerstone of my journey.

Chapter 1 : Introduction

1.1 Background

The paradoxical nature of life that presents itself during one of the most natural occurrences, birth, is one to raise concerns. Globally, Maternal and Neonatal Health has become an important topic of discussion where permanence cessation of life happens even before it begins or when being formed (*SDG Target 3.1 Maternal Mortality*, 2024). With an estimated global population of about 8.2 billion, all in existence because of birth, one would assume that birth comes with zero complications (*World Population Clock*, 2024). However, this is not the case (*SDG Target 3.1 Maternal Mortality*, 2024).

In developing countries such as Kenya, the Neonatal Mortality Rate (NMR) stands at 21 deaths per 1000 live births, while the Maternal Mortality Rate (MMR) is reported at 530 deaths per 100,000 live births (*Maternal Mortality Rates and Statistics*, 2024). In contrast, developed countries like Italy report much lower rates, with 1.76 neonatal deaths per 1,000 live births and only 12 maternal deaths per 100,000 live births (World Bank Open Data, 2023). Table 1.1 clearly shows mortality rates between Kenya and Italy.

Table 1.1: Disparity of NMMR between Kenyan and Italy

Country	MMR	NMR
Kenya	355	18.42
Italy	12	1.76

Despite ongoing efforts to address the issue, high rates of preventable maternal and infant mortality persist, driven by factors such as inadequate access to timely healthcare, socioeconomic challenges, and poor educational backgrounds. One of the critical factors that stands out in addressing these challenges is education, with studies indicating substantial differences in mortality rates between educated and uneducated women.

Different studies have presented evidence of strong relationship between NMMR and education levels (Andriano & Monden, 2019; Vikram & Vanneman, 2020; Workie, 2023). Andriano and Monden, (2019) allude to an estimated reduction of 50% in IMR worldwide between 1970 – 2009, because of Maternal Health Education (MHE). Additionally, Workie, (2023), highlights that maternal education significantly influences child mortality, with uneducated mothers facing higher risks. Mensch et al., (2019) further states that an addition of only 1 year of primary education could have a potential impact on NMMR as illustrated in Figure 1.1. The Figure showcases distribution of maternal deaths by years of maternal education. The gap lies in translating education into a language that is culturally relevant, easy to understand, less sensitive and easily accessible.

Efforts such as printed materials, websites based content, radio programs and community health programs are often used in delivering education however, they struggle to engage populations, which is critical in sustaining motivation during learning as alluded Laine and Lindberg, (2020). Additionally, these types of methods leave out important people particularly younger individuals and men, who play a crucial role in maternal and child health decisions. The complexity of information, along with the lack of culturally relevant content, makes it difficult for these populations to effectively absorb and apply health information in critical situations (Putri et al., 2020).

The background clearly shows innovative solutions are needed to bridge these gaps. Game-based learning, which incorporates principles of engagement, interactivity, and contextualization, has shown promise in other educational fields and is increasingly being used to improve health education. Studies suggest that gamification can enhance knowledge retention, motivate behavioral change, and engage diverse audiences (Laine & Lindberg, 2020). However, the use of AI-powered, game-based tools in MHE remains relatively unexplored, particularly in the context of culturally adaptive solutions tailored to local needs.

This study seeks to design an AI-powered, adaptive, game-based solution for maternal and neonatal health education. By leveraging the engaging and interactive nature of games, this approach aims to make MHE more accessible, understandable, and appealing, particularly to hard-to-reach populations

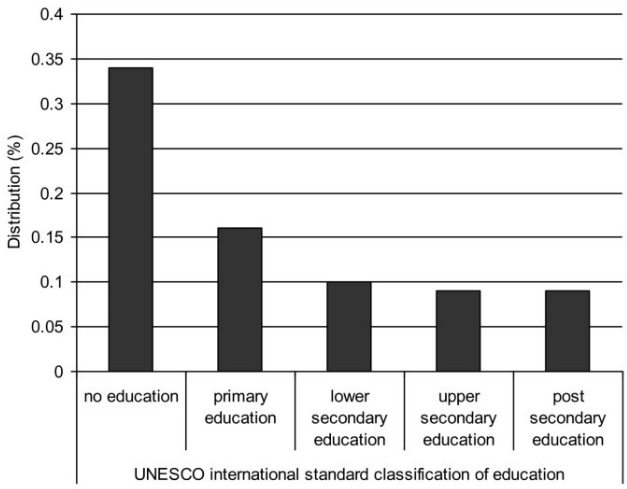

Figure 1.1: Distribution of MMR against Education.(Karlsen et al., 2011)

1.2 Problem Statement

Despite ongoing global and local efforts to improve maternal and neonatal health (MNH) outcomes, high rates of preventable maternal and neonatal deaths continue to plague many developing countries, including Kenya. In Kenya, the Maternal Mortality Rate (MMR) stands at 530 deaths per 100,000 live births, while the Neonatal Mortality Rate (NMR) is 22 deaths per 1,000 live births (World Bank, 2023). These rates are significantly higher compared to countries with more advanced healthcare systems. This disparity is largely attributed to the lack of effective health education and awareness around key maternal and neonatal care (Workie, 2023; Kiprotich et al., 2019; Olukade & Uthman, 2022). Figure 1.1 clearly explains the distribution of MHE against mortality rates.

Traditional approaches to maternal health education, such as printed materials, radio broadcasts, and community health worker-led sessions, have struggled to engage key target audiences, including men, younger individuals, and those with limited literacy (AlDughaishi et al., 2023 ; Sahoo et al., 2021b ; Kagia, 2013). These methods often fail to contextualize the information or make it accessible in a way that resonates with different people of different backgrounds (Lisnawati et al., 2024). Furthermore, educational content is frequently too complex, and when accessed through the internet, content heavy, leading to poor understanding and delayed decision-making in critical situations (Musiimenta et al., 2022). This clearly shows that there is a need for accessible maternal health education solution that is easy to understand, engaging, context-specific, simplified, and less sensitive in its approach.

1.3 General Objective

The study aims to develop an adaptive AI-driven game based educational tool as a proof-of-concept for improving maternal and neonatal health education with the aim of enhancing knowledge accessibility and promoting health-seeking behaviors.

1.3.1 Specific Objectives

i. Assess the link between maternal education levels and neonatal/maternal mortality rates (NMMR) in Nairobi.
ii. Evaluate current strategies addressing educational deficiencies impacting maternal and neonatal mortality rates in Nairobi.
iii. Develop an adaptive, AI-powered, game-based educational tool

iv. Evaluate the usability and feasibility of the proposed game-based solution as a proof-of-concept for integrating gamification and AI into maternal and neonatal health education.

1.3.2 Research Questions

i. What is the association between maternal education levels and NMMR?
ii. What are the current strategies addressing educational deficiencies impacting NMMR?
iii. How can an adaptive, AI-powered, game-based educational tool be designed to improve maternal and neonatal health education?
iv. What are the usability and feasibility outcomes of the proposed game-based solution as a proof-of-concept for integrating gamification and AI into maternal and neonatal health education?

1.4 Justification

Recent studies underscored the crucial role of education in addressing Maternal and Neonatal Mortality. However, MHE is highly sensitive, faces cultural biases, has dense content and is highly complex to understand. This research therefore stands out as being important as it addresses the issue of MNMR by ensuring MHE is readily, less sensitive, and easily understandable. Research from studies like Olukade and Uthman (2022), have presented evidence on the negative relation of education levels and MMR and NMR prove the importance of this study.

Additionally, with our objective based on coming up with an AI game-based solution for MHE, the sudden increase in technology, particularly in the field of mobile devices, allows for its adoption (Damaševičius et al., 2023; Zolfaghari et al., 2021). There has also been an adoption of game solutions for education—driven by factors such as motivation, entertainment, fantasy, curiosity, and the challenge presented (Laine & Lindberg, 2020). The integration of gaming elements into health applications offers a promising opportunity. This approach is particularly beneficial for maternal and neonatal health, where it can effectively engage users and provide crucial education and support while ensuring the topic is easy to understand and readily available.

1.5 Scope and limitations

The scope of this study encompasses the development and implementation of an AI-driven game based educational intervention focused on MNH for individuals aged 16 and above. The study adopts a needs assessment approach aimed at showcasing the gaps in existing MHE solutions particularly in the context of prenatal care. Since the aim of the research is to demonstrate the need for the solution, the relationship between maternal education levels and neonatal/maternal mortality rates have been assessed. Additionally, the study has evaluated current strategies addressing educational deficiencies impacting mortality rates and finally, the study tested the feasibility and effectiveness of the prototype in delivering targeted education.

However, the study had several limitations such as, the need assessment study focused on Nairobi, Kenya as a representation of a Low- and middle-income country, hence limiting the generalizability of the findings to other locations. Nairobi may find the system essential but other locations may need adjustments due to different factors. Additionally, factors such as access to technology, literacy levels and cultural beliefs, may influence the adoption of the system as well the effectiveness of the educational intervention.

The study's timeframe and resource constraints limited the depth and breadth of the research conducted, especially in testing the concepts. Although the system was tested by developers, the population did not necessarily test the meaning of the system, the effectiveness of the tool in practice remains theoretical at this stage. Future studies, such as longitudinal research, will explore the long-term impact of the tool on maternal and neonatal health outcomes.

Chapter 2 : Literature Review

2.1 Introduction

Maternal Health Education entails administration of maternal health information and resources to families, women and community (*Maternal Health Education | Pregnancy & Postpartum | Elevance Health*, 2024). The administration of MHE is essential in increasing the knowledge level of communities in relation to maternal health, promoting overall wellbeing of mothers during childbirth, delivery and postnatal period. Additionally, MHE boosts confidence of families and mothers during pregnancy and birth as women become more aware of their physiological and biological changes through pregnancy (Wulandari & Laksono, 2020a). MHE is particularly important as pregnancy is accompanied by many changes that need to be understood by mothers and families alike. Making informed health decision is important in ensuring there is a proper delivery plan, reduced costs and proper moral and emotional support (World Health Organization, 2024).

MHE entails four main important information sets which include: Firstly, Prenatal care where the information revolves around the importance of regular health check-ups, nutrition, exercise, and the different lifestyle choices during pregnancy that can affect the mother and baby ("Prenatal Care," 2024). Secondly, Labor and delivery preparation, this is the period during pregnancy. This is important in providing knowledge about the childbirth process, pain management options, and recognizing signs of Labor or complications ("Childbirth," 2024).

Thirdly, MHE has postnatal care which is the period after childbirth. It basically entails what best ways to take care of oneself and baby to ensure speedy recovery. Teaching new mothers about postpartum recovery, breastfeeding, newborn care, and recognizing potential health issues (Lopez-Gonzalez & Kopparapu, 2024). Finally, though not directly under pregnancy, family planning and contraception is also an important MHE guide. It allows women to make informed decisions about birth spacing and future pregnancies. MHE is critical in reducing maternal and neonatal mortality by empowering women with knowledge to take care of their health and make informed decisions (Wulandari & Laksono, 2020b).

2.2 Theoretical Literature and Basis Behind Gamification

One of the innovative solutions that have emerged as an approach in addressing Maternal Health Education (MHE) and efforts to reduce Neonatal and Maternal Mortality Rates (NMMR) is Game-based learning. With the advancement in technology, AI has emerged as a tool that can support game-based learning allowing for potential in offering tailored educational experiences that address gaps in traditional health education models (Laine & Lindberg, 2020). Game-based learning usually is divided into two main components: the Game and the Context. The game usually entails problems that players should solve based on different rules and objectives, whereas the context includes the setting elements in which the game appears. This may either be the plot of the game of the character (Safadi et al., 2015).

When AI comes in play as support for the game -based learning, it can support the Context or the Game as illustrated by Table 2.5, showcasing the differences. In context AI, AI focuses on supporting the game narrative and how the character interacts with the game. However, in game AI, AI is used to help the character navigate different game specific problems by focusing on the character's behaviors i.e., AI can make the enemy stronger in combating the player based on the move

Table 2.1: Summary of difference between Context AI and Game AI

Aspect	**Game AI**	**Context AI**
Focus	Solving gameplay-related problems	Enhancing narrative and character interactions
Example	Enemy AI in combat, pathfinding	Character reactions, plot progression
Goals	Create challenging gameplay	Developing immersive storytelling
Scope	Limited to game mechanics	Involves narrative and player choice

According to Safadi et al., (2015), serious games are normally focused on strengthening either the cognitive or the physical abilities of player based on the overall objective of the game. The study further explains that AI is uniquely tailored for individual game needs in that AI for a game like car race will be different from AI in strategy games. However, games with the same genre, can use basic AI behaviors that can be shared across different games as they often share common challenges. This is known as the conceptual AI illustrated in Figure 2.9. Many expectant mothers lack the comprehensive knowledge and decision-making skills required during pregnancy due to the poor traditional methods that offer MHE.

However, Game-based solutions, supported by AI, have the potential to address this gap (Sahoo et al., 2021a). One of the ways in which game based learning supported by AI has managed to achieve this is through learning based on scenarios ("Game Based Simulated Learning for Nurse Education," 2023). ASMAN is an example of game-based scenario learning that simulated real- world maternal health challenges for nurses to identify risks on a safe and virtual environment. The simulations from ASMAN allow nurses to practice decision making that is informed and safe. These situations can improve the nurses' response mechanism in case there is an actual challenge.

According to a study by (Laine & Lindberg, 2020), Behavioral Change through Reinforcement learning intervention has also shown promising result in keeping up engagement of the learning. Maslow's hierarchy of need supports this notion by breaking the hierarchy of needs in to five hierarchy the last one being self-actualization where one's need is in understanding and unleashing their full potential (*Maslow's Hierarchy Of Needs: What Is It?*, 2020). Reinforcement learning is a way to self-actualization as one learns not based on extrusive motivation but intrinsic motivations. By regularly engaging with game-based educational content, users are more likely to internalize key maternal health practices, leading to behavior changes that can positively impact maternal and neonatal outcomes.

Gamification has several positive contributions that contribute to motivation, and behavior change. These changes can be particularly important in education and the modification of behaviors. However, the psychological mechanisms behind gamification is not very thoroughly examined, lacking a comprehensive overview (Kirchner-Krath et al., 2021). Despite this, numerous studies have sought to connect different theoretical approaches to gain a deeper understanding of how gamification supports learning and motivation.

Several core principles in the theoretical perspective have emerged to explain how gamification works and its effects particularly in education. Main principles that guide gamification include: clear defined goal and their importance, guided paths through nudges, providing immediate feedback, reinforcing good performance, and simplifying complex tasks into manageable steps (Kirchner-Krath et al., 2021). Additionally, users in gamification are allowed to pursue individual goals that presents progress path that motivates users in completion. Gamification supports adaptation of the system to users' abilities mechanics. Social elements of gamification further enhance social comparison and collaboration towards shared goals (Kirchner-Krath et al., 2021). These principles can be particularly important when developing our system.

2.3 Empirical Literature Review

According to Mensch et al.,(2019), in public health, one of the strongest relationship established is between education and child mortality. He further alludes that numerous studies have shown an inverse relation between education and Maternal and Child Health (MCH). In this section, existing literature is explored to establish the link between NMMR and education level, the section will also take you through the different MHE intervention and their relation to NMMR as well as the different interventions that have come up so far and finally, game solution and AI in education.

2.3.1 Direct Impact of Education on Maternal Health

In Maternal and Child Health, the immediate consequence of attaining education is the increased improvement of their outcomes. Studies have been conducted not only showing the relation between maternal education but also paternal education level and its effects in NMMR. Balaj et al., (2021) alludes that even a single year of increased formal education such as primary level, can have an increased effect on the outcome's mothers and child health. Research indicates that educated women are more likely to use family planning methods, seek medical care for their children, and understand health-related information. For instance, mothers with primary education demonstrate better childcare practices, including seeking immunizations. Some of the studies that have showcased the inverse relation between MCH, and education levels include:

Balaj et al., (2021) incorporated data from 5339 unique records and 300 studies across 92 countries for a large-scale meta-analysis. In this study, a relationship was established between both maternal and paternal education level. The study was majorly focused on under-5 mortality in relation to education level. That said, the stronger predictor in this study was maternal education, with mothers that had 12 years of education compared to those with no education having a 31% reduction in under-5 mortality. A single additional year of maternal schooling was associated with a 3.04% reduction in child mortality. This study highlighted how significant MHE is in the reductions in child mortality, particularly after the neonatal period.

Similarly, in a different study, where mother's education was measured against the achievement of best practices in child care specifically, breast feeding, a direct link was observed (Laksono et al., 2021). The study found that exclusive breastfeeding practices were more likely practiced by mothers with higher levels. This is particularly important as breast feeding improves child health by reducing infections, and enhancing nutritional status, in turn reducing the IMR. The study further alluded that there was 1.167 times more likelihood for mothers who completed elementary school to exclusively breastfeed compared to those with no education. Additionally, those with tertiary education had 1.203 times more likelihood. This study underlies the critical role maternal education plays in shaping positive health behaviors.

Moreover, (Wulandari & Laksono, 2020a) highlights that there is a relationship between the danger signs knowledge of pregnancy and education level. In the study the likelihood was twice (1.973 times) for women with primary education in recognizing danger signs compared to those with no education. Additionally, those with secondary and higher education showed an even higher likelihood of around 3.355 and 7.169 times more likely, respectively. This is particularly important since when danger signs such as severe headaches, bleeding, and abdominal pain are recognized early, early intervention and prevention of maternal and neonatal complications can be adapted. Though the study also pointed out other factors as contributors to maternal knowledge gain, such as age, employment, and wealth status, education remained the most significant predictor.

In a different study by, Schnitman et al., (2022), 55 studies were analyzed where the studies focused on patient education through the digital filed. This education ran throughout pregnancy. The study reported that the majority (69%) of the studies had significant positive outcomes for maternal health. The intervention's primary benefits included an increase in Maternal Health knowledge (MHK) (83.3%), emotional support (73.7%), and changes in behavior (60.6%), especially during the prenatal period. The digital education was demonstrated through various formats such as text with images (40%), SMS (30.9%), and video (25.5%). These methods showed tremendous capabilities in effectively supporting maternal health by enhancing understanding of critical information. Notably, videos produced the highest rate of positive patient outcomes, although no statistical significance was found.

2.3.2 Education Interventions and Mortality Rates

MHE has currently been addressed through community outreach programs, face-to-face consultations, and printed materials but as technology adoption increased, different innovative solutions have been developed (Schnitman et al., 2022). There has been a couple of education intervention in Kenya that have proved lucrative in addressing education interventions with some being digital interventions while others having a more traditional approach of classes room structure, group-based and in person consultations (Laksono et al., 2021). The main aim of the different interventions was from a belief that education level is a contributing factor to NMMR. Some of the interventions have had positive outcomes for maternal and child health, generally reducing the overall NMMR. These include:

2.3.2.1 Traditional MHE Delivery Approaches - Community Health Workers Programs (CHWP)

In Kenya, the CHWP as supported by a group called the Community Health Volunteers. They deliver their service based on a defined geographical location known as a Community Health Unit comprised of 5000 people or 1000 households and are serviced by 10 CHVs (*Kenya's Community Health Volunteer Program*, 2020). In this intervention, CHVs as mandated by the government and based on their curriculum they support mothers with educative material during their home visits as well as make referrals and linkages to health facilities based on the mother's condition (*Kenya's Community Health Workers Shortage Undermines Universal Health Care*, 2023).

CHVs are significantly effective in serving as link between different health care systems and the pregnant women. They are critically positioned in the communities, allowing them to easily identify those in need of care. They also provide health education based on their training and recommend interventions where necessary. CHWS can effectively deliver essential information on infant care, antenatal care, immunization and nutrition where access to healthcare facilities is limited (Olaniran et al., 2019).

Olaniran et al., (2019) shows that CHWs with varying levels of training (ranging from 8 days to 3 years) are involved in different MNH responsibilities. For instance, those with more than three months of training provide therapeutic care, antenatal care, skilled birth attendance, and contraceptive services. However, CHWs with less than three months of training focus on community mobilization and patient tracking, which are essential for encouraging attendance at health facilities and follow-up care. This differentiation ensures that even minimally trained CHWs can contribute to MHE by reinforcing health-seeking behaviors and providing timely information.

CHWs are a key intervention for promoting maternal health education in underserved communities. Their close ties with the community allow them to deliver essential MNH services, especially in regions with limited healthcare access. However, optimizing their contribution requires addressing challenges related to training, scope of practice, and role clarity. Expanding their capacity through appropriate training and policy support can maximize their impact on maternal health education. Some initiatives have been brought up in Kenya to support CHWs such as the Chamas for Change Initiatives in Western Kenya (Maldonado et al., 2020).

The implementation of the intervention involved using Community Health Volunteers (CHVs), who were government sponsored in recruiting pregnant women. The CHVs basically, focused on women who were attending their first antenatal care (ANC) in rural health facilities as best candidates for the initiates. It was a prospective matched cohort where the women recruited enrolled in Chamas and every woman enrolled in chamas had to commit to attending group-based health education and microfinance sessions for one year. Table 2.2 shows the key insights from the initiative (Maldonado et al., 2020).

Table 2.2: Key activities of the Chamas for change Initiative

Key Activities and Results from Chamas for Change	
Key Activities	**Explanation**
Health Education:	In this activity, educational sessions that included the importance of facility-based delivery, prenatal care, breastfeeding, and postpartum support, were presented to the participants.
Microfinance Support:	The program also provided financial resources to help women access healthcare services and improve their overall economic stability.

Table 2.3: Results for the Chamas for Change Initiative

Results of the Chamas for change Initiative		
Outcomes	**Chamas Participants**	**Control Group**
Deliveries done in facilities	84.4%	50.4%
Attendance for Antenatal Care Visits	64.0%	37.4%
Breast Feeding Exclusivity	82.5 %	47.0%
Postpartum Care visit from CHV within 48 hours postpartum	75.8%	38.3%

In the initiative, the results point out that most of the participants exhibited lower rates of stillbirths, miscarriages, infant deaths, and maternal deaths compared to the control group, indicating potential improvements in overall health outcomes. Through the initiative, the odds of facility-based deliveries and positive health practices among participants have been encouraged and improved significantly. This clearly shows that though traditional in nature, any form on education delivery during pregnancy gives positive outcomes.

2.3.2.2 Digital MHE Delivery Approaches - MHealth Interventions

According to Walter et al., (2022), COVID-19 pandemic forced the medical field to reevaluate their MHE delivery methods and shift towards leveraging digital tools for maternal and neonatal health education. In this intervention, the usage of mobile health (mHealth) technology through mobile devices and wireless technology is leveraged in conveying MHE. This has been widely supported due to the growing use of mobile phones. This is particularly an advancement for MHE delivery as it removes confines of the delivery from the classroom or unnecessary visitations to clinics.

Sowon et al., (2022) alludes that mHealth has had major impact in mostly infectious diseases and maternal health. According to a systematic review that was focused on assessing the impact of mHealth on NMMR, (Bossman et al., 2022), mHealth interventions, particularly those using simple technologies like SMS and voice reminders, effectively support behavior change in pregnant women and healthcare workers. Babyscripts is a risk detection mobile application that curate's educational content. This application is linked to a Bluetooth-enabled (wearable device) that can monitor the mother's weight scale and blood pressure cuff, it then offers educational content based on the mother's monitored vitals (Walter et al., 2022 ; DeNicola et al., 2018).

Additionally, mHealth using SMS, can be used in reminder for ANC visits. Antenatal Care visits (ANCs) are particularly important in addressing MHE. A study conducted by Adeke Oramisi et al., (2019) aimed at showcasing the relation between SMS and reducing postnatal clinic not-attendance. This study main objective was to address the high rates of NMMR based on the failure to attend ANCs in Kenya. It did this through sending SMS reminders for antenatal care visits to the test group so they can attend all their ANCs. The effectiveness of SMS reminders in reducing failure-to-attend (FTA) rates for postnatal clinic visits at Pumwani Maternity Hospital, Nairobi was evaluated Table 2.3 further illustrates the concept.

Musiimenta et al., (2022) give examples of mobile interventions for MHE such as Safe delivery App, mMitra, MomConnent from South Africa GiftedMom from Cameroon and

TotoHelath from Kenya. All the applications mentioned are designed for maternal health education delivery for instance, Safedelivery is an application that contains basic guidelines that are easily accessible by health care workers in different modules. The app is mostly designed to guide CHWs in different areas particularly in safe delivery. The idea that mHealth has gained so much traction from its usage shows how effective digital solutions can be.

Table 2.4: Results of Failure to Attend (FTA) Using SMS Reminder

Result of SMS intervention to reduce FTA	
Period	**Outcome**
2 weeks	80% reduction
6 weeks	60% reduction
Main reason for FTA	Forgetting the appointment. Cited by 42.1% of women at two weeks and 41.7% at six weeks

The idea that one has a readily available MHE delivery platform through their phones makes work easier and reduces unnecessary costs. However, there are several issues that still hinders the adoption of mhealth in MHE such as system design, system usefulness, data management and user experience (*Journal of Medical Internet Research - Assessment of the Barriers and Enablers of the Use of mHealth Systems in Sub-Saharan Africa According to the Perceptions of Patients, Physicians, and Health Care Executives in Ethiopia: Qualitative Study*, 2024). In the case of the MHE the sensitivity is not necessarily addressed in the intervention (Laine & Lindberg, 2020) but still based on the different studies, it is evident that any form of MHE delivery to mothers has an impact on the overall outcome of the mothers and child's health.

2.3.2.3 Game Based Solution in MHE and NMMR

Game Based Solution also known as gamification is the application of designs from game principles in a context other than for entertainment or in non-game context (Damaševičius et al., 2023; Laine and Lindberg, 2020 ; van Gaalen et al., 2021). Game based solution were designed to tackle issues such as lack of motivation, poor concentration, low engagement and confusion in flow experience (Oliveira et al., 2023). Game based solutions have had a popularity in ensuring the motivation as engagement of learners. According to a study done by Laine and Lindberg, (2020), people desire to learn however, the challenge arises in keeping the motivation and engagement in learning.

Laine and Lindberg, (2020), allude games, as opposed to other forms of education delivery, have the capabilities of keeping the users engaged and motivated. The study describes motivation as the thing that keeps a learner engaged while learning and engagement as the response the learners have towards the learning process (the learner's involvement). The study further categorizes motivators as intrinsic and extrinsic. The study leans towards intrinsic as being the best engagement in learning (where one gets motivation intrinsically, e.g. curiosity, excitement and challenge) as opposed to extrinsic learning (Where motivation is based on extrinsic component such as money reward, fear of punishment or worry).

Game-based solutions in learning are based on intrinsic motivations as they allow for curiosity and excitement. This is specifically important in MHE as an understanding has been made regarding the relationship between education and MMR and NMR (Laine & Lindberg, 2020). However, the challenge lies in finding education delivery methods that are easy to understand, engaging as well as motivating. In this section we will go through the different game-based solutions in MHE and their impacts in MMR and NMR as well as knowledge levels of the individuals.

In MHE, Gamification has been used in various context with different studies explaining their prominence and impact in the field. Lisnawati et al., (2024) – enhancing antenatal knowledge through gamification - is a notable game application example developed to enhance antenatal care and midwifery services. In the study, pregnant women's knowledge was assessed against the how well the application's usage impact. In the game, quizzes were featured after educational videos being watched. The assessment was based on how fast and accurate the pregnant women gave answers after watching the different educational videos on the app as illustrated in Figure 2.1 showing the flow of the game.

Results of the application were presented as follows: There was a 50 % improvement with the pregnant women's knowledge level from pretest to post-test scores with pretest scores ranging between 10 and 25, while post-test scores ranging between 25 and 29. The statistical analysis confirmed a significant correlation between the use of the app and the improvement in mothers' knowledge scores.

In a different study by (Lewey et al., 2022), an assessment of a digital health intervention leveraging gamification was conducted. The aim of the study was to check if the intervention will enhance physical activities in postpartum women with hypertension that leads to cardiovascular risks. From the intervention, participants in the intervention group showed a significantly greater increase in mean daily steps from baseline compared to the control group.

The adjusted difference was 647 steps per day (P = 0.009), indicating the intervention's positive effect on physical activity levels.

In a different study by (Putri et al., 2020) on Game based solution using a folklore game, snakes and ladder modified to an education based game, it was noted that the game had a high impact on the mother's knowledge and attitude towards ANC. ANC is important as it allows for early detection of risks to mothers as well as provides the best guidelines during pregnancy that allows for low morbidity and mortality rates. Although the game provided a positive outcome, this was not a digital game. It was a large carpet that had bright colors that allow it to be attractive and exciting allowing for higher motivation in learning. Figure 2.2 further showcases the game design of the study.

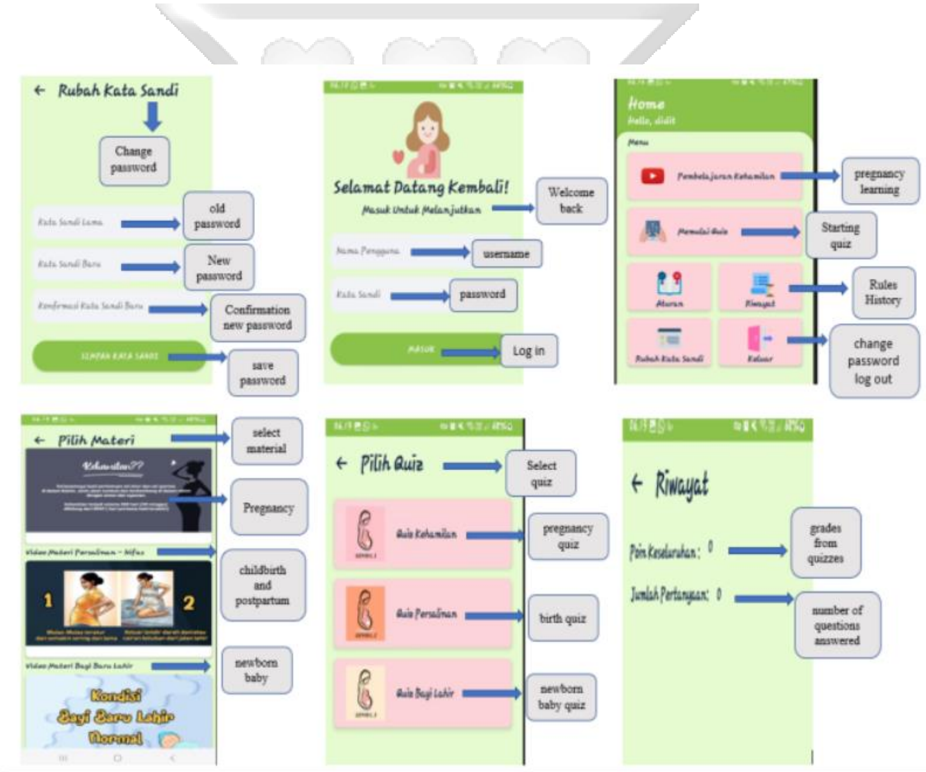

Figure 2.1: Flow of enhancing Antenatal care Knowledge Game.(*Lisnawati et al., 2024)*

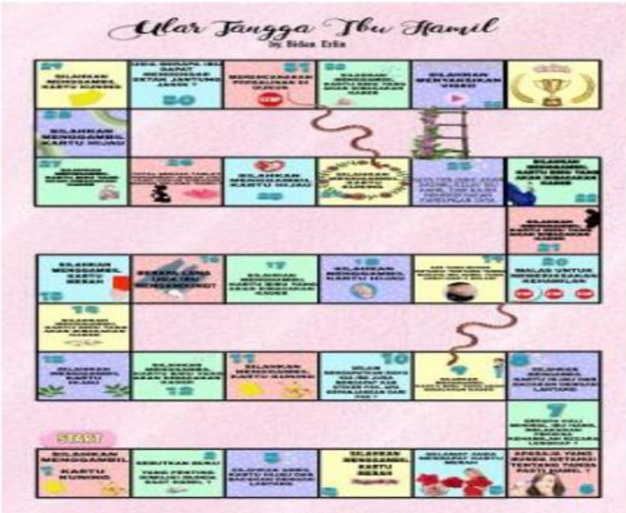

Figure 2.2: A Snakes and Ladders Game for Pregnant Women.(Putri et al., 2020)

2.3.2.4 AI in MHE and NMMR

AI is the development of intelligent machines or models that normally try to imitate human intellect. It is branch of computer science and has models that can perform various tasks that are normally closely related to human intellect such as decision-making, predictions, learning, thinking among others (Khan et al., 2022). To achieve the mimic of human intellect a branch of AI known as Machine Learning (ML) plays a huge role. To develop intelligent algorithms, ML utilizes several tools and techniques and can be divided as supervised, un-supervised, semi-super supervised or reinforcement learning. Basically, ML algorithms are usually trained on large datasets. These algorithms analyses and evaluate the dataset then the outcome of the analysis is applied to make judgement. In Figure 2.3, a simple roadmap on an AI based system is presented to show how the models are constructed, evaluated and trained using preprocessing methodologies on trained data. It further explains the real-world testing on the developed framework.

Khan et al., (2022) describes several applications of AI as used in MHE for reduction of NMMR. The applications are based on the timely managed of maternal health issues such as preterm deliveries, miscarriages, gestational diabetes, heart disease and postpartum depression as outlined in Figure 2.4: One of the application Khan et al., (2022) suggests is monitoring the mothers during gestational periods.

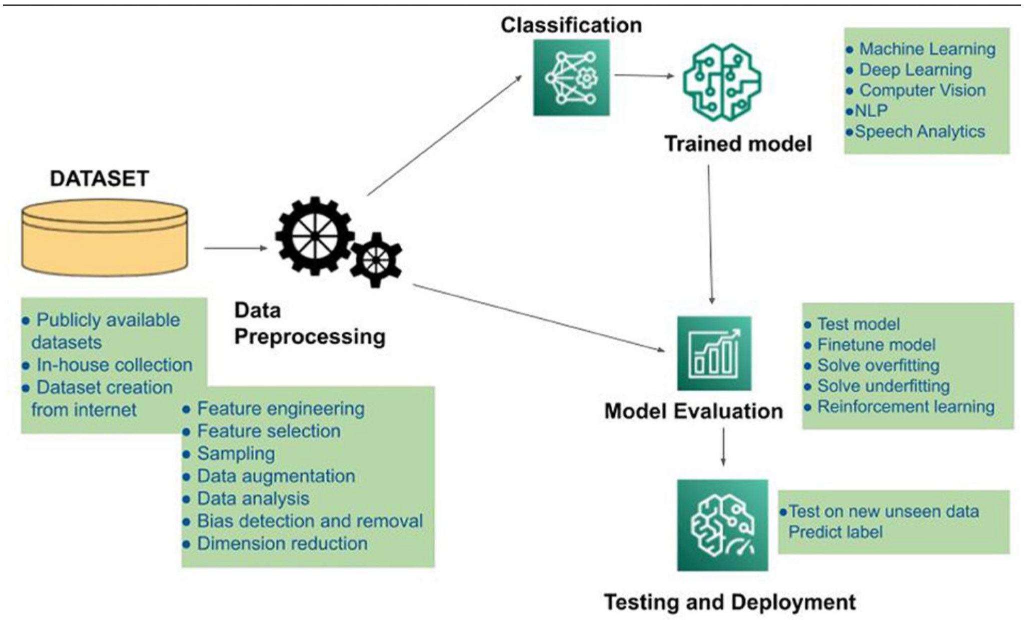

Figure 2.3: Different Sets of AI based Systems(Khan et al., 2022)

During pregnancy, many women face a risk of hypertension where transportation of blood can be inhibited due to factors such as arteries and veins being swollen. This then leads to pre-term deliveries and pre-eclampsia that can in turn lead to NMRs. By incorporating AI with IoT smart wearable systems can be created that can help in real-time monitoring of mothers to check if there is risk of hypertension.

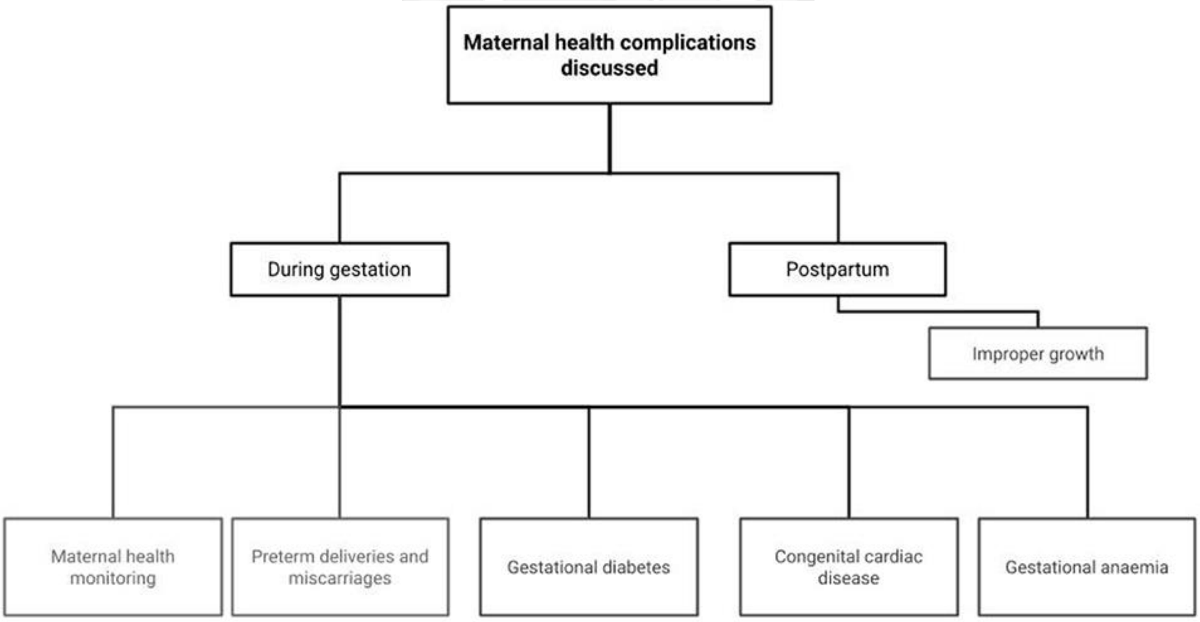

Figure 2.4: Role of AI in MHE.(Khan et al., 2022)

Additionally, Khan et al., (2022) further presents a use of AI in the prediction of risks such as preterm deliveries, miscarriages, and gestational diabetes. The study points out a significant application as the prediction of pre-term deliveries. The machine learning model utilizes the analysis of proteomic and metabolomic data from pregnant women, to predict preterm birth with notable accuracy. AI also contributes to the detection and management of gestational diabetes, a condition that arises due to deficiency in insulin (Khan et al., 2022). To achieve prediction in gestation diabetes, neural networks and machine learning algorithms are utilized predictions are made as early as the first trimester, based on factors like family history, age, and blood glucose levels. These predictive models help tailor early interventions, reducing the long-term health risks associated with diabetes in both mothers and their babies.

Moreover, Artificial intelligence (AI) is increasingly being utilized to address gaps in diagnosing and predicting postpartum depression (PPD). Models here analyze data from electronic health records, social media activity, and wearable devices to identify patterns and risk factors associated with PPD. These AI systems analyze both behavioral and physiological markers, such as sleep patterns, mood changes, and social interaction levels, to flag at-risk individuals earlier than traditional methods. This proactive approach allows for timely mental health interventions, which can significantly improve outcomes for both mothers and their newborns.

Additionally, AI plays a major role in neonatal health to manage high risk conditions such as jaundice, pain assessment, sepsis and malnutrition. This is majorly done through assessments automation and prediction. For pain assessment, facial strain has been used to assess the pain in infants (Zamzami et al., 2015). Classifiers like k-nearest neighbors (KNN) that achieved a high accuracy of 96% and Support Vector Machines (SVM) were utilized. Zamzmi et al. (70) extended this with a multimodal pain assessment approach that incorporated vital signs alongside facial expressions, increasing the overall accuracy to 95%. (Salekin et al., 2019) further explored combining facial expressions and body movements in their model, achieving 92.48% accuracy using a Long Short-Term Memory (LSTM) network. Khan et al., (2022) further presents a study that utilized SVM and K-Nearest Neighbor (KNN) to predict late onset sepsis.

In a different study by (Silva et al., 2024) , AI was integrating in telemedicine to achieve personalized health care and self-management. Different health parameters were acquired in the systems of the patient such as weight, blood pressure, nutrition, physical activity and mental health. These parameters were then used to provide a personalized health care plan and detect or predict complications on mothers. AI technologies are enhancing neonatal and maternal health by offering tools for early detection, assessment, and monitoring of critical conditions. However, despite the potential benefits, AI also faces a couple of challenges such as biases in algorithms, privacy issues and human oversight.

2.3.2.5 Game Based Solution in MHE and NMMR Supported by AI

Combining the two innovative solutions, game-based and AI can be revolutionary. This has been made possible largely due to the rise in technology usage and its adoption (Dave & Patel, 2023). One of the use of the integration of AI in to serious games is for the delivery educative materials (Abd-alrazaq et al., 2022), specifically, several solutions have come up as educational intervention aimed at addressing maternal health education (MHE) and reducing neonatal and maternal mortality rates (NMMR). By leveraging engaging and interactive elements of serious games and utilizing AI's ability to personalize and adapt content, health knowledge and behaviors among pregnant mothers and healthcare providers have been improved (Khan et al., 2022).

As opposed to traditional methods of education delivery, which are sometimes inaccessible due to infrastructure and financial problems as well as less engaging, (Lisnawati et al., 2024), the integration of gamification into maternal health education creates an engaging learning environment where users can interact with realistic scenarios, make decisions in virtual settings, and receive feedback on their actions (Laine & Lindberg, 2020). By focusing on core areas of antenatal care, Labor, and postnatal care, a game-based solution can offer; Risk Scenarios such potential health risk experiences either during pregnancy, Labor or postpartum period can be simulated. This in turn helps mothers recognize danger signs early (*AI for Assisting NGOs in Improving Maternal and Child Health Outcomes*, 2023). Additionally, the solution can offer interactive learning where users can practice safe decision-making through virtual environments. This can be made possible in game solutions that cover key health topics like nutrition, vaccination, and hygiene in an engaging format (Savareh & Bashiri, 2024).

The main importance of AI in the integration would be personalized feedback based on the player's responses, learning pace, and comprehension (Khan et al., 2022). Players can be evaluated in real-time by understanding their knowledge levels as well as making efforts to improve on the same. AI can also track progress, adapt challenges to the user's ability level, and provide reminders about important health milestones, such as prenatal visits. The expected outcomes of implementing a game-based solution in MHE include: Maternal knowledge being improved where mothers and caregivers can become more aware of antenatal risks, healthy pregnancy practices, and the importance of early detection of complications (Wulandari & Laksono, 2020b).

Additionally, changes in behaviors such as encouragement and confidence in mothers can be attained (Lisnawati et al., 2024). Moreover, healthier behaviors such as making informed decisions, and seeking timely healthcare services, which are crucial for preventing complications during pregnancy and childbirth can be adopted. Finally, Serious games can help in the Reduction in Maternal and Neonatal Mortality Rates as reported by (Lisnawati et al., 2024). Increased knowledge and better health practices, fostered through gamified learning and AI-driven feedback, have the potential to lower maternal and neonatal mortality rates by empowering mothers to take proactive steps in managing their health.

By using this innovative approach, existing gaps such as the lack of engaging and accessible content are handled. This is made possible by the capability of the model to deliver interactive and personalized education (Savareh & Bashiri, 2024). Additionally, it overcomes barriers like limited access to healthcare professionals or traditional learning resources by offering a digital platform that can be widely accessed, especially in regions with high mobile penetration (Sahoo et al., 2021b) .

Examples of game-based solutions supported by AI for MHE include: Bodhi Health's Game-Based Learning (*About Bodhi Health*, 2020). This is a game-based learning used to train labor room nurses and midwives in remote areas of India to handle complicated childbirth cases effectively, aiming to reduce maternal and child mortality rates. Bodhi Health developed an interactive game that simulates real-life complications during childbirth. Participants engage in problem-solving by performing assessments, making diagnoses, and managing cases based on evidence-based practices. Deployed under Project ASMAN, the game has reached over 2,000 healthcare providers across two Indian states. It features multilingual support, adaptive learning paths, and a leaderboard to foster competition among participants. The game has been recognized for changing how clinicians approach childbirth complications

Another example is the SAHELI AI System that was developed to optimize outreach efforts by health workers in improving maternal and child health outcomes (Verma et al., 2023). The SAHELI system utilizes a Restless Multi-Armed Bandit (RMAB) framework to identify beneficiaries who require assistance. This AI-driven approach allows for efficient resource allocation among limited healthcare workers. Impact: In partnership with the NGO ARMMAN, SAHELI has reached approximately 100,000 beneficiaries and is on track to serve 1 million by the end of 2023. The system has demonstrated significant improvements in engagement metrics, showcasing the effectiveness of AI in public health settings

2.4 Frameworks / Models for Education Delivery

There are a couple of frameworks and models that have been used in achieving the best gamification results as well as utilization of AI in education.

2.4.1 The three paradigm – Artificial Intelligence in Education

According to Ouyang and Jiao, (2021) there are several ways in which AI interacts with and supports learners that can be adopted when created an AI based supported system. These ways are defined as paradigms based on educational theory and have transformed the role of both AI and learners over time. They include AI-Directed, Learner-as-Recipient, AI-Supported, Learner-as-Collaborator and finally, AI-Empowered, Learner-as-Leader. The three define the three different frameworks used in AIiED over a period respectively from oldest to newest.

AI-Directed, Learner-as-Recipient In this paradigm, learners learn passively. There is very minimal interactive between AI and the learner. AI becomes a directive role presenting structure content to users and guiding the learners in a particular pathway (Ouyang & Jiao, 2021). This was the first paradigm suggested when AI was introduced in education, it was the earliest paradigm before the evolution of the second paradigm, AI as a collaborator. Here there were very little interactions from the learners with the models and basically learners were viewed as passive receipts and AI utilized as directive instructors. AI already had predefined guidelines on the best way to follow during content delivery.

AI-Supported, Learner-as-Collaborator as AI technology. In this paradigm, a shift from AI having predefined guidelines and pathways happened and the idea of introducing AI as a collaborator came in (Ouyang & Jiao, 2021). Here, AI supports learning by acting as a collaborator with the student. Learners engage in active participation, working alongside AI to enhance their educational experience. Here, AI systems are designed to facilitate problem-solving, provide real-time feedback, and support learning activities where students are collaborators in their education. The AI serves as a tool to scaffold learning, with the learner contributing to the process rather than being a passive recipient.

AI-Empowered, Learner-as-Leader In the most recent paradigm, AIEd aims to empower learners to take control of their own learning journeys. AI enables personalized learning experiences, where students actively lead their educational processes. In this paradigm, learners are not just collaborators but decision-makers who guide their learning with AI as a support system. AI tools dynamically adapt to the learner's needs, preferences, and progress, creating a personalized and iterative learning environment. Students are encouraged to reflect on their learning, provide feedback to the AI system, and take agency in directing their educational experiences (Ouyang & Jiao, 2021).

The integration of AI in education, particularly in game-based learning environments and health education, such as in maternal health, offers a powerful tool for both formal and informal learning settings. It provides the potential for adaptive learning experiences that meet individual learners' needs, thus empowering them to take an active role in their education.

2.4.2 Gamification of Learning

Gamification of learning is the application of game design elements and principles in non-game contexts to enhance engagement and promote learning. In educational settings, gamification incorporates game mechanics, such as points, badges, leaderboards, and timed performance, to motivate and reinforce desired behavior's and knowledge acquisition (Laine & Lindberg, 2020). According to research, gamification typically relies on three key elements:

Firstly, Game Dynamics: This refers to the behaviors, interactions, and overall experiences that the game facilitates for the player. It includes player engagement, decision-making, and social interactions that occur as part of the gameplay. In maternal health education, dynamics could involve simulated decision-making processes regarding prenatal care or recognizing danger signs during pregnancy(Laine & Lindberg, 2020). Secondly, Pedagogical or Instructional Design: The design of the game's educational content is critical. The game must be tailored to the learning objectives, ensuring that the player acquires the desired knowledge or skills. For example, modules in the game-based solution could focus on antenatal care, Labor, and postnatal care, delivering content in an interactive and engaging format.

Finally, Game Mechanics: These are the procedures, rules, and feedback systems that guide the player's actions and learning progress. The mechanics include scoring systems, levels, and challenges that motivate the player (Laine & Lindberg, 2020). In the context of maternal health, players could earn points for correctly identifying symptoms or making informed decisions about prenatal care. Various types of serious games exist, depending on their therapeutic or educational purpose such as Exergames: These are video games that incorporate physical activity, motivating users to engage in fitness while playing (Laine & Lindberg, 2020).

Although not directly relevant to maternal health education, the principles of activity-based engagement could be applied in educating mothers on physical wellness during pregnancy. Another example is cognitive behavioral Therapy Games: These games offer structured approaches for the player to recognize and address negative thoughts and beliefs, promoting mental well-being. In maternal health, similar games could help mothers cope with stress or anxiety related to pregnancy (Abd-alrazaq et al., 2022).

Cognitive Training Games are also another example of education-based games. These games aim to enhance cognitive abilities, including memory and executive function. For maternal health education, cognitive training can improve knowledge retention and decision-making capabilities during pregnancy. Gamification in learning should affect three major components with individuals such as learning, behaviors and motivation. This is further illustrated in Figure 2.5. Finally, biofeedback Games are games that use sensors to monitor physiological responses, such as heart rate, and allow players to control their physical states. Such biofeedback mechanisms could potentially be used to help mothers manage stress or anxiety during Labor or other critical moments in pregnancy (Abd-alrazaq et al., 2022).

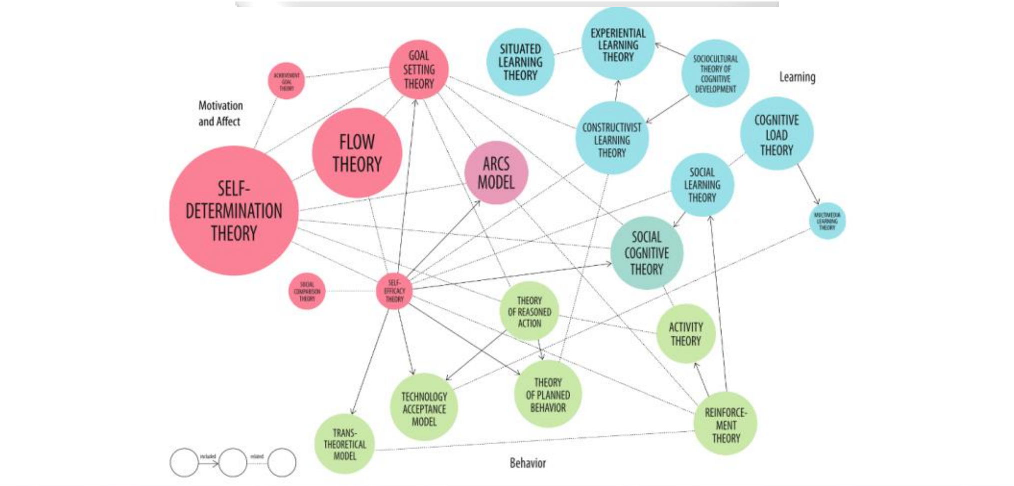

Figure 2.5: Factors affected in Gamification of learning.(Kirchner-Krath et al., 2021)

2.5 Architectural Designs in Games Based Solution for Education Delivery

2.5.1 Introduction

An architectural design is a process of visually representing all elements that make a system or part of it (*What Is an Architecture Diagram, and Why Do You Need One?*, 2022). In this section, we will explore architectural design first in AI as a supporting tool in problem solving and then AI in game development.

2.5.2 Architectural Design AI as a Supporting Tool

Khan et al. (2022) proposes comprehensive architecture that encompasses the AI system's data collection, preprocessing techniques, training, evaluation, and testing processes, which can serve as a foundational framework for other solutions. Figure 2.3 further illustrates the comcept. This architecture highlights the steps AI models follow to make judgments and predictions about real-world events, providing a clear roadmap for integrating AI into various solutions. The proposed architecture gives a step-by-step guide on achieving an accurate AI model by highlighting the different important aspects required in the development of an AI model.

Another architecture that is worth exploring is by (Silva et al., 2024) who further explores AI in telemedicine and its incorporation in a chatbot (Figure 2.7). The architecture contains different modules that have been integrated together to achieve a specific functionality in this case, supporting expectant mothers through their pregnancy journey. In total it had 6 modules i.e. user interface that contains a conversational chatbot, chatbot and NLP, for the understanding of text and queries allowing for answer generation, a personalized engine for personalized responses based on the users data, data management for secure data management, telemedicine integration where based on the chatbot response, one can remotely consult with health care providers and finally, health modules for the specific topic focus. The idea behind the solution was to increase patient engagement as well as early diagnosis of risky symptoms.

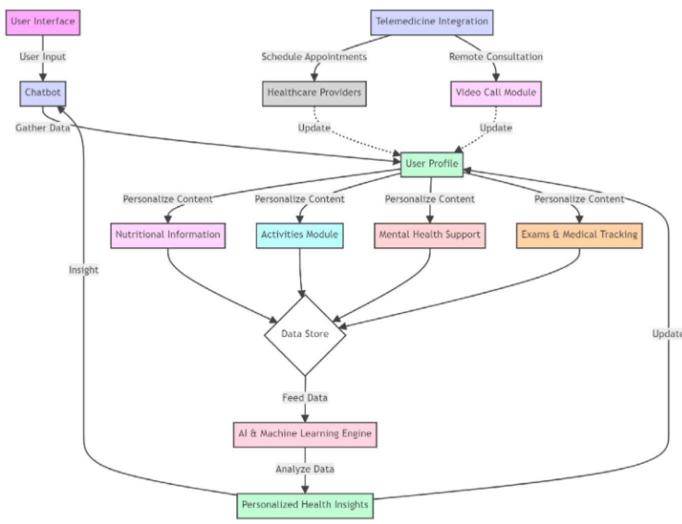

Figure 2.6: Architectural Design for AI various mHealth solutions.(Silva et al., 2024)

2.5.3 Architectural Design AI in Game Based Solution

Now that we have discussed the general integration of AI into various solutions, it is essential to explore how AI can be applied to support game-based learning. One example is the

EMOTE project, which focuses on developing robotic tutors designed to interact empathetically with students in a shared environment (Sequeira et al., 2015). In this project they created a modified version of EnerCities (EC) that was based on building an energy city that is sustainable. It involves three players, mayor, environmentalist and economist that can control different decisions that contribute to the development of the city. Based on the different decisions made by the human players, the AI module communicates with both the robotic tutor's decision-making module and the multilevel collaborative EnerCities (MCEC) game engine.

This then allows for real-time decision making based on the human players allowing for the robotic tutor to give suggestions based on the player’s moves. Such systems emphasize the importance of integrating AI into game mechanics, where the AI not only responds to player input but also guides behavior by simulating real-world challenges. Communication between the AI's decision-making module and the game engine is key to maintaining the game's educational focus, ensuring that players are consistently encouraged to make decisions that reflect real-life sustainability challenges showcased in Figure 2.7.

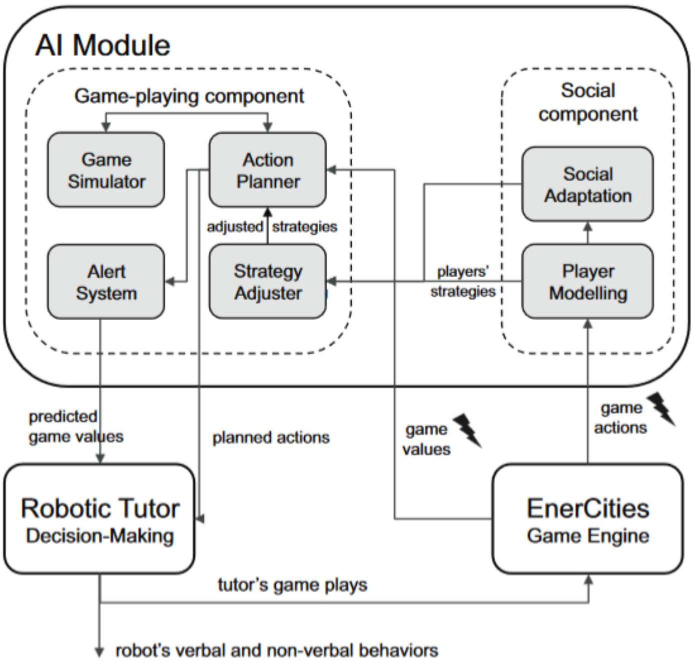

Figure 2.7: Architectural design "Let's Save Resources!".(Sequeira et al., 2015)

Another architecture by (Ahmad et al., 2022), is presented to support a Smart Serious Game (SSG) prototype that intersects physical and cyber spaces through the integration of different technologies. In the SSG, the game influence is based on the players' real-world actions captured through sensors and processed within a digital platform. In the proposed architecture for SSGs in health care, the first pillar is formed by Application Management also known as the Client Interface module. The module consists of four main modules that include Game Composition, Player Management, Device Management and finally Action Management. Game Composition is supported by natural language processing (NLP) to generate game episodes, goals, and winning criteria based on game requirements and player objectives while the Player Management: Handles player registration, tracking, and penalties. During play, players use Restful API to access the IoT sensors that will influence the digital game.

The Device Management that Manages IoT devices. And finally, Action Management generates actions based on game parameters (episodes, goals, penalties) and shares relevant data with the data management layer, which is the second pillar of architecture. These components work together to expose various data such as actions, penalties, player scores, and IoT device data for further processing.

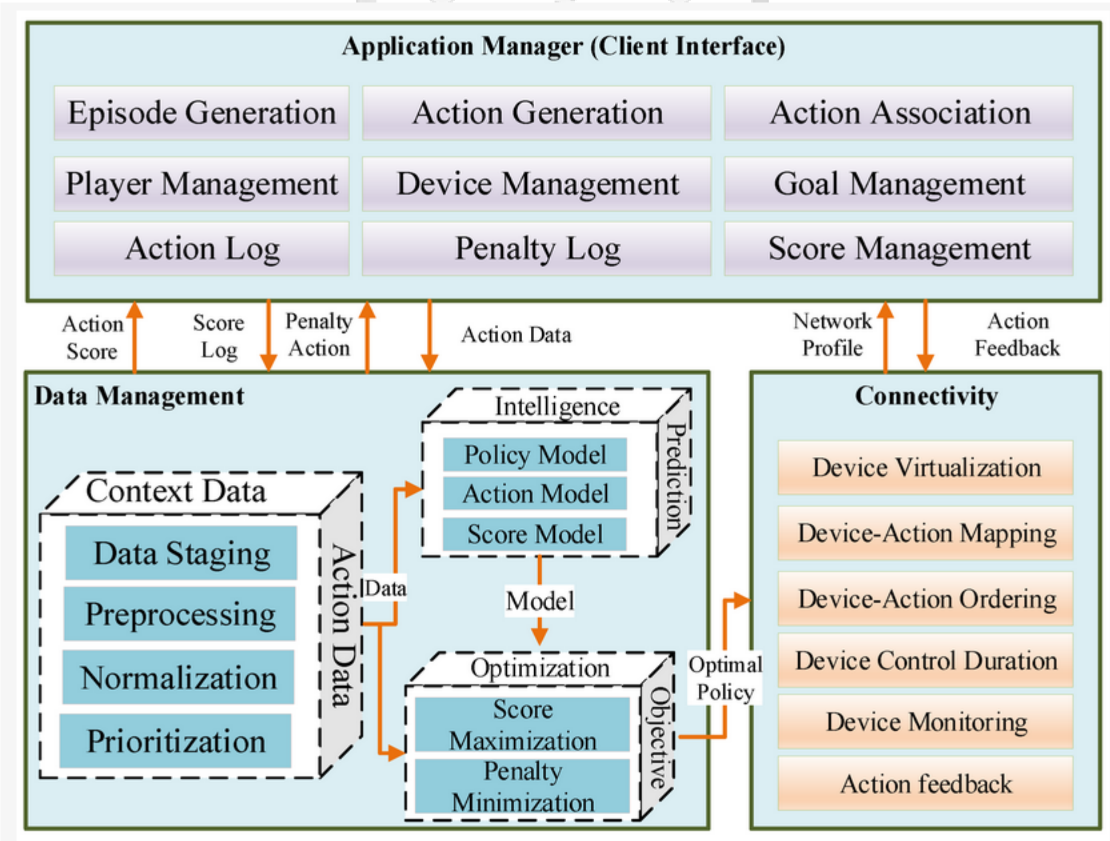

Figure 2.8: Serious Smart Game Architectural Representation.(Ahmad et al., 2022)

A different architecture worth examining is a study by (Safadi et al., 2015), where the focus was on examining how to create a unified framework known as conceptual AI where game elements and interaction are represented in abstraction. This allows for reuse of AI models in gaming context. Architecture can be understood as a system of **conceptual views** and **conceptual controls**, which interact with the **conceptual data space.** Conceptual Data Space: This is where the game stores its internal state in a form that is meaningful for the AI. Instead of game-specific objects (like a specific weapon or spell), the data space contains more general concepts such as "melee combat" or "long-range attack." Conceptual Views: These are projections or interpretations of certain parts of the game state into this conceptual data space. For example, instead of identifying a character as a "wizard," the AI sees it as a "ranged combatant." Conceptual Controls: These define how the AI influences the game, issuing abstract commands based on conceptual data. Instead of ordering "use spell X," it might issue a command like "perform ranged attack."

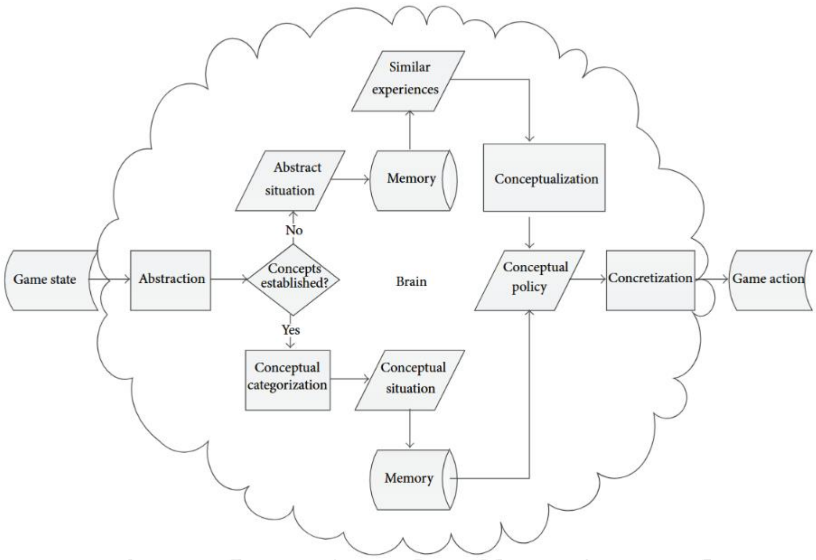

Figure 2.9: Unified Framework for AI in Video Game Solution.(Safadi et al., 2015)

2.6 Algorithms for Game-Based Educational Tools

Based on given alternative, algorithms are set of rules or instructions that are used to complete certain tasks of solving specific problems. In relation to game-based learning, supported by AI there are specific algorithms that have been used in various ways to achieve different solutions. When selecting algorithms for game-based learning supported by AI, the primary goal is to enhance the learning experience while ensuring ethical, effective, and personalized outcomes (Gorman et al., 2024). AI algorithms in this context need to offer adaptability to different learning styles, real-time feedback, and intelligent content delivery(Gorman et al., 2024).

The section contains a focused discussion on key algorithms used in AI-supported game-based learning, with a special emphasis on their roles, strengths, and applications: Decision

Trees are widely used in educational games for their simplicity and transparency. This algorithm is particularly valuable in game-based learning because it creates easily interpretable rules that adapt to learners' actions within the game (Gorman et al., 2024). Role: Decision Trees help personalize the learning journey by guiding players through different game scenarios based on their answers and performance. Transparency and interpretability are some of the algorithm strengths where it can be visualized, making it easier for educators to explain decisions to students or parents. It can be used to assess a learner's progress, identify knowledge gaps, and offer appropriate challenges or learning materials at various stages of gameplay (Gorman et al., 2024).

Random Forests build on Decision Trees by using multiple trees to improve accuracy and reduce overfitting. This makes it a more robust option for larger datasets or more complex game dynamics (Gorman et al., 2024). In AI-powered educational games, Random Forests can identify patterns in player behavior and learning outcomes to tailor the game experience to individual needs. It Offers higher accuracy and can handle large, complex datasets while still maintaining some level of transparency. In adaptive learning environments, Random Forests predict player learning styles and preferences, adjusting game difficulty or suggesting new tasks accordingly(Gorman et al., 2024).

Reinforcement Learning (RL) is particularly suited to game-based learning due to its focus on trial and error. In RL, the AI learns to make decisions through continuous interaction with the game environment, receiving rewards for correct actions and penalties for mistakes (Gorman et al., 2024). RL can adapt gameplay dynamically, offering challenges that evolve with the player's learning curve. It encourages learning by rewarding progress and providing penalties for incorrect answers, improving engagement (Gorman et al., 2024). RL has high adaptability and flexibility where it learns directly from the environment, which is key for open-ended, exploratory learning games. Often, it is used to design intelligent tutoring systems, RL adapts game difficulty, pacing, and content delivery based on the player's skill level and performance during gameplay.

Neural Networks, specifically Deep Learning models, are used in game-based learning to recognize complex patterns in user interactions (Gorman et al., 2024). Though less interpretable, these models excel at predicting and personalizing learning paths based on vast datasets. Neural Networks in educational games analyses large volumes of player data to provide precise insights into learning styles and performance. It is exceptional at capturing nuanced patterns in learner behavior, making them effective for tailoring complex, personalized learning experiences (Gorman et al., 2024). It is used to predict how players will perform in future tasks or to personalize content delivery on a granular level, though they require significant data and computational power (Gorman et al., 2024).

Bayesian Networks use probability theory to predict learning outcomes based on past data, making them useful in educational games that need to handle uncertainty and incomplete data (Gorman et al., 2024). These networks help predict the likelihood of a learner succeeding or failing at a task based on their previous interactions, allowing the game to adjust content dynamically(Gorman et al., 2024). It is good for decision-making under uncertainty, interpretable in terms of probabilities. Ideal for scenarios where the game needs to adapt in real-time based on uncertain or partial input from the learner.

KNN is a simple, instance-based learning algorithm that classifies players' actions based on their proximity to previous learners' behavior(Gorman et al., 2024). KNN can group learners with similar performance profiles, allowing the game to recommend challenges and tasks that have worked well for learners with similar abilities. It is easy to implement, highly interpretable, and useful for small datasets. It is often used in recommended systems within educational games, helping to suggest learning tasks or levels based on what has worked for other learners with similar patterns of interaction.

2.7 Algorithm Selection Criteria for Game-Based Learning

When choosing algorithms for game-based learning, several factors are considered. Gaining the users trust is one of them and this can be achieved by algorithms that an explainable approach especially in educational settings (Gorman et al., 2024). Decision Trees and Random Forests perform well in this regard because their decision-making processes can be easily understood and explained.

Additionally, users want to experience games that have high performance and are adaptable to users' gaming dynamics. This can be achieved through models such as, Reinforcement Learning and Neural Networks provide high adaptability and precision in personalizing learning experiences but often at the expense of explainability (Gorman et al., 2024).

Moreover, in education, it is important to ensure that every path and game direction is fair and free from bias: Algorithms must ensure non-discrimination and fairness, particularly in educational contexts. Transparent models like Decision Trees and Bayesian Networks are easier to audit for fairness compared to more opaque models like Neural Networks (Gorman et al., 2024).

Finally, when developing any system, scalability options should be laid out clearly on the Table. There are algorithms that can be easily scalable while others are not that much. Algorithms like Random Forest and Neural Networks are more suited for handling larger datasets and complex user interactions, which is important as games scale with more users and data.

When it comes to the maternal and neonatal health educational game, Llama 3.2 was picked because of its adaptability, scalability, and efficiency. Llama 3.2, developed by Meta, is a very advanced language model made using the transformer architecture and is established with the help of the self-attention mechanism (*Llama*, 2025). This feature lets it understand a more complicated contextual situation and to promptly respond to the decisions of the players. Even with its pretrained capacities, Llama 3.2 eliminates the need to build complex algorithms from scratch.

While most pre-trained models are biased either towards scalability or personalization, Llama 3.2, on the contrary, balances its abilities well. Its educational game like the interactive one is a platform for the results. It has been fine-tuned to handle large datasets and diverse scenarios, which is essential as the game expands with more health-related content. The model is also open-source meaning developers have access to the basic architecture of the model and are enabled to tweak it according to their needs as well as get it readily integrated into their applications. Such a policy encourages openness, transparency, and adaptability, which makes it a good choice for projects requiring frequent updates or modifications, such as the one that deals with maternal and neonatal health education.

Although Reinforcement Learning and Neural Networks uphold a meticulous approach and result in higher precision but displaying their interpretability can represent a stumbling block in educational environments (Gorman et al., 2024). With the assistance of Llama 3.2, one can take advantage of a very robust, pretrained model which is easy to scale, works well with new data and leads to vivid aspects of learning. Its transparent nature and ability to facilitate the learner's pace of skill acquisition and better overall learning experience turned out to be its middle and aeronautic selection for both reliable and appealing educational tool that focused on maternal and neonatal health.

2.8 Maternal Health Discussion

Maternal Health is health that revolves around expectant women, during pregnancy, delivering and or post-delivery of infants ("Maternal Health," 2024 ; World Health Organization, 2024) This is particularly important since birth is not void of complications or worry (Balaj et al., 2021; Karlsen et al., 2011). By placing extra attention on health of women during these periods, improvements on birth outcomes are ensured. Different health care facets are involved in Maternal Health such as family planning, preconception, prenatal care and post-natal care. All these facets require proper guidelines to ensure positive health outcomes for both mothers and their infants throughout pregnancy. In Figure 2.1, different health conditions have been outlined that may pose concerns during the different stages of birth.

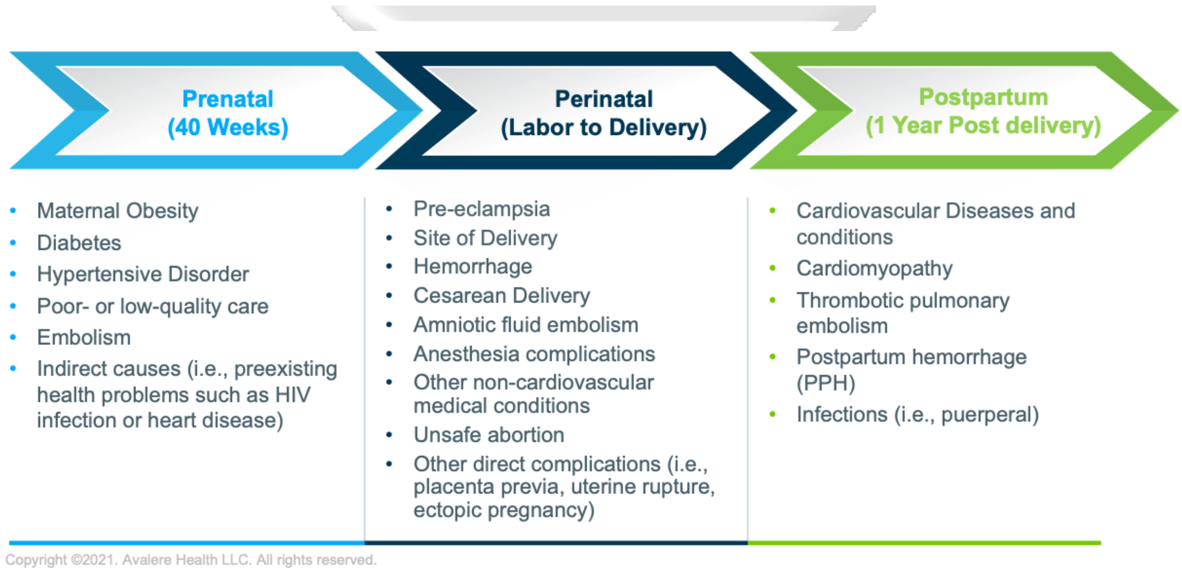

Figure 2.10: Key Aspect of Maternal Health Conditions(avalere_wp, 2021)

2.8.1 Prenatal Care (Before Birth)

This is a Preventive Health Care (PHC) measure for Maternal Health also known as antenatal care. It involves medical checkups throughout the pregnancy based on what trimester the pregnant mother is in. Through these medical checkups mothers are given recommendation on ensuring healthy lives of mothers and children alike such as; preparation for the physiological and biological changes during pregnancies, nutrition advice as well as education on supplements and prenatal nutrition ("Prenatal Care," 2024). These PHCs routines such as screening, recommendation preparation and diagnosis help reduce birth and child preventable complications such as miscarriages, maternal mortality, birth defects, low birth weight and infant infections.

2.8.2 Childbirth (Perinatal – Labor to delivery)

This is the period that results in the actual delivery of a child. Safe delivery practices such as being handled by skilled attendance during birth, facility-based deliveries and understanding the different stages of birth for mothers to mentally prepare are highly recommended to reduce the risk of complication and NMR and MMR. Additionally, to relieve pain there are different positions that mothers can try out. These practices are important to ensure minimal risks to the mother and child. The are two type of delivery a woman could go through based on the mother's health condition, C-section and Vaginal delivery. If complication arises, c-section will have to be conducted however, the woman undergoes normal vaginal delivery.

Vaginal delivery is the most common delivery where it involves four stages, as further illustrated in Figure 2.11. In the first stage, the cervix open, then the baby descends and is delivered, in the second stage, the birth of the placenta occurs in the third stage and finally the fourth stage involves recovery period of the infant and mother, where the infant is monitored and the umbilical code is cut ("Childbirth," 2024). The famous kangaroo method is highly advised right after the fourth stage where the baby is placed on the mother's chest for skin-to-skin contact. It should be noted that Vaginal pregnancy is highly recommended as the first option and C-section can have increased complications and mothers may experience longer recovery. Child birth is a critical part for pregnancy since all the preparation that had been put in place were to ensure safe delivery (*The Stages of Labour and Birth*, 2020).

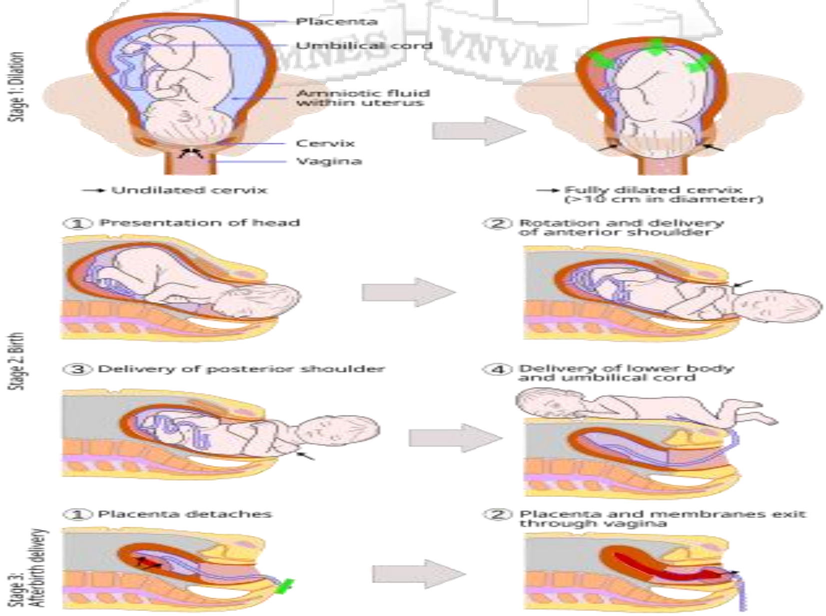

Figure 2.11: Stages of Labor and Birth(The Stages of Labor and Birth, 2020).

2.8.3 Postnatal Care (After Birth)

This is health care that comes 6 weeks after birth. It is an important time to closely monitor the health of mother and child post-delivery. It entails monitoring of mothers to ensure that there are no complications like infections, postpartum hemorrhage (heavy bleeding) and postpartum depression. Newborns are also monitored closely for issues such as weight, infection and milestones achievement in development. Finally, mothers are encouraged to breast feed, as breast milk contains essential nutrients for babies. Postnatal Care is important as it lays foundation for the long-term health of both mother and child after deliver (Lopez-Gonzalez & Kopparapu, 2024).

2.9 Research Gap - Challenges Associated with MHE

From the literature Review, though significant effort has been made to handle the delivery of MHE, a couple of challenges still emerge. Depending on the intervention certain drawbacks can be identified e.g. searching through the internet can be tough on mother due to the enormity of the content and sometimes questionable accuracy. Additionally, solutions such mHealth and telemedicine still poses some sensitivity in their delivery and are mostly dedicated to mothers, health care providers and sometimes CHWs, leaving out important support such as husbands and family out. Additionally, as alluded by (Laine & Lindberg, 2020), the problem is not desire to learn by the motivation through learning. Based on the interventions, are the challenges associated with them.

2.10 Challenges with Traditional Methods

Challenges in Accessing Health Care is a huge drawback for Tradition Community Health Programs (CHPs). Traditionally, either CHWs would visit mothers in the household or women would have to go to clinics to receive information. However, many women and families from underserved communities with high financial constraints and high cultural beliefs end up being limited in access health care. This forces mothers to go through their nine months with very little or zero antenatal care visits that are one of the major administrators of MHE (Stein, 2023). Additionally, the long distance from the residence of mothers to health care also limits their access to health care. According to Sahoo et al., (2021), worldwide, health inequalities has a high disproportionate level with children under 5 in Low and Middle Income Countries (LMIC) having an 18 times higher chance to succumb to death as opposed to those in developed countries. This is due to social economic disparity due to limited access to health care, education and economic opportunities

Additionally, there is a challenge with work force capability. In Kenya 10 CHVs are to service either 5000 people of 1000 households per month (*Kenya's Community Health Workers Shortage Undermines Universal Health Care*, 2023 ; *Kenya's Community Health Volunteer Program*, 2020). Health Care Workforce. One of the challenges that women go through in not gaining the right MHE stems from shortage of skilled healthcare providers. In many LMIC trained healthcare professionals, such as midwives and obstetricians, have highly unavailable leading to suboptimal care during pregnancy and childbirth (Grépin & Bharadwaj, 2015). Additionally, Providers have high workload having limited time to have detailed attention to their patients. This in turn leaves very limited time to deliver comprehensive education and support to pregnant women (AlDughaishi et al., 2023). This situation is particularly acute in low-resource settings where the demand for services exceeds the available workforce.

Another challenge that affects the traditional methods is privacy issues. In a study done by AlDughaishi et al., (2023), through a series of interviews between selected researchers and health care providers as well as pregnant women , one of the issues that arose was a lack of privacy. Some of the health care providers stated that there are so many women who would like to discuss sensitive issues but due to shared examination rooms, many women hold back and do not ask questions. This specifically, affects the transfer of knowledge on sensitive topics e.g. women with existing conditions such as HIV might hold back from asking sensitive question disrupting the preparation as well as knowledge transfer on the specific topic

Moreover, teaching resources may not be available in clinics or with CHWs. Some health care facilities due to limited resources and support lack different teaching resources such as prerecorded videos on maternal health (AlDughaishi et al., 2023). Many facilities depend on leaflets and some leaflets don't cover some topics. This leaves certain important topics not clearly elaborated on or explained.

AlDughaishi et al., (2023), further points out the issue of health care providers not being able to address issue for each woman due to lack of understanding of what the women wants. More time is then wasted in health care providers HCP trying to Figure the desired education need for each woman which mostly they do not have due to the low work force and large amounts of work. To compensate HCP, give superficial answers that may not address women's issues. Additionally, disasters really impact the continuity of Maternal Heal Care (MHC). Disasters such as pandemics and natural disasters really disrupt access to MHC. An example could be in the instance of COVID-19 where there was heavy quarantine which disrupted antenatal care visits.

2.11 Challenges with Internet Search

The internet, though quite resourceful, can be dangerous. As addressed by (Putri et al., 2020), 95% of women get their information from the internet. However, the information from the internet may have questionable accuracy and an enormous volume of information that can be confusing. A report by (*Maternal Health Education | Pregnancy & Postpartum | Elevance Health*, 2024), reports that families and mothers alike desire to learn about MHE, however, finding the right source that has MHE related content is not necessarily easy and many end up doing their search through the internet or asking guidance from families and friends.

The challenge with this is on how best to sift the information, especially for those who end up online. Additionally, it is hard to know what information to go with as some content can have questionable accuracy, not based on evidence and not up to date. Javanmardi et al., (2018) further alludes that most women using the internet as point of reference do not discuss their findings with their doctors hence leading to misinformation and sometimes conflicts in care giving.

2.12 How the Proposed Solution Responds to Existing Gaps

The study addresses key limitations identified in existing literature, such as cultural biases, the overwhelming and often unfiltered nature of internet-based content, and the sensitivity of maternal health topics that hinder inclusive learning—especially among male support systems. By offering a structured, adaptive, and user-centered solution, the system ensures continuous engagement through gamified learning while minimizing discomfort around sensitive topics. This approach promotes inclusive education by creating a culturally sensitive and accessible platform that empowers not only expectant mothers but also their partners and families to learn about pregnancy and maternal health in a supportive environment.

2.13 Conceptual Framework for AI-Powered Game-Based MHE

In this conceptual framework, we focus on the different factors that push for the idea of the development of an AI-powered game-based solution addressing the existing gaps in maternal health education (MHE). It also highlights the factors that can either negatively or positively intervene in the solution. The outcomes of our solution are highly dependent on the independent variables either being solved, created or adapted in the solution. The framework provides a theoretical basis for understanding the connections between the various components of the intervention further showcased in Figure 2.12.

2.13.1 Conceptual Framework

The system's conceptual design entails how the system has been developed to achieve the best outcomes in relation to MHE delivery. It is grounded in educational theories like constructivism, where learners build knowledge through active engagement (Piaget, 2003). By offering personalized, adaptive learning experiences, the system aligns with principles of differentiated instruction, ensuring that each user gets content that is suited to their needs, abilities, and progress.

It also incorporates gamification elements, which have been shown to increase engagement and retention (Laine & Lindberg, 2020). The integration of AI allows the system to act as a "smart tutor," providing immediate, personalized feedback to enhance learning outcomes. This framework, along with continuous feedback and adaptability, ensures that the system addresses the critical gaps in maternal health education, ultimately contributing to reduced maternal and neonatal mortality rates. The game's educational impact goes beyond traditional learning, encouraging players to engage in decision-making scenarios that reflect real-life pregnancy risks and benefits, all while ensuring a safe delivery by the end further illustrated in Figure 2.12.

The system has different components that work together to ensure seamless provision of MHE delivery. These components include the front end, where the user interacts with the system. The user Interaction initiates the learning journey sending data to the APIs. The Backend receives this data and processes it, interfacing with the AI Module to generate personalized learning paths. The AI Module (LLaMA), based on the player's progress and performance, generates specific questions and challenges. The model is also supported by RAG improving the accuracy and relevance of model responses by combining information retrieval with text generation.

By labeling data (e.g., questions about nutrition with labels indicating difficulty or performance level), the model can identify patterns and personalize future challenges. It adapts these challenges if the player is struggling, providing hints or additional content through the Feedback Mechanism. The Database stores relevant information, such as previous answers, progress, and content, and allows for continuous data flow between the Backend and AI Module to refine the game's challenges. Finally, APIs ensures that all data between the components flows seamlessly, allowing the player's progress to be tracked in real-time and personalized learning paths to be adjusted accordingly showcased in Figure 2.12.

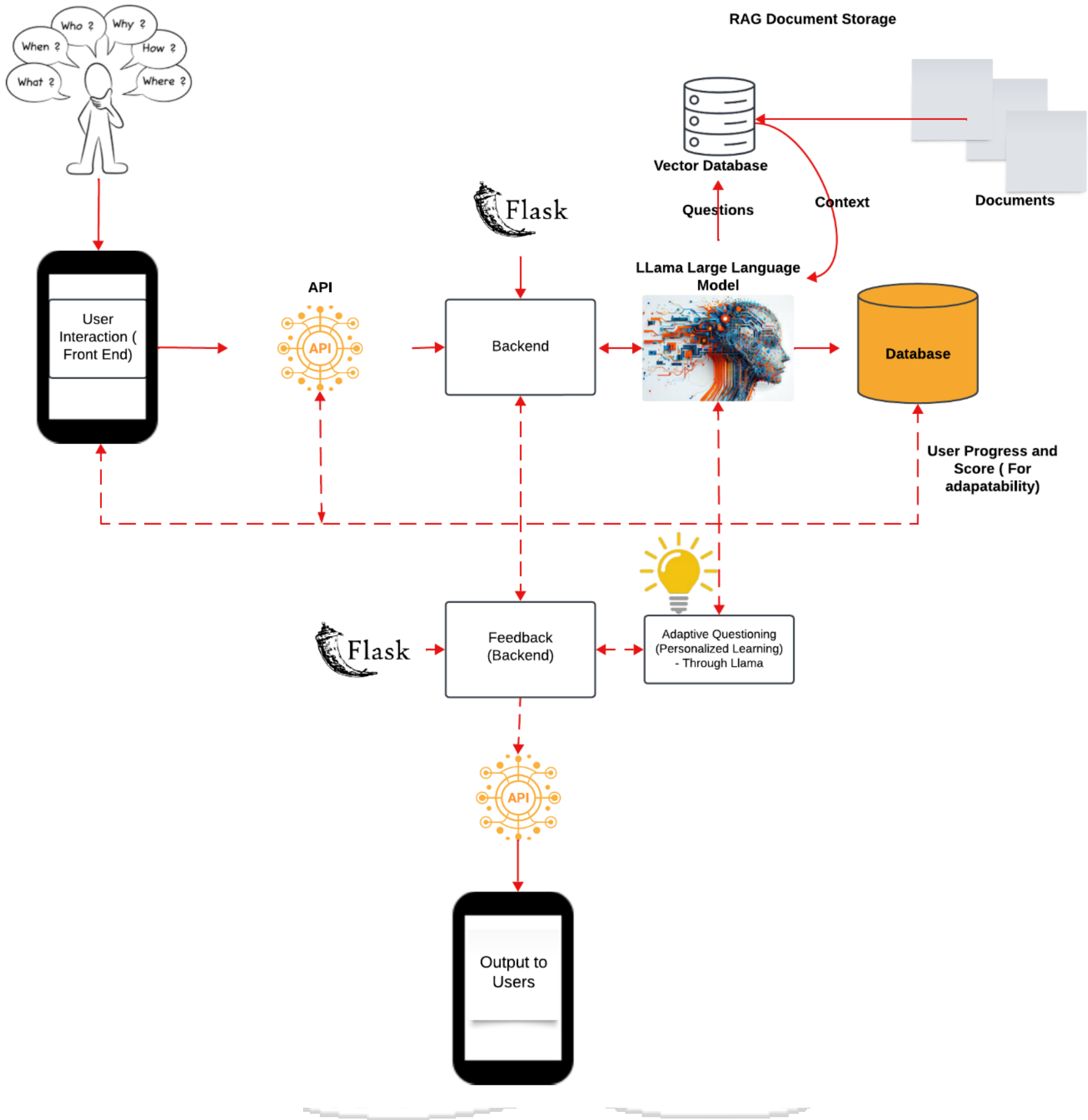

Figure 2.12: Conceptual Design

Chapter 3 : Research Methodology

3.1 Introduction

Research methodology is the process of identifying the appropriate techniques for collecting and analyzing data (Sreekumar, 2023). This study employs a Design Based Research (DBR) approach to create an AI-powered game-based solution for maternal and neonatal health education. The focus was on leveraging secondary data to inform the design and development process while incorporating iterative validation through expert review. **Design-Based Research (DBR)** is an adaptive research methodology, particularly well-suited for the development and iterative improvement of educational technologies (DE-TEL, 2024). It creates solutions that address real-world problems through a continuous process of designing, testing, and refining, based on feedback from stakeholders which was particularly critical in this research.

3.2 Research Design and Phases

DBR is typically divided into several stages, each focused on the iterative design, implementation, and evaluation of the solution. The phases of DBR were adapted to the research project as follows:

3.2.1 Principles of Design-Based Research (DBR)

The study uses the basic principles of DBR but with an emphasis on secondary data rather than direct user interaction. These include, firstly, **Iterative Development** which involves cycles of designing, testing, and revising. However, in the context of our research during the revisions, existing studies, reports, and datasets on maternal and neonatal health were utilized.

The second principle involves **Collaboration with Existing Data** where instead of collecting new data for our research, we focused on analyzing existing reports, research findings, and secondary data sources to inform the design of the educational intervention. The third principle involves **Real-World Focus**: The goal in this principle remains to address real-world problems, in this case improving maternal and neonatal health education and tackling educational deficiencies that contribute to high mortality rates. Finally, **Theory-Driven** is the final principle that emphasizes analysis of the design again existing theories. Secondary data analysis was aligned with theoretical frameworks in health education, gamification, and AI in learning. Our research was conducted through 5 different phases as follows:

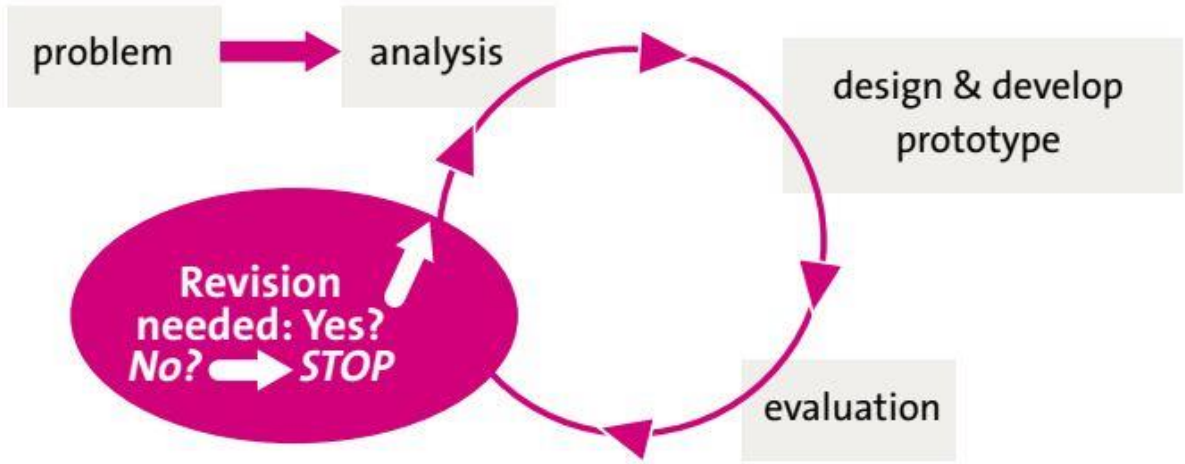

Figure 3.1: Design-Based Research (DBR) approach(DE-TEL, 2024)

3.2.2 Phase 1: Problem Identification and Needs Analysis

The primary objective of this phase was to identify and address the core problem—educational deficiencies contributing to high maternal and neonatal mortality rates. Our aim was to establish a clear correlation between maternal education levels and mortality rates, further refinement and analysis continued throughout the study as additional relevant literature was obtained.

Key data sources included:

i. **WHO Reports:** Global and regional health data, particularly focusing on maternal and neonatal mortality trends.
ii. **UNICEF Statistics:** Data emphasizing maternal health and educational access, providing contextual insights.
iii. **World Bank Databases:** Socioeconomic data, including education metrics and health outcomes.
iv. **Academic Literature:** Studies examining the interplay between maternal education and mortality rates.

To ensure reliability and accessibility:

i. **Publicly Available Government and NGO Reports** were leveraged:
   a. **Reason:** These reports are openly published to enhance transparency and support evidence-based research or policymaking.
   b. **Examples:** WHO's "Global Health Observatory," UNICEF's maternal and child health reports, and World Bank's health-related open-access data.

Using this data, we identified clear patterns by isolating key variables such as education levels (e.g., years of schooling, literacy rates) and health outcomes (e.g., maternal and neonatal mortality rates). This approach ensured a thorough understanding of how educational deficiencies exacerbate maternal and neonatal health challenges.

3.2.3 Phase 2: Design and Prototyping

In this phase, our objective was to design an adaptive, AI-powered educational tool. This included but not limited to the UI/UX, the choice of model adapted and finally the integration of the model to the UI to bring out the best user experience.

3.2.4 Phase 3: Evaluation of Current Strategies

The objective here was to evaluate existing strategies addressing educational deficiencies in maternal health. This phase included the evaluations of maternal health education interventions and their impact. Additionally, the effectiveness of past educational tools, gamification strategies, and AI applications in health education were also discussed. Our data source included previous studies on health education programs, government reports, evaluations of maternal health programs in developing countries, and reviews of game-based learning in health education.

3.2.5 Phase 4: Content and Feedback Refinement

In this phase the refinement of the tool based on secondary data insights and relevant educational theories was done. Based on existing studies, the game's content, focusing on the different stages of pregnancy in maternal health education was identified. This spanned from, prenatal care, birth and postnatal care are evident from the application. Existing research on maternal health education gaps, user feedback from similar educational tools, and theoretical frameworks on learning and health communication were used.

3.2.6 Phase 5: Reporting and Conclusion

Finally, the feasibility and impact of integrating AI and gamification into maternal health education was assessed. This phase depended on secondary data to evaluate the effectiveness of similar interventions and insights from secondary data on the potential impact of AI-powered educational tools was documented. Our data source included studies that report on the outcomes of AI and gamification in education, academic papers on adaptive learning technologies, and secondary data on educational outcomes related to maternal health.

3.3 Data Collection Methods

Consequent to this research, secondary data was used to guide the AI-powered, game-based educational tool developed for maternal and infant health. The data collection methods consisted of the following:

3.3.1 Secondary Data

This involved drawing data from an array of existing sources to bring together all the necessary information on maternal and neonatal health. It included:

i. Existing study: An overall analysis and review of Academic research, systematic reviews, and meta-analyses that focuses on examining maternal and neonatal health was done. Additionally, the study focused on studies that examine the role of education in improving health outcomes, and the impact of gamification in health education.

ii. State/ Government Reports: Reports from NGOs (e.g. WHO and UNICEF) and from the relevant national health centers were merged into the observed maternal and neonatal mortality data and the efficacy of educational interventions in the respective countries.

iii. Publication: Articles from health institutions and educational journals focusing on maternal health education strategies were also explored. Additionally, the study focused on the potential of gamification and AI in training the public on matters related to different health issues.

3.3.2 Quantitative Analysis

This phase focuses on utilizing numerical data with an aim to draw insights into trends and correlations regarding maternal health education and maternal health. To achieve this, data from national health surveys, which provide statistics on maternal health and education levels were assessed. This allowed the study to establish links between education and maternal/neonatal mortality rates. Additionally, the study examined Maternal Health Statistics which includes data on maternal mortality rates, birth outcomes, and the effects of educational interventions in reducing risks associated with maternal health. Finally, this phase evaluates the effectiveness of existing maternal health education programs, focusing on those that incorporate digital tools, gamification, or other innovative methods.

3.3.3 Qualitative Analysis

In this phase, the aim was to utilize non-numerical data to gather deeper insights. The study uses resources such as Case Studies analysis of health education programs, published expert opinion and past educational programs. The idea is to utilize these resources to identify key insights into the challenges and opportunities in maternal and neonatal health education.

3.4 Utilization of the Research Results

The idea behind this research is to advance knowledge and improve maternal and neonatal health education. To achieve this, the section outlines the steps taken for its utilization:

i. **Development of Educational Tools**: The primary result involves the design and refinement of an AI-powered game-based tool for maternal and neonatal health education. The findings from the research are to be used to enhance the educational content and interactive features of the tool, ensuring it effectively addresses gaps in current education.

ii. **Policy Implications:** The research is intended to inform policy makers and healthcare organizations about a double effect of gamification and AI on educational deficiencies that contribute to Maternal and Neonatal Mortality. The research presents policy orientation through the education of mothers about health promotion and by ensuring they are not only consumer but also producer of medical knowledge.

iii. **Educational Practice:** The research helps in improving and adding value in strategies, such as in the rural areas where maternal and neonatal health education is missing. The findings of the study recommend the integration of digital means into the existing healthcare education frameworks to help in the achievement of the health objectives.

3.5 User-Centred Design Approach and Future Usability Testing

While the current research primarily uses secondary data to inform the design and development of the AI-powered game-based educational tool, it also aligns closely with user-centered design (UCD) principles to ensure that the solution effectively addresses the needs of its intended users — pregnant women, mothers, and community health workers (CHWs). **User-Centered Design (UCD)** is an iterative process in which designers focus on the users and their needs in each phase of the design process. It involves understanding the target users' contexts, preferences, limitations, and interactions with the system, leading to more usable and accepted solutions (Norman, 2013). Although direct user involvement was not part of the current study, the research acknowledges the critical role of engaging users in future stages through usability and feasibility testing.

3.5.1 Potential Usability and Feasibility Testing

To validate the tool's practical applicability and effectiveness, the following steps are proposed for future work:

i. **Usability Testing:** Conducting small-scale usability tests involving the target population (pregnant women, mothers, and CHWs) to assess how easily and effectively users can navigate and interact with the game. Data collection methods may include task completion rates, user observation, think-aloud protocols, and post-test questionnaires to gather user feedback on satisfaction, ease of use, and perceived educational value.

ii. **Feasibility Study:** Evaluating whether the tool can be effectively implemented within real-world settings such as health centers or community education programs. This could involve pilot deployments, interviews with health workers and participants, and measurement of initial outcomes such as engagement rates and knowledge gain.

iii. **Iterative Refinement:** Based on feedback and findings from usability and feasibility studies, iterative improvements will be made to the game's content, interface, and underlying AI models to better meet user needs and enhance learning outcomes.

3.6 Dissemination of the Research Results

To make sure that the research results are disseminated to the right stakeholders, the dissemination plan includes a variety of methods that are adapted to different audiences:

i. **Academic Publications:** The common way to disseminate information in academia is through academic publication specifically peer review journals specializing in healthcare education, AI applications, and maternal and neonatal health. Thus, the research becomes part of ongoing academic dialogues and thus adds to academic discussions in these areas (Sreekumar, 2023; DE-TEL, 2024).

ii. **Online Platforms:** The findings were shared on social media platforms like LinkedIn to improve access to a wider audience, such as health professionals, teachers, and the public. This promotes awareness of the tool in turn sparking conversation on maternal and neonatal health education.

In collaboration with most of the professionals, the research results will be most effectively distributed, and the knowledge will help to make noticeable positive shifts in the healthcare practice and outcomes.

3.7 Ethical Considerations and Limitations

It is important to note that our study was not keen on primary data, however, it was important to have every ethical consideration considered particularly during phase 1 of our research. Phase 1 established a clear correlation between maternal education levels and mortality rates. This is particularly important as some of the data from proprietary research and academic studies, funded by private organizations or universities, required permission and guidelines in how to comply with intellectual property rights and usage agreements. Additionally, any secondary data that included confidential case studies or interviews required following ethical standards to protect privacy and ensure informed consent. Getting an ethical board review approval guaranteed that the research met these requirements, preserves the data's integrity, and conducts a careful and truthful examination of the data including both analysis and its distribution.

i. **Data Privacy**: The study ensures that any secondary data used respects privacy and confidentiality guidelines.
ii. **Cultural Sensitivity**: Additionally, the study ensures that the tools and content reflect cultural norms and do not perpetuate harmful stereotypes.

Chapter 4 : System Analysis and Design

4.1 Introduction

System analysis and design are an integral part of any software engineering research and development process. In this research, the system was carefully studied and the best design that could bring out maximum result and impact in regard to Maternal Health Education delivery in regard to an adaptive Game based solution was agreed upon (*System Analysis vs System Design - What Are the Differences?*, 00:00:20+00:00).

The system analysis involved data gathering, problem identification and understanding the objective of the system. This phase allowed for the documentation of the requirements / data gathered, analysis of the systems' performance, the quality of output before development and identification of areas of improvement. The system design included different system diagrams being used to create a blueprint of how the system would look like before the actual implementation. This saved time when the development process began as all the planning was in order. Using these blueprints, it was easier to come up with analysis of the requirements against the design as well as areas of improvement.

In brief, specifications of the system's requirements, both functional and non-functional, have been detailed in this chapter. Additionally, the system narrative as well as design diagrams, which outline the structural and behavioral aspects of the system have also been included.

4.2 System Requirement Analysis

In this phase, the system's needs were documented. Basically, system requirements analysis is a structured, or organized, methodology for identifying appropriate set of resources to satisfy a system need. Additionally, the actual requirements that provide a sound basis for the design or selection of those resources are also identified and outlined. These requirements are then agreed upon by the developers and the customers to ensure that the system will satisfy the customers based on their need ("Requirements Analysis," 2025).

4.2.1 Functional Requirements

To meet the users' needs and achieve the systems goals, the functional requirements were clearly looked in to. The system allows users to first sign in or log in based on whether they are an existing user or new users. Once this is done, the system should allow the user to move to the next stage where the user can select a pregnancy stage (Preconception, Antenatal, Birth, Postnatal). Based on the stage picked the system will allow the users to play different educational scenarios. The system should present a minimum threshold of unique scenarios (10), specific to that stage, that a user must complete. Once a user attempts a scenario, the system should provide AI-generated responses to user answers, indicating correctness and explanations when incorrect. Scenarios in this case, are questions regarding maternal health education that users should attempt to answer e.g. Nutrition Choice: What is the best food for a pregnant woman in her first trimester?

To ensure proficiency of the user, once they have completed the first 10 scenarios, they can still attempt the stage again. This allows users to complete as many attempts as possible, all with different attempts from the initial ones, at the same stage. The system AI should adapt by reenforcing weaker areas based on user responses. Users are allowed to retry incorrectly answered scenarios. Additionally, the system can track user performance and adapt the difficulty and teaching pace based on their learning progress. The users will be allowed to take the final challenge that will allow them to go through scenarios that cut across all the four stages. This will in turn allow them to get awarded badges based on successful completion and mastery of stages. A user should be considered proficient if they achieve all the requirements which include:

i. Have **attempted enough scenarios** (in this case completed at least 30 scenarios in total for each stage).
ii. Have **achieved a mastery score** (in this case, they are required to score 80% or higher across multiple attempts).
iii. Have **demonstrated improvement** in areas where they previously struggled (adaptive learning ensures weaker topics are repeated).

An “Ask Funza” chatbot will be included for additional support. The system should allow users to review past performances and revisit weaker areas. It should store the progress of users and allow continuation of learning over multiple sessions. Finally, administrative functionality tracks the users.

4.2.2 Non- Functional Requirements

These are requirements that may not meet the customer’s needs directly but ensure seamless interaction with the system. Responsiveness or cross platform compatibility of the system is one of the most integral requirements where the system is accessible from all devices without tampering with the user’s experience and interface. Additionally, the system is scalable where multiple users can be supported to enjoy the game concurrently. Performance is also an integral part where our AI model generates responses and scenarios in a short period of time. The system also has usability in that it has a user-friendly interface and functionality which should not prove any difficulty for the user. The system has supportability in that it has a simple user manual that allows different users to use the application. The system also ensures that user data is securely stored and protected against unauthorized access. Additionally, the system allows easy updates and modifications.

4.3 System Narrative

FunzaMama is an adaptive game-based system that provides an engaging learning environment for maternal health education. Users interact with the system by selecting a pregnancy stage and attempting scenario-based learning activities. The AI model generates contextualized learning experiences, reinforcing correct knowledge and guiding users through incorrect responses. Users earn badges after mastering a stage, ensuring progressive learning. The "Ask Funza" chatbot provides additional assistance, making the system an adaptive and supportive educational tool.

4.4 System Design Diagrams

This section presents graphical representations of the system architecture and workflows to provide a clear understanding of its structure and interactions. The system design helps us specify specific needs and requirements of a project, business or organization through the engineering of a coherent and well running system. For this project, different diagrams such as a use case diagram, the Data Flow Diagram (DFD), the entity Relationship Diagram and a D2 schema will be used to design the project clearly describing the elements of the project.

4.5 Use Case Diagram

The Use Case diagram is a diagram that shows the different system users and administrators and how they interact with the system. The main use cases in this system include choosing a stage, playing scenarios, retrying wrong scenarios, monitoring progress, and engaging with the chatbot.

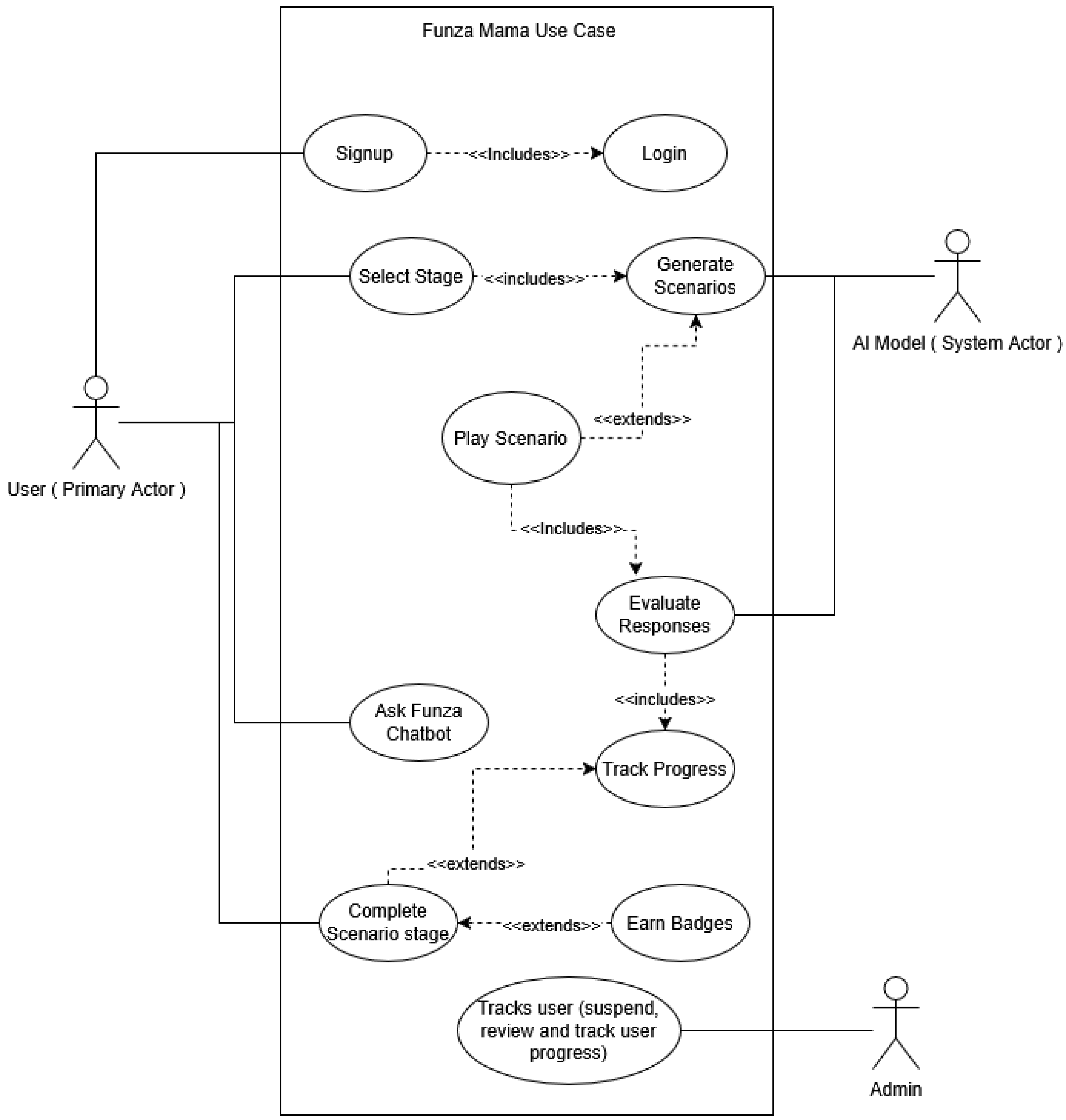

Figure 4.1:Funza Mama Use Case Diagram

4.6 Data Flow Diagram (DFD)

The DFD diagram looks at the system in a detailed manner whereby major processes in context-level is broken into sub-processes (*What Is a Data Flow Diagram (DFD)?*, n.d.). It models the data flow between system components. It depicts user interactions, scenario generation, performance tracking, and database storage processes. It maps out the flow of information for any process in the system.

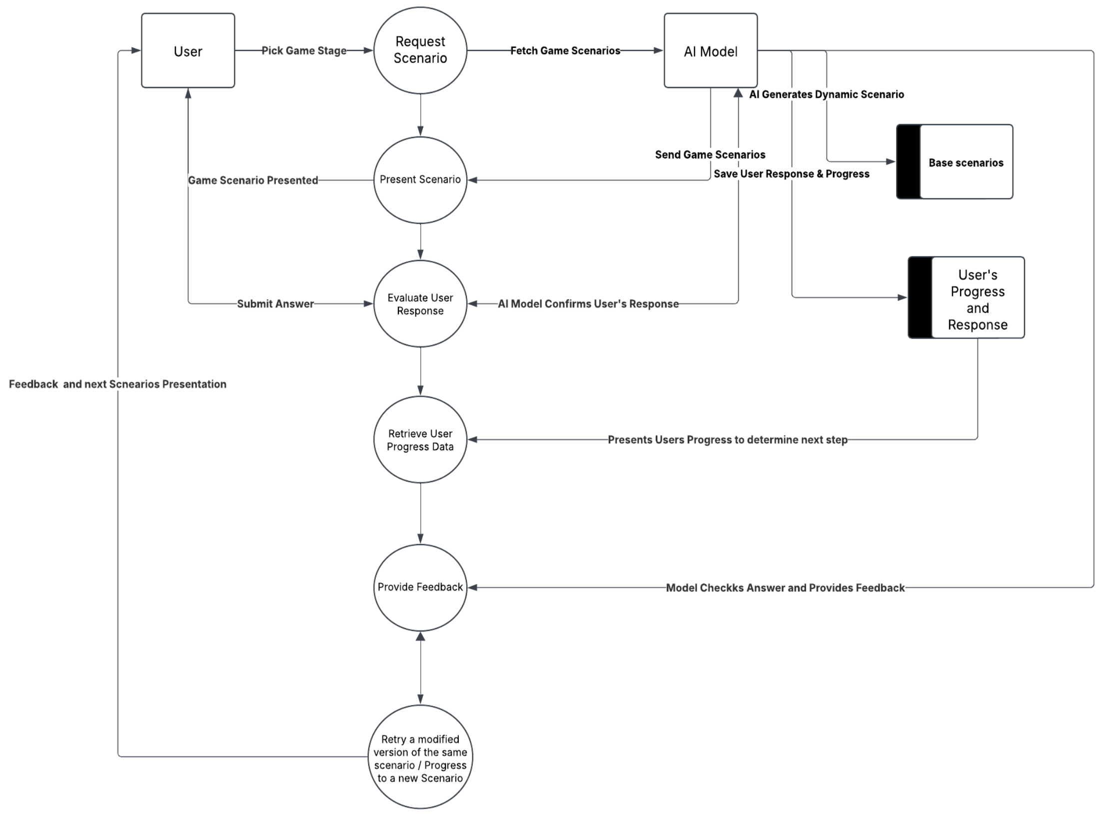

Figure 4.2: Data Flow Diagram

4.7 Entity Relationship Diagram (ERD)

The ERD Diagram highlights the database structure, clearly defining the key entities such as Users, Scenarios, Stages, AI Responses, and Badges, along with their relationships. It is a graphical representation of an information system that depicts the relationships among users, objects, places, concepts or events within the system. It shows the relationships between various entities in an information system. This diagram is useful during the system design because Entity Relationship Diagrams provide a visual starting point for database design that can also be used to help determine information system requirements throughout an organization.

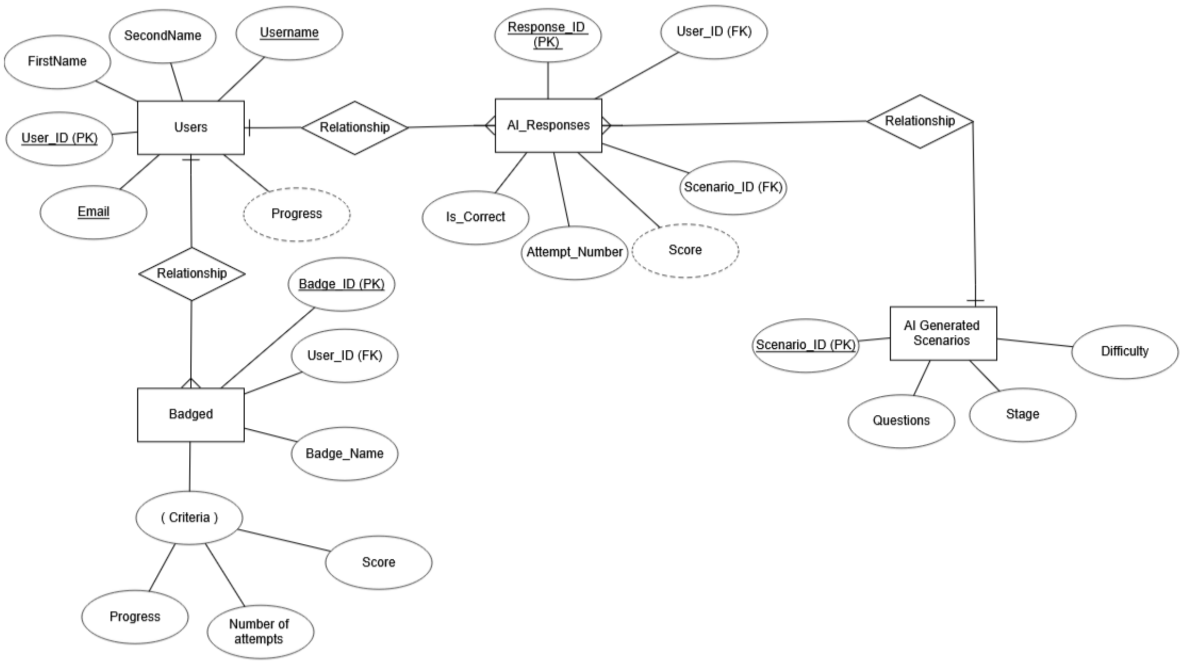

Figure 4.3: Entity Relationship Diagrams Highlighting Relation of my Database

4.8 Data Schema

This shows the actual database structure for the system. It is a more defined and condensed graphical representation of an Entity Relationship Diagram. It allows the developer to base which back-end tool to use depending on the requirements on the schema.

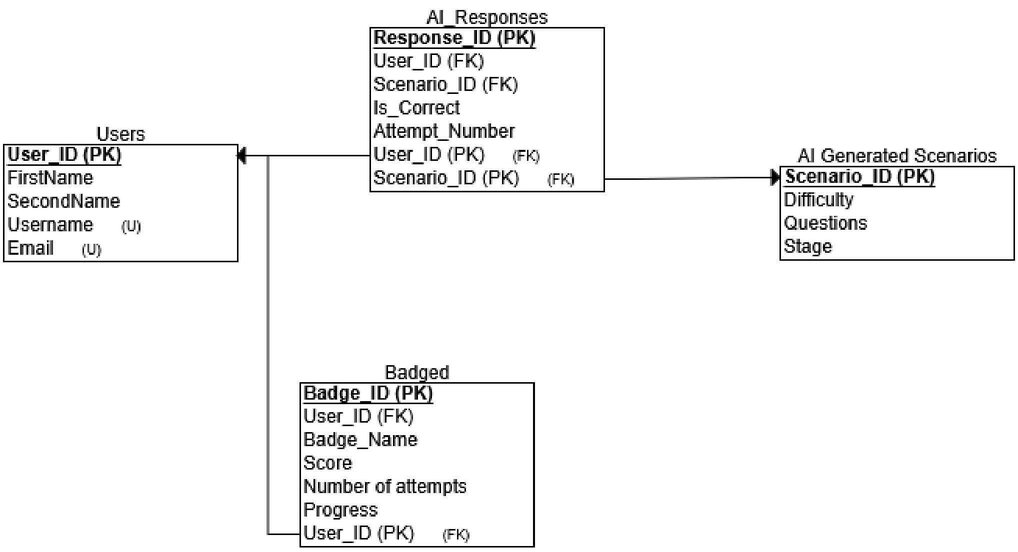

Figure 4.4: Data Schema Diagram

4.9 Sequence Diagram

The sequence diagram represents the flow of interactions within the system, showcasing how users progress through the stages, receive AI feedback, retry scenarios, and interact with the chatbot. Sequence diagrams are a popular dynamic modelling solution in UML because they specifically focus on lifelines, or the processes and objects that live simultaneously, and the messages exchanged between them to perform a function before the lifeline ends. As development is in processes it helps the developer understand what different modules require to perform certain functionalities.

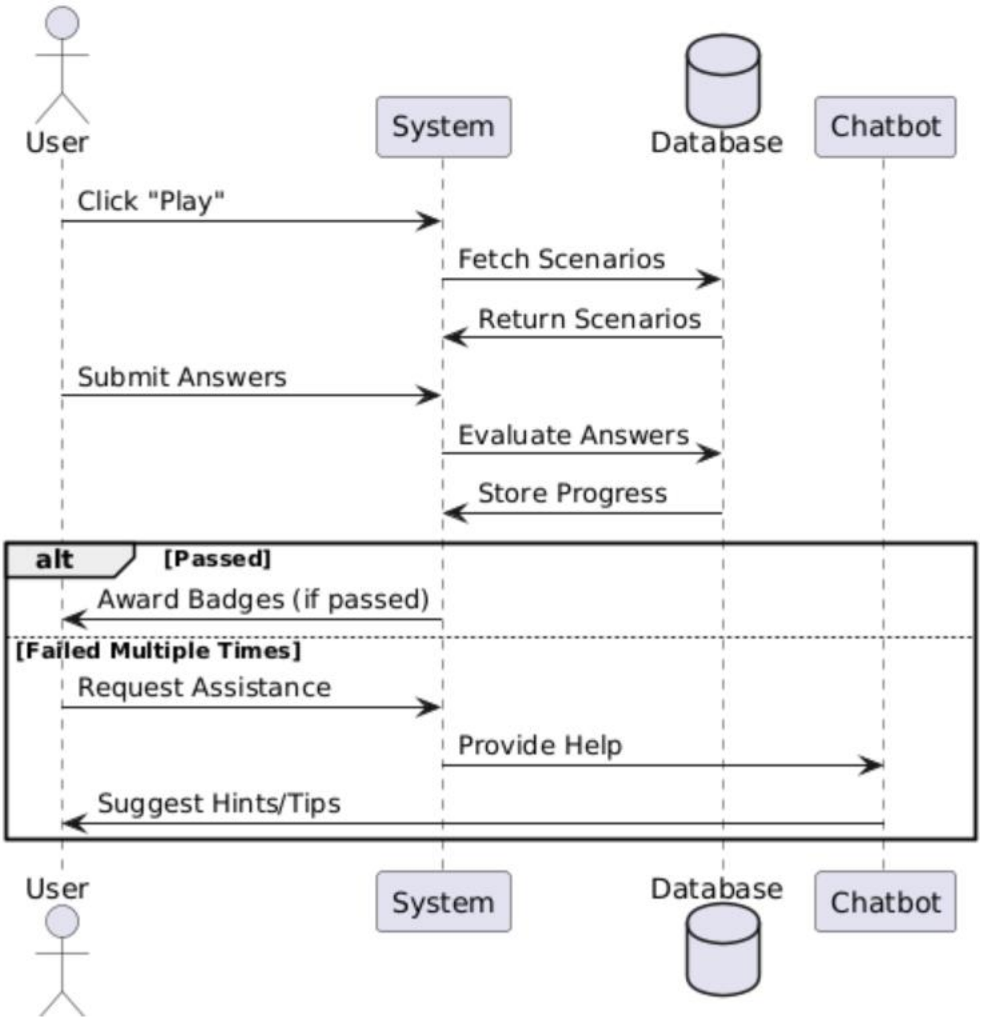

Figure 4.5: Sequence Diagram

Chapter 5 : System Implementation and Testing

5.1 Introduction

This chapter highlights the three modules developed and tested in the FunzaMama Trivia Game Based Challenge MHE delivery project. The modules include:

i. User interaction module with the scenarios generated
ii. Evaluation and Feedback AI Module
iii. User Progress Tracking and Reward System

The idea behind implementing the three modules was for provision of a seamless learning experience, user tracking progress and finally a consistent and correct offer of AI-driven feedback and scenario generation. In this chapter each module is explained and the features implemented are also outlined. Additionally, the testing conducted on each module has also been highlighted to ensure continuity and ease of understanding for each module. Finally, Figures on the user interaction with the system or the specific module have also been included to visually explain the system.

5.2 User Interaction Module and Scenario Generation

In this module, the user upon logging in is presented with different stages that represent the different stages in pregnancy including preparation for pregnancy, prenatal care, birth and finally postnatal care. The user is then presented with AI generated scenarios specific to a stage, upon clicking any of the stages. The AI-generated scenarios are specific to the stages and challenge the user to engage in decision-making and problem-solving. The challenges are relevant to maternal and neonatal health.

A fine-tuned LLaMA (Large Language Model Meta AI) is utilized dynamically generating the different MHE scenario questions which are diverse but contextually appropriate. The AI model is used in the generation of the scenarios rather than having static questions, the AI dynamically creates variations based on the selected stage to ensure that users encounter fresh and meaningful learning experiences with each attempt. This prevents repetition while maintaining the relevance of each scenario to the stage being explored.

Whenever a learner chooses a stage, they are introduced to a scenario and asked for a response. The AI then checks their answer and based on the learner's choice, the model gives the users quick feedback and informs them on the answers, if right or wrong. The platform records the number of attempts, the scores, and the improvements made by the user over time, and therefore tracks user progress. Students can try different cases in one stage; each stage selection gives them new AI-based challenges for the possibility to improve their learning.

5.2.1 Features Implemented

The user interaction module includes several functions that can help make the process of learning more interesting and experiential. Users interact with scenarios in different levels based on stages and difficulty levels, allowing our learners to gradually build their knowledge and problem-solving skills. Moreover, users receive feedback in real time as they resolve each scenario. Finally, the system has a way of tracking important game data such as number of attempts, user scores, and overall progress, ensuring personalized learning experiences tailored to individual performance.

5.2.2 Figures in Relation to User Interaction Module Implemented

Figure 5.1: Landing Page Implementation

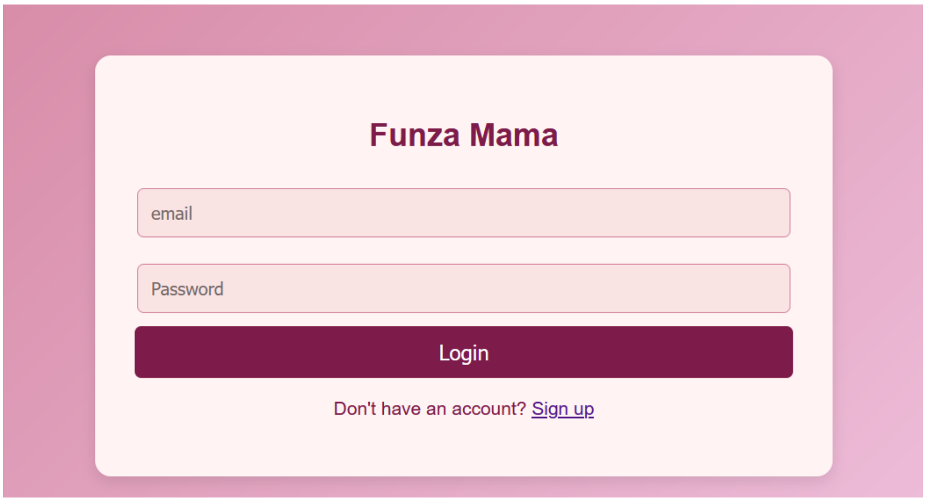

Figure 5.2: Login Page Implementation

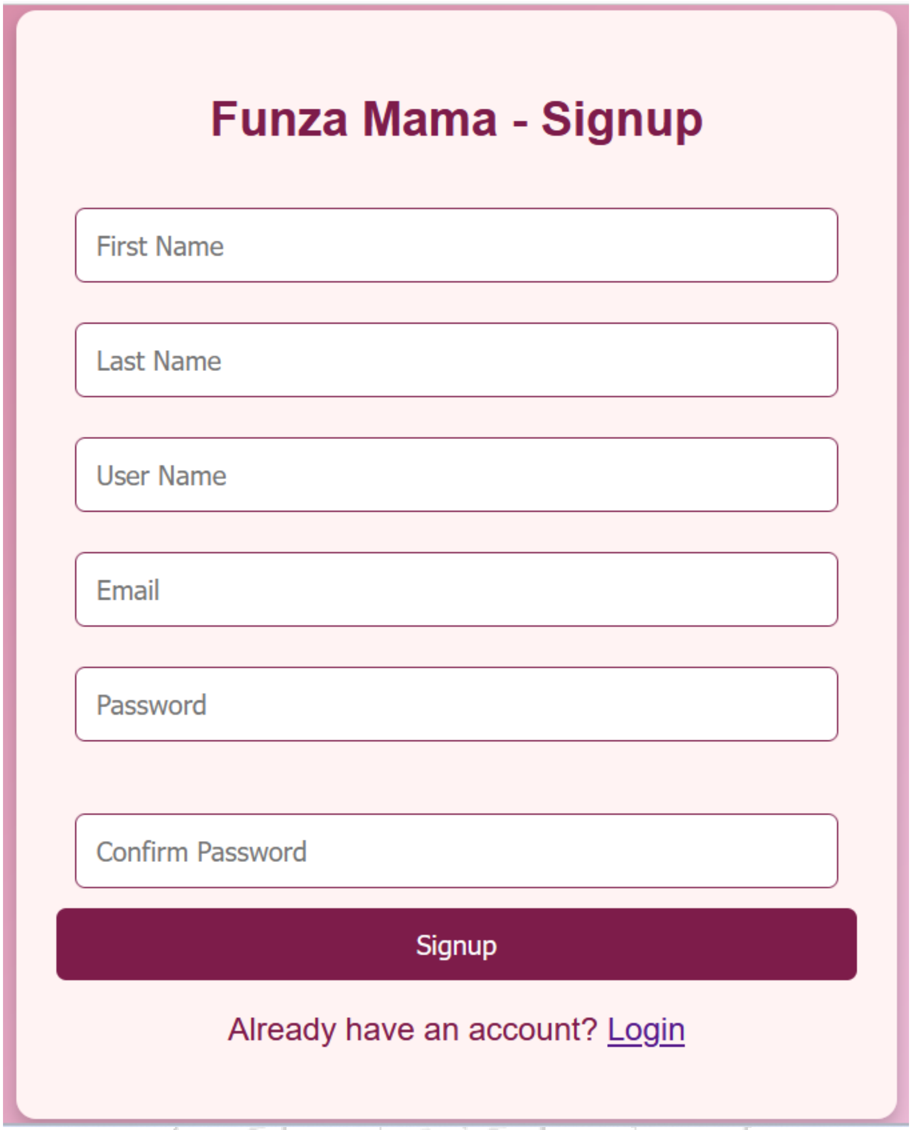

Figure 5.3: Signup Implementation

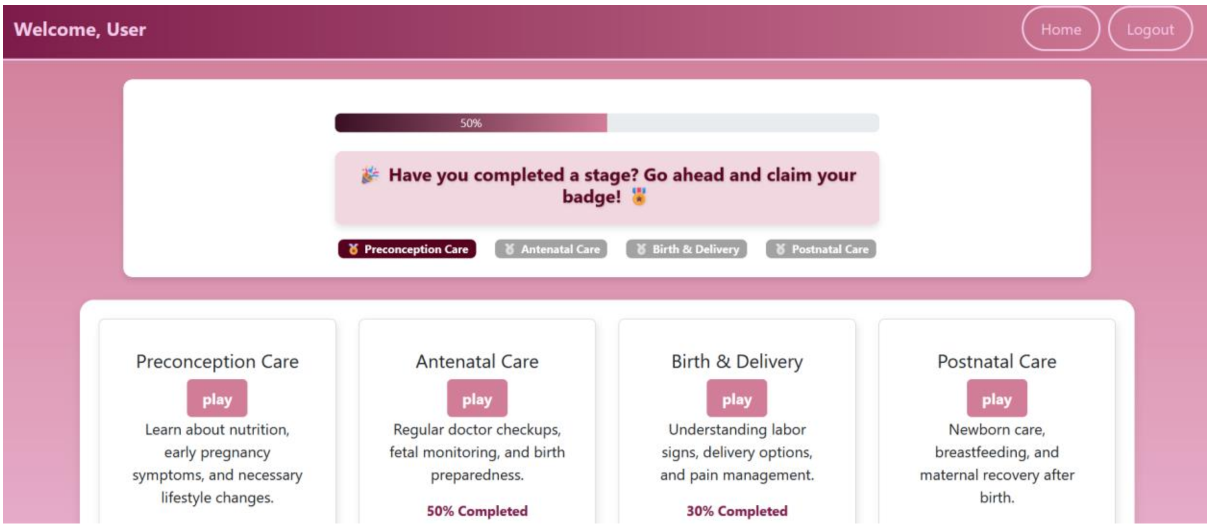

Figure 5.4: Game Stage UI Implementation

5.3 Evaluation and Feedback – AI Module

The AI assessment module is a significant part of the system that analyzes the answers and gives responsive feedback. This module is empowered to fulfil its task through the LLaMA model to develop an accurate interpretation of users' inputs and to assess the correctness based on the evaluation criteria defined. The Logic of AI-driven not only checks the correctness but also it tracks the progress of users, identifying mistakes that are being repeated. The learning experience will be improved by a system that can adapt additional support to user performance. If the user cannot answer the problems correctly, the system triggers the bot that allows user to directly ask why he or she was wrong. It answers the user's questions by explaining the right answer, hints, and by reinforcing key learning concepts. By including the features of the AI-driven assistant system, the system makes sure that the users get the support they need to improve their understanding and make the right decisions.

5.3.1 Features Implemented:

The AI module includes key functionalities that contribute to an interactive and adaptive learning process. It evaluates user responses in real time and assigns scores based on accuracy. The system provides immediate feedback, informing users whether their answers are correct or incorrect. Additionally, the chatbot assistant is triggered when a user struggles with multiple failed attempts, providing personalized support to reinforce learning.

5.3.2 Figures:

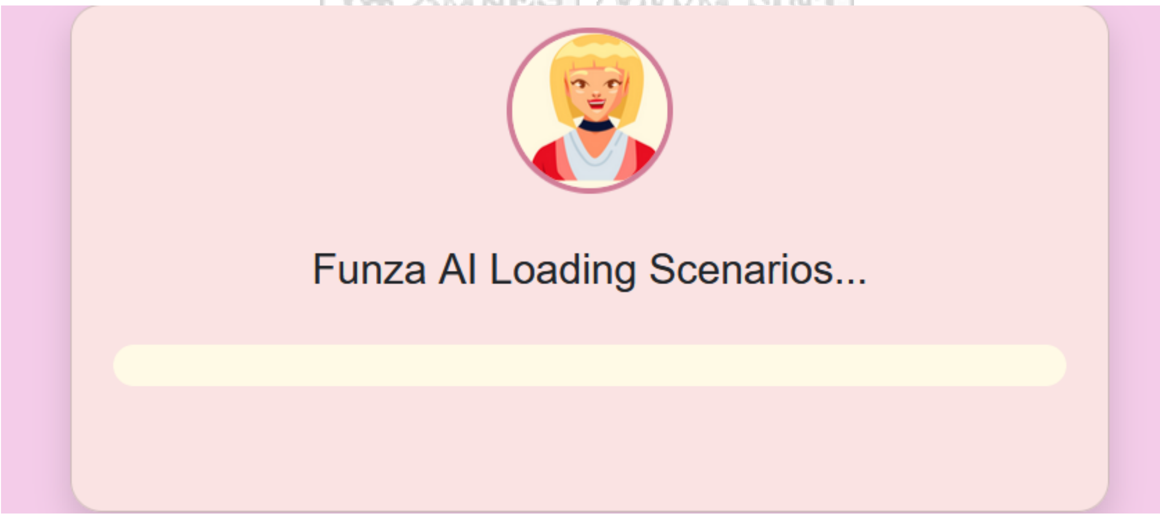

Figure 5.5: Model Generating Trivia Questions

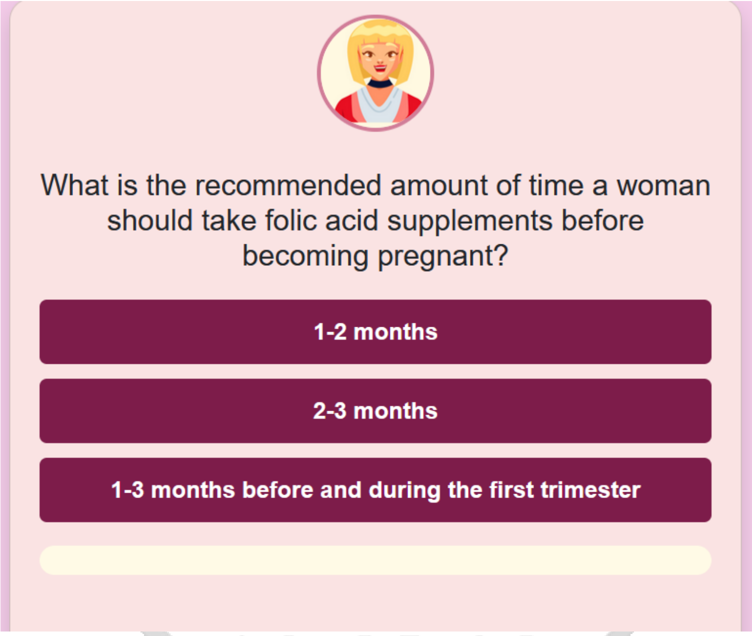

Figure 5.6: Example Scenarios from Model

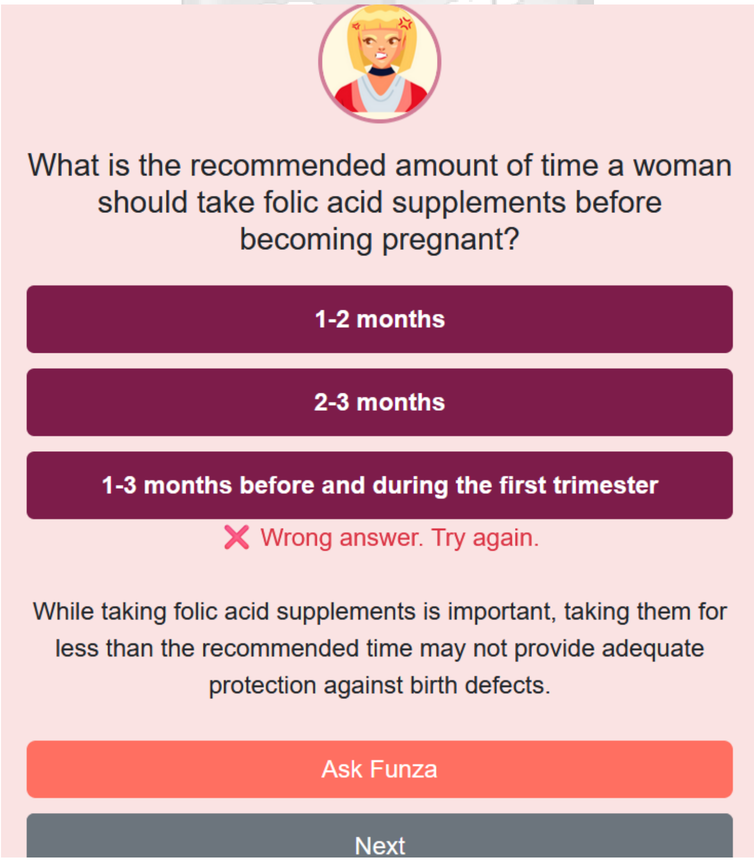

Figure 5.7: User Interaction to Scenario (Game) if Wrong

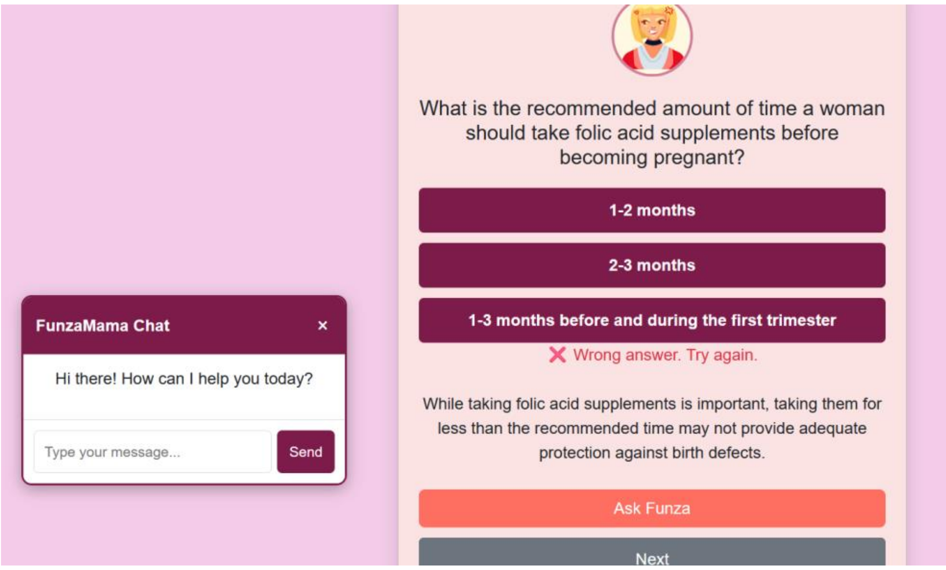

Figure 5.8: Ask Funza AI (AI chatbot) if Wrong

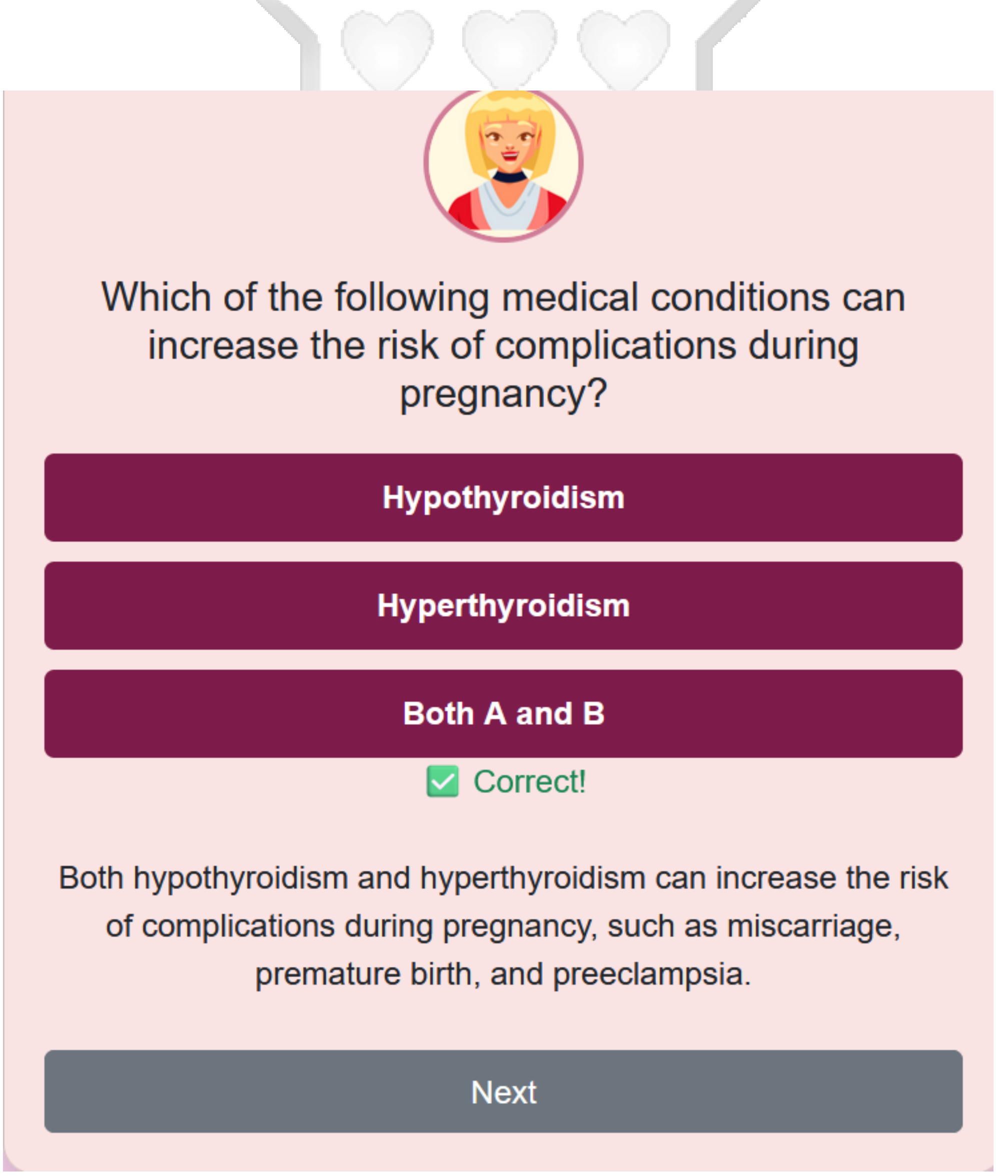

Figure 5.9: User interaction to scenarios (Game) if correct

This AI-powered approach enhances engagement and provides a structured yet flexible learning environment where users can continuously improve their maternal health knowledge through scenario-based interactions and real-time feedback.

5.4 User Progress Tracking and Reward System

The user progress tracking and reward system is devised to update the users' game performance progress. Basically, how many quizzes or questions have been attempted, how many were scored correctly, how many scored wrongly, and what is the overall score of the stage being attempted. This gives the users motivation and excitement, ensuring that they're continuously engaged, hence learning in the process. The model also tracks users' improvements from accounting to knowledge retainment. This module registers user scores, the number of times the user has made attempts, and the number of badges earned by the performance. The system catalyzes the learning process by rewarding the learners with a badge for their achievements and milestones. Moreover, users are able to monitor their progress visually through an interactive dashboard, so that they can trace their accounts of improvements in time.

5.4.1 Features Implemented

The system has the responsibility of collecting and updating user scores, which also tracks the number of attempts per stage. Badges are given to users, in case they satisfy different conditions, like constantly providing the right answers or winning the difficult scenarios. To increase user participation, progress is displayed for every attempted scenario. It provides an understanding of learning and progress.

5.4.2 Figures

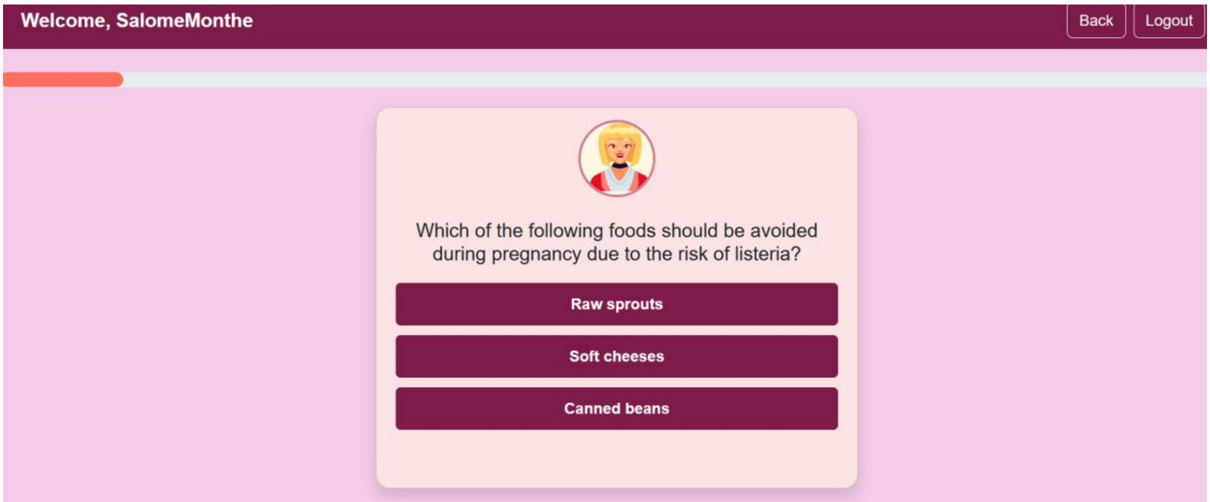

Figure 5.10: Progress Tracking UI

This module enhances user motivation and engagement by providing immediate feedback on progress, reinforcing positive learning behaviors, and offering incentives for continuous improvement.

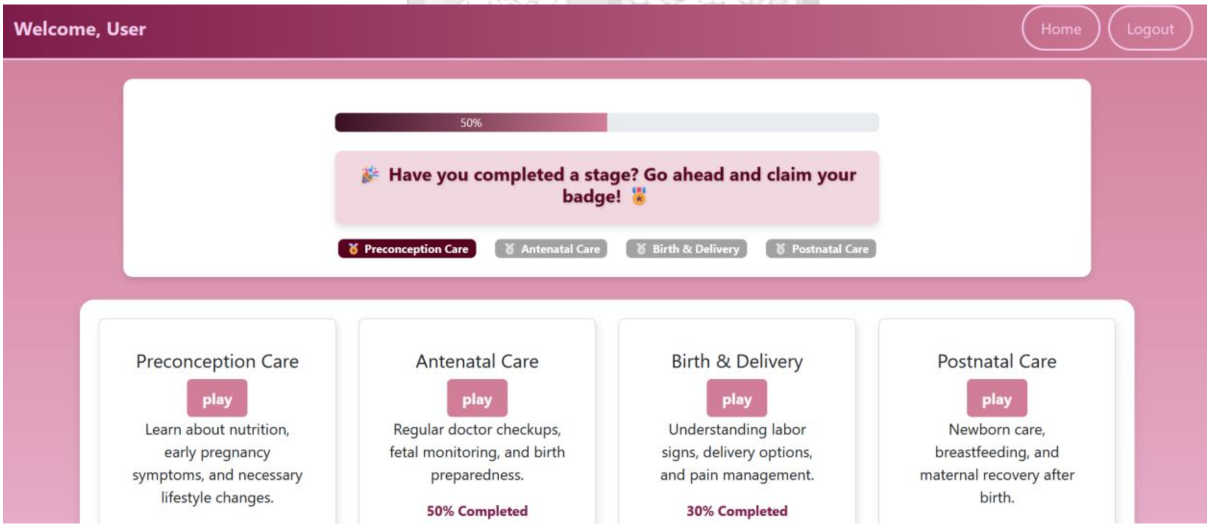

Figure 5.11: Claim a badge after Successful Metrics

5.5 Technologies Used

When coming up with a system, it is important to think about how seamless and accurate the operations are running. This in turn requires considering the best technologies that can work together to achieve the goal in mind. To ensure the same when implementing this system, a variety of technologies were used including Bootstrap framework for the front end providing a user-friendly and responsive interface. Flask was used to develop back-end logic, which is used to manage user interactions, scenario selection, and AI response evaluations. LlaMa, a pretrained model (**Meta-Llama-3.1-405B-Instruct-Turbo)**, was used to avoid the creation of complex algorithms from scratch allowing for more time in system creativity and development.

The model was obtained from Together AI, a platform used to store different large language models and access is through an API. **FAISS (Facebook AI Similarity Search)** for efficient search was used in going through the ground data used in supporting our model. When a user asks a question, the system converts it into an embedding and searches the closest matching response through our ground data allowing for **fast, scalable** information retrieval before resorting back to the model's knowledge base if data is not found in our ground data. To achieve this, a text embedding model was also used**, Sentence Transformers (all-MiniLM-L6-v2)** that converts text into numerical vectors (embeddings) for FAISS to process.

The evaluation of the model was done using **Precision**, **Recall**, and **F1-Score.** Measures how accurately FAISS retrieves the correct responses. Uses **scikit-learn metrics** to calculate:

- **Precision** (Measures the relevance of the retrieved results?)
- **Recall** (Checks whether all relevant results were found?)
- **F1-score** (Balance of precision & recall)

Additionally, for our database, the MySQL database was used to capture the user's data as they progress through the game exhibiting the user's progress, scenario interactions, and system-generated responses, guaranteeing data persistence and the tracking of learning results efficaciously. After the completion of the implementation, different system tests were conducted for the various modules, to ascertain accurate functioning. Unit testing was used to assess scenario selection and response submission, and to confirm that AI-generated scenarios appeared correctly. Additionally, the user interaction with the scenarios were also assessed to ensure that there was accuracy in evaluating the feedback as well as generation of right scenarios based on stage.

5.6 Llama Model Support and System Integration (meta-llama/lama-3.2-1b)

The system is powered by the **Meta-Llama-3.2-1b** model, seamlessly integrated to enhance maternal health education delivery. This model processes user queries, retrieves relevant information from a structured knowledge base, and generates AI-driven responses tailored to the user's needs. By leveraging **FAISS-based retrieval**, the system ensures that responses are drawn from verified and relevant data sources, maintaining high accuracy and reliability. The code used to support the system has also been shared on GitHub through this repository https://github.com/Chemiatsalome/maternal-health-education-delivery-app.git. It has all the implementation process for our front end, our back end as well as how the model was implemented. To validate the accuracy and effectiveness of the retrieval mechanism, we conducted an evaluation of the **FAISS-based information retrieval system**. The results demonstrated a **100% precision, recall, and F1-score**, confirming optimal retrieval performance:

```
y_true: [1, 1, 1, 1]
y_pred: [1, 1, 1, 1]
FAISS Retrieval Evaluation:
{
    "Precision": 1.0,
    "Recall": 1.0,
    "F1-Score": 1.0
}
```

Figure 5.12: FAISS Evaluation Results

These outcomes highlight that the system retrieves the most relevant responses efficiently, thus, users are guaranteed **accurate and dependable maternal health education** in real time. The decision was taken to use FAISS retrieval instead of going for the Llama model with fine-tuning, because it not only saves time but also has overcome its acute issues with efficiency, scalability and accuracy. The number of computational resources and time taken for fine-tuning could have been quite high and the system would have to keep being retrained frequently once new data was inserted. FAISS, on the other hand, offers a **low-cost, versatile, and high-performance** solution that ensures rapid and precise information retrieval without the risks of model hallucination.

```python
# Function to evaluate FAISS retrieval accuracy
def evaluate_faiss_accuracy(test_queries, ground_truths):
    retrieved_results = [get_relevant_data_faiss(query) for query in test_queries
    y_true = [1 if truth else 0 for truth in ground_truths]
    y_pred = [1 if res else 0 for res in retrieved_results]

    print("Retrieved Results:", retrieved_results)
    print("y_true:", y_true)
    print("y_pred:", y_pred)

    precision = precision_score(y_true, y_pred)
    recall = recall_score(y_true, y_pred)
    f1 = f1_score(y_true, y_pred)
```

Figure 5.13: Function to evaluate FAISS retrieval accuracy

```python
precision = precision_score(y_true, y_pred)
recall = recall_score(y_true, y_pred)
f1 = f1_score(y_true, y_pred)

return {"Precision": precision, "Recall": recall, "F1-Score": f1}
```

Figure 5.14: Continuation Function to evaluate FAISS retrieval accuracy

By integrating **Meta-Llama-3.2-1b** with **FAISS retrieval**, the system delivers a scalable, real-time maternal health education solution, optimizing both accuracy and user experience.

5.7 System Testing

To ensure the reliability and functionality of the system, white box testing was used. White box testing involves test cases that are highly targeted based on the knowledge of the system (*What Is White Box Testing?*, 2025). This includes tests that can focus on checking the different paths of the system. This ensures that all conditional parts of a system work correctly. Additional tests include validation of outputs where we focused on the inputs to the systems and the expected output based on the input. In this research, data flow testing was also conducted where the testing focused on how data flowed throughout the program. Given that the system utilizes a fine-tuned LLaMA model for AI-driven response evaluation, testing also focused on verifying the accuracy of AI evaluations and chatbot interactions.

5.7.1 White Box Testing

There are three types of white box testing that were explored in testing the system which include: Unit testing, integration testing and finally the regression testing (*What Is White Box Testing?*, 2025). Unit testing ensures that each component and the functionality in the system are working correctly, ensuring that the system design meets the requirements of the system. Integration testing is the second phase in white box testing where the focus is ensuring that the working component individually can work seamlessly together. Finally, regression testing will continually be explored upon deployment of the system, where the system works correctly even with different updates.

5.7.2 Unit Tests Conducted

Under unit testing we focused on each component of each user interface of the system which includes, first landing page; login, signup, play and funza AI chat bot, the stage game page and finally the actual game page illustrated in Table 5.1:

Table 5.1:Unit Testing

Landing Page		
Component	**Functionality**	**Test**
Login Button	Directs you to the login page	Pass
Signup Button	Directs you to the Signup Page	Pass
Play Button	Directs you to the game stage page if already logged in if not login page	Pass
Funza Mama Button	Opens a chatbot	Pass
Stage Game Page		
Logout Button	Users are logged out and directed to the home page	Pass
Home Button	Users are taken back to home page	Pass
Stage Button	Users are directed to the specific stage	Pass
Claim Badge	User claim budge based on completion of stage	Pass
Choose Avatar	Avatar to be used throughout the game	Pass
Actual Game Page		
Back Button	Take you back to the stage page	Pass
Logout	User Logs out and is taken back to the home page	Pass
Try Again	This allows the users to retry the attempts again	Pass

Complete	This allows the user to complete the stage and go back to the stage game	Pass
App Responsiveness		
Landing Page Stage Game Page Actual Game Page	System should adapt based on the user device and all components should fit the screen without losing the UX.	Pass

Under the login and signup section, the main process entailed ensuring they worked correctly, that is ensuring that for signup, user details were stored in the user Table in the backend and for login, the authentication was working correctly, that is if the username and password are correct then the user is directed to the stage UI page but if wrong they are requested to try again. Additionally, a test was made regarding triggering the different scenarios quizzes based on stage selection. To ensure that the model generated dynamic scenarios that are correct based on stage, the AI model was also tested. Additionally, the responses from the model that evaluates the users were also assessed. This ensured that user responses were classified correctly as correct or incorrect and that the scoring system assigned points accurately.

Tracking user progress is also equally important, as it keeps users motivated. The idea behind the system is sustained motivation and engagement that is keeping the users on the game playing, to gain as many rewards as possible ultimately learning in the process. This necessitated the testing of the progress tracking that confirms scores, attempt numbers, and allows users to earn badges based on certain conditions and then correctly stores, retrieves, and dynamically updates. Additionally, the chatbot assistance triggering mechanism was tested to verify that the chatbot activated after repeated failures and provided relevant, context-specific feedback based on incorrect answers.

5.7.3 Integration Testing

Systems are formed by many different integrated components that seamlessly work together ("System," 2025) and this is no different from what this research created. To ensure that the user has the best user experience the integration must be smooth and easy to understand and that requires rigorous testing called integration testing. This type of testing under white box ensured that how data flowed and how the data interacted across the different components was seamless and accurate. It ensures that the system's modules worked together as expected.

The AI evaluation, as well as the storage of the scores, were validated to certify that the user's responses were analyzed correctly. The Funza AI chatbot was tested to ensure that the chatbot was activated automatically and thus guided the user if they had provided three wrong responses consecutively. On the other hand, the badge issuance system was checked to confirm that the badges were issued, based on correct criteria.

Table 5.2: Integration Testing

Actual Game Page		
Component	**Functionality**	**Test**
Scenario Retrieval	Ensure scenario retrieved are based on the stage picked on the stag game page (i.e. for each stage)	Pass
User input processing	Ensures that the user input on quizzes was evaluated corrected by the model and feedback given immediately	Pass
Ask Funza AI Button	The button pops up after a failed attempt	Pass
Next button	The next button shows after a user has attempted a quiz and allows user to proceed to the next scenario	Pass
Stage Game Page		
Score and progress	Ensures that users get their score and progress for each stage	Pass
Overall progress	Ensure users get their overall score based on completion of the different stages	Pass
Claim badge	Users claim badge only after attempting the stage 3 times, completing the stage, got an overall score after the three attempts of 80 each time.	Pass

5.7.4 Regression Testing

This is an ongoing testing process ensuring that any new feature or update done to the system, did not introduce new bugs or cause system failure e.g. when updating the stage scripts, for my trivia game for each stage, a bug was introduced where the complete button was not working correctly, if not for the regression testing I would assume that everything works correctly because they did before the updates. Regression testing allows you to retest the whole system flow ensuring that they still work correctly even after updates and added functionalities.

Table 5.3: Regression Unit Testing

Landing Page		
Component	**Functionality**	**Test**
Login Button	Directs you to the login page	Pass
Signup Button	Directs you to the Signup Page	Pass
Play Button	Directs you to the game stage page if already logged in if not login page	Pass
Funza Mama Button	Opens a chatbot	Pass
Stage Game Page		
Logout Button	Users are logged out and directed to the home page	Pass
Home Button	Users are taken back to home page	Pass
Stage Button	Users are directed to the specific stage	Pass
Claim Badge	User claim budge based on completion of stage	Pass
Choose Avatar	Avatar to be used throughout the game	Pass
Actual Game Page		
Back Button	Take you back to the stage page	Pass
Logout	User Logs out and is taken back to the home page	Pass
Try Again	This allows the users to retry the attempts again	Pass
Complete	This allows the user to complete the stage and go back to the stage game	Pass
App Responsiveness		
Landing Page Stage Game Page Actual Game Page	System should adapt based on the user device and all components should fit the screen without losing the UX.	Pass

Table 5.4: Regression Integration Testing

Actual Game Page		
Component	**Functionality**	**Test**

Scenario Retrieval	Ensure scenario retrieved are based on the stage picked on the stag game page (i.e. for each stage)	Pass
User input processing	Ensures that the user input on quizzes was evaluated corrected by the model and feedback given immediately	Pass
Ask Funza AI Button	The button pops up after a failed attempt	Pass
Next button	The next button shows after a user has attempted a quiz and allows user to proceed to the next scenario	Pass
Stage Game Page		
Score and progress	Ensures that users get their score and progress for each stage	Pass
Overall progress	Ensure users get their overall score based on completion of the different stages	Pass
Claim badge	Users claim badge only after attempting the stage 3 times, completing the stage, got an overall score after the three attempts of 80 each time.	Pass

5.8 User Validation and Future Testing

Due to time and resource constraints, this study did not conduct a pilot usability test or gather direct feedback from target users such as pregnant women or community health workers (CHWs). While this limits the empirical evaluation of the system's effectiveness, the importance of user-centered validation is well recognized. As part of future work, the system will be subjected to pilot testing involving a small group of target users. This will include usability testing, structured questionnaires, and short interviews to assess the educational impact, ease of use, and overall experience with the AI-powered game. These findings will be used to iteratively refine the prototype and improve its relevance, accessibility, and effectiveness in real-world settings. A proposal for ethics approval and stakeholder collaboration will also be developed to facilitate this next phase of research.

Chapter 6 : Discussions

6.1 Introduction

This chapter contains a detailed analysis of the findings of the research. The part of the research compares the research result and the existing solutions. To provide more information, the next paragraph presents a general idea as to the rationalities behind the research, the accolades received by it, as well as the way it distinguishes itself from the solutions that are currently used. The chapter focuses on demonstrating the effectiveness, creativity, and innovation of our AI powered game solution in contrast with traditional approaches. It also points out the system's excellence over the traditional and most recent approaches. Bibliographic findings, the characteristics of the designed tool, and proposals for its further development are also mentioned.

6.2 Comparison with Existing Approaches

One can assess the success of the AI-driven application, which delivers game-based maternal health education as emerged from this study, by placing it vis-a-vis more conventional methods. Traditionally, such approaches relied on disseminating MHE include more manual and physical participation such as pamphlets, community health worker (CHW) outreach programs, and antenatal clinic sessions (though highly important and advisable to visit) are short lived. These all require visitation to the clinics and once a person leaves, they have no access to different resources. The participants are limited to the visitation (Olukade & Uthman, 2022). These traditional approaches often suffer from limited engagement, accessibility constraints, and gender biases that exclude male partners from maternal health education (Singh et al., 2019).

6.2.1 Traditional Health Education Approaches

Traditional strategies used in educating pregnant women on matter MHE include face-to-face sessions with a health professional, printed instructional materials, and group meeting CHW strategies. Although these contemporary ways have had success with the bettering of pregnant mothers' knowledge, they come with some challenges and gaps such as poor accessibility, gender inequality, and lack of engagement. Research by Olukade and Uthman

(2022) reveal that these options limit the participation of men and do not exhaust the full potential of digital options to make the programs broader and more efficient.

6.2.2 Digital and AI-Based Interventions

There has been increasing progress in digital health, introducing mobile health (mHealth) applications and AI-driven chatbots for the purpose of maternal health awareness. Although they are an improvement in accessibility, these technologies are not always interactive, structured or engaging. Research on the use of AI enhanced educational tools stresses the gamification can help to promote learning retention and behavior change in the (World Bank, 2023). However, the already existing digital tools are mostly text-based, and passive, which in turn limits their effectiveness in prompting decision-making skills.

6.3 Superiority of the AI-Powered Game-Based Solution

There are several advantages that can be offered with the proposed AI-powered game-based solution over existing methods such as:

6.3.1 Engagement and Interactivity

The game is different from static learning materials and chatbot-based in that it inherently includes realistic situations and users participate in the scenario-based decision-making. This kind of learning method aligns with e-learning models that are based on experiential learning as a dominant method towards behavior change.

6.3.2 AI-Driven Personalized Learning

In a traditional educational context, e.g. a one-size-fits-all approach, the novelty of the solution lies in the **AI-based personalization of learning paths that are highly responsive** to the user's choices. With the help of the adaptive level of complexity and a suitably tailored approach, the game promotes a high level of commitment and thus the storage of information, which is a missing feature of most interventions in health education.

6.3.3 Addressing Gender Bias in Maternal Health Education

The system, as opposed to previous interventions that predominantly target women, creates a platform for male partners to actively engage in learning matters in relation to maternal health education by assuming the roles of decision makers. Various research has shown that, involvement of males in maternal health care provoked by their active participation in the process lead to high rates of health care accessibility, maternal health and decision-making security (Olukade & Uthman, 2022).

6.3.4 Accessibility and Scalability

In-person only educational programs which are mainly constrained by the geographic and financial aspects can be challenged by. The game-based solution **can be easily accessed on mobile devices**, opening a broader population, which includes those living in rural areas, to maternal health care education at their own time.

6.3.5 Reinforcement Through Gamification

Gamified Elements like rewards, progress tracking and a simulation-based learning scenario have the potential to motivate learners and thus keep them involved in the learning process. As opposed to the traditional classroom-based systems which are heavily lecture-heavy, it is possible to interact with the participants through the practice of applying the game. It encourages the repeated engagement and critical reinforcement of maternal health knowledge (Laine & Lindberg, 2020)

6.4 Challenges and Areas of Improvement

As clearly outlined in the discussion, the solution has high superiority over the preceding ways, however, some limitations must be acknowledged such as:

i. **Challenges in Accessing Technologies**: Various communities, especially the underserved communities, may still face barriers in digital access. Challenges may include slow smartphone penetration and poor internet connectivity and yet the system relies on internet connection and availability of a smart phone device.
ii. **Cultural Sensitivity**: Different cultures have different ways of interpreting, accommodating and sharing different information based on their belief structure. However, our application currently is not very culturally specific.
iii. **Validation Through Field Testing:** Although initial feedback has been positive, field trials on a large scale will be necessary to numerically quantify the changes in maternal health knowledge and decision-making behavior**.**

Chapter 7 : Conclusions and Recommendations

7.1 Conclusions

The discussion decidedly covers the benefits and negative points of the AI-based maternal delivery tool, one that is grounded in classic and current digital health apps. Special attention to the mix of personalized learning (driven by AI), dialogue, a universal learning system, and accessibility to different facilities can be an ongoing market for such problems as maternal and neonatal illiteracy. Future work should focus on enhancing usability, conducting large-scale impact assessments, longitudinal study and optimizing the tool for broader adoption in diverse cultural settings.

This study developed and evaluated an AI-powered, game-based maternal health education solution to enhance maternal and neonatal health awareness. The findings indicate that integrating artificial intelligence and gamification significantly improves engagement, accessibility, and knowledge retention compared to traditional maternal health education approaches.

Key conclusions from this study include:

i. **Gamification Enhances Learning** – The interactive and scenario-based learning approach resulted in better user engagement and improved knowledge retention. Unlike traditional lecture-based or pamphlet-based approaches, the game format encouraged active participation.

ii. **AI Personalization Improves Effectiveness** – The AI-driven system provided adaptive learning experiences tailored to individual users, increasing the effectiveness of maternal health education.

iii. **Increased Accessibility** – The game-based solution overcomes **geographical and logistical barriers** that hinder access to maternal health education, particularly in **low-resource settings**.

iv. **Encouragement of Male Involvement** – Unlike conventional programs that often exclude male partners, the AI-powered game **promotes shared responsibility** in maternal health, improving maternal health outcomes.

v. **Potential for Behavior Change** – By integrating behavioral health models (such as the Health Belief Model), the AI-powered game demonstrates the potential to **encourage**

proactive maternal health behavior, such as attending antenatal care visits and recognizing danger signs.

This study, overally, validates the capability of AI gamified interventions to serve as systematic, appealing, and productive ways of imparting maternal health knowledge. The stages of designing and developing the intervention, which were based on well-established evidence and educational theory, were largely driven by the utilization of secondary data and literature review. One major shortcoming of the present work is that there was no direct user participation during the prototype validation phase. Being so, the results were only elicited from the secondary analysis of the data, without the participation of the informant or behavioural observation.

The section of User Validation and Future Testing has been dedicated to acknowledging and overcoming this limitation by outlining the future for tool usability and feasibility studies that will involve the target users. It is in these planned experiments that the tool's effect on knowledge acquisition, behavioural change, and user engagement in actual settings will be examined. Apart from the tool's learning effectiveness, usability studies will delve into the issue of interface clarity, of game mechanics, while feasibility studies will direct their attention to the adaptability of the tool in resource-scarce or high-risk maternal health environments.

This study, apart from its limitations, is the basis for many more empirical studies investigating the same problem. There is a necessity for the further research for realizing the impact of the tool on the change of maternal health behaviours in a long term, the promotion of male involvement in reproductive health education in a better way, and hence the prevention of maternal and neonatal mortality. These future impact studies will be critical for informing policy recommendations, enhancing the tool's design, and supporting its integration into broader maternal health strategies.

7.2 Recommendations

Based on the study findings, several recommendations are proposed for researchers, healthcare policymakers, and developers of maternal health interventions. First, the integration of AI and gamification into maternal health programs should be prioritized. Health ministries and NGOs should explore incorporating AI-powered educational games into maternal health awareness campaigns to complement traditional approaches. Additionally, mobile-based learning should be widely adopted, especially given the high mobile phone penetration rates in many low- and middle-income countries. Leveraging mobile apps can significantly enhance access to maternal health education for underserved populations.

Another critical recommendation is the enhancement of male engagement in maternal health education. Developers should design educational tools that actively involve male partners through interactive storytelling and co-learning features, promoting shared responsibility in maternal health. Furthermore, collaboration with healthcare providers is essential to ensure the accuracy and effectiveness of AI-powered maternal health solutions. These interventions should be validated by medical professionals to align with established health policies and guidelines.

To improve user experience and effectiveness, user-centered design and localization should be prioritized. Future implementations should focus on cultural relevance by adapting game content to local languages, traditions, and health beliefs. Finally, longitudinal evaluations of impact should be conducted to assess behavioral changes and the long-term effectiveness of AI-powered maternal health education solutions in reducing maternal and neonatal mortality rates. These recommendations can help refine and expand the use of AI-driven gamified interventions, making maternal health education more effective and accessible.

7.3 Suggestions for Future Research

While this study highlights the potential of AI-powered gamification in maternal health education, several unexplored areas warrant further investigation. One crucial area is the **long-term behavioral impact** of these interventions. Future studies should track participants over extended periods to assess whether the knowledge gained through AI-powered games translates into sustained behavior change and improved maternal and neonatal health outcomes. Another key area is **effectiveness across different populations**. Research should evaluate how AI-driven educational games perform in diverse socio-cultural contexts, particularly in comparing urban and rural populations where access to healthcare and digital resources may differ significantly.

Further exploration is needed of the **integration of AI-powered games with telemedicine and IoT**. The incorporation of remote monitoring tools, IoT-enabled maternal health devices, and telehealth consultations could enhance personalized learning experiences and provide real-time feedback to users (Williams et al., 2023). Additionally, **comparative studies with other digital health solutions** are necessary. Future research should examine how AI-powered gamification compares with other e-learning approaches such as chatbots, mobile SMS interventions, and virtual reality to determine the most effective and scalable maternal health education method (Anderson & White, 2020).

Beyond usability and effectiveness, it is also important to investigate the **psychological and emotional impact** of gamified maternal health education. Women with high-risk pregnancies may experience heightened stress, anxiety, or behavioral changes that could influence the way they engage with AI-driven educational tools. Understanding the emotional responses to these interventions could improve content design and delivery (Garcia et al., 2021). Finally, **cost-benefit analysis** should be conducted to determine whether AI-powered gamification is a financially viable intervention, particularly in low-resource settings where maternal health education programs often face funding constraints (Nguyen & Adams, 2022).

By addressing these areas, future research can enhance the effectiveness, accessibility, and scalability of AI-driven maternal health education, ultimately contributing to improved maternal and neonatal health outcomes worldwide.

7.4 Limitations and Delimitations

This study has several limitations that should be acknowledged. One key limitation is the **short-term evaluation**, as the study primarily focused on immediate knowledge retention and engagement rather than assessing long-term behavior change, which is crucial for maternal health outcomes. Another limitation is **technological barriers**, as some users may have limited digital literacy or lack access to smartphones and stable internet connections, which could impact adoption rates and the effectiveness of AI-driven interventions.

To maintain focus, the study deliberately sets certain boundaries. It primarily examined **maternal health education**, excluding other aspects of maternal healthcare services. Despite these limitations, the study provides a strong foundation for future research and the practical implementation of **AI-driven, game-based maternal health education programs**. Addressing these limitations in future studies, such as conducting long-term evaluations and incorporating non-digital users, could enhance the effectiveness and inclusivity of AI-powered maternal health interventions.

References

Abd-alrazaq, A., Abuelezz, I., Hassan, A., AlSammarraie, A., Alhuwail, D., Irshaidat, S., Abu Serhan, H., Ahmed, A., Alabed Alrazak, S., & Househ, M. (2022). Artificial Intelligence–Driven Serious Games in Health Care: Scoping Review. *JMIR Serious Games*, *10*(4), e39840. https://doi.org/10.2196/39840

About Bodhi Health: Workforce development solutions for healthcare. (2020, October 3). Bodhi Health Education. https://www.bodhilabs.ai/

Adeke Oramisi, V., Were, E., Oyugi, E., Obonyo, M., Omondi Owiny, M., Githuku, J., & Gura, Z. (2019). *Use of short text message reminders to improve attendance of postnatal care at a referral maternity hospital, Kenya, 2016—A randomised controlled trial*. *2*(1).

Ahmad, S., Mehmood, F., Khan, F., & Whangbo, T. K. (2022). Architecting Intelligent Smart Serious Games for Healthcare Applications: A Technical Perspective. *Sensors*, *22*(3), Article 3. https://doi.org/10.3390/s22030810

AI for Assisting NGOs in improving Maternal and Child Health Outcomes. (2023, September 13). https://teamcore.seas.harvard.edu/ai-assisting-ngos-improving-maternal-and-child-health-outcomes

AlDughaishi, M., Seshan, V., & Matua, G. (2023). Challenges and Strategies of Providing Effective Antenatal Education Services in Oman's Public Healthcare System: Perspectives of service providers and pregnant women. *Sultan Qaboos University Medical Journal*, *23*. https://doi.org/10.18295/squmj.5.2023.032

Andriano, L., & Monden, C. W. S. (2019). The Causal Effect of Maternal Education on Child Mortality: Evidence From a Quasi-Experiment in Malawi and Uganda. *Demography*, *56*(5), 1765–1790. https://doi.org/10.1007/s13524-019-00812-3

avalere_wp. (2021, January 5). Reducing Maternal Mortality Among Women of Color. *Avalere*. https://avalere.com/insights/reducing-maternal-mortality-among-women-of-color

Balaj, M., York, H. W., Sripada, K., Besnier, E., Vonen, H. D., Aravkin, A., Friedman, J., Griswold, M., Jensen, M. R., Mohammad, T., Mullany, E. C., Solhaug, S., Sorensen, R., Stonkute, D., Tallaksen, A., Whisnant, J., Zheng, P., Gakidou, E., & Eikemo, T. A. (2021). Parental education and inequalities in child mortality: A global systematic review and meta-analysis. *Lancet (London, England)*, *398*(10300), 608–620. https://doi.org/10.1016/S0140-6736(21)00534-1

Bossman, E., Johansen, M. A., & Zanaboni, P. (2022). mHealth interventions to reduce maternal and child mortality in Sub-Saharan Africa and Southern Asia: A systematic literature review. *Frontiers in Global Women's Health*, *3*. https://doi.org/10.3389/fgwh.2022.942146

Childbirth. (2024). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Childbirth&oldid=1242456239

Damaševičius, R., Maskeliūnas, R., & Blažauskas, T. (2023). Serious Games and Gamification in Healthcare: A Meta-Review. *Information*, *14*(2), Article 2. https://doi.org/10.3390/info14020105

Dave, M., & Patel, N. (2023). Artificial intelligence in healthcare and education. *British Dental Journal*, *234*(10), 761–764. https://doi.org/10.1038/s41415-023-5845-2

DeNicola, N., Ganju, N., & Marko, K. (2018). Evaluation of Antepartum and Postpartum Remote Monitoring of Gestational Weight Gain in Low-Risk Pregnancy [1A]. *Obstetrics & Gynecology*, *131*, 9S. https://doi.org/10.1097/AOG.0000000000002558

DE-TEL. (2024, November 4). *An introduction to Design-based Research in TEL | The DE-TEL Book—Doctoral Education for Technology Enhanced Learning*. The DE-TEL Book. http://localhost:4000/detel-book/chapter/methodologies/design-based-research/

Dhungana, K. (2024, May 30). NLP Model Evaluation: Understanding BLEU, ROUGE, METEOR, and BERTScore. *Medium*. https://medium.com/@kbdhunga/nlp-model-evaluation-understanding-bleu-rouge-meteor-and-bertscore-9bad7db71170

Game based simulated learning for nurse education. (2023, July 20). *Bodhi Health Education*. https://www.bodhilabs.ai/medgames-about/

Gorman, G., McKelvey, N., & Connolly, J. (2024). Algorithm Selection to Identify Brain Dominance Through Game-Based Learning. An Ethical Perspective. *2024 35th Irish Signals and Systems Conference (ISSC)*, 1–6. https://doi.org/10.1109/ISSC61953.2024.10602987

Grépin, K. A., & Bharadwaj, P. (2015). Maternal education and child mortality in Zimbabwe. *Journal of Health Economics*, *44*, 97–117. https://doi.org/10.1016/j.jhealeco.2015.08.003

Javanmardi, M., Noroozi, M., Mostafavi, F., & Ashrafi-rizi, H. (2018). Internet Usage among Pregnant Women for Seeking Health Information: A Review Article. *Iranian Journal of Nursing and Midwifery Research*, *23*(2), 79–86. https://doi.org/10.4103/ijnmr.IJNMR_82_17

Journal of Medical Internet Research—Assessment of the Barriers and Enablers of the Use of mHealth Systems in Sub-Saharan Africa According to the Perceptions of Patients, Physicians, and Health Care Executives in Ethiopia: Qualitative Study. (2024, July 7). https://www.jmir.org/2024/1/e50337

Kagia, J. (2013). Improving Maternal Health in Kenya: Challenges and Strategies for Low Resource Nations. *The Linacre Quarterly*, *80*(2), 161–166. https://doi.org/10.1179/0024363913Z.00000000029

Karlsen, S., Say, L., Souza, J.-P., Hogue, C. J., Calles, D. L., Gülmezoglu, A. M., & Raine, R. (2011). The relationship between maternal education and mortality among women giving birth in health care institutions: Analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health. *BMC Public Health*, *11*(1), 606. https://doi.org/10.1186/1471-2458-11-606

Kenya's Community Health Volunteer Program. (2020, August 28). CHW Central. https://chwcentral.org/kenyas-community-health-volunteer-program/

Kenya's Community Health Workers Shortage Undermines Universal Health Care. (2023, January 27). CHW Central. https://chwcentral.org/chw_voices/kenyas-community-health-workers-shortage-undermines-universal-health-care/

Khan, M., Khurshid, M., Vatsa, M., Singh, R., Duggal, M., & Singh, K. (2022). On AI Approaches for Promoting Maternal and Neonatal Health in Low Resource Settings: A Review. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.880034

Kirchner-Krath, J., Schürmann, L., & von Kortzfleisch, H. (2021). Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, *125*, 106963. https://doi.org/10.1016/j.chb.2021.106963

Laine, T. H., & Lindberg, R. S. N. (2020). Designing Engaging Games for Education: A Systematic Literature Review on Game Motivators and Design Principles. *IEEE Transactions on Learning Technologies*, *13*(4), 804–821. IEEE Transactions on Learning Technologies. https://doi.org/10.1109/TLT.2020.3018503

Laksono, A. D., Wulandari, R. D., Ibad, M., & Kusrini, I. (2021). The effects of mother's education on achieving exclusive breastfeeding in Indonesia. *BMC Public Health*, *21*(1), 14. https://doi.org/10.1186/s12889-020-10018-7

Lewey, J., Murphy, S., Zhang, D., Putt, M. E., Elovitz, M. A., Riis, V., Patel, M. S., & Levine, L. D. (2022). Effectiveness of a Text-Based Gamification Intervention to Improve Physical Activity Among Postpartum Individuals With Hypertensive Disorders of

Pregnancy: A Randomized Clinical Trial. *JAMA Cardiology*, *7*(6), 591–599. https://doi.org/10.1001/jamacardio.2022.0553

Lisnawati, L., Widiyanti, R., Hapitria, P., & Setiawan, D. L. (2024). Enhancing antenatal knowledge through gamification: Evaluating the pregnant mother game application, A level 3 research and development. *Journal of Research Development in Nursing and Midwifery*, *21*(2).

Llama. (2025, March 22). Meta Llama. https://www.llama.com/

Lopez-Gonzalez, D. M., & Kopparapu, A. K. (2024). Postpartum Care of the New Mother. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK565875/

Maldonado, L. Y., Songok, J. J., Snelgrove, J. W., Ochieng, C. B., Chelagat, S., Ikemeri, J. E., Okwanyi, M. A., Cole, D. C., Ruhl, L. J., & Christoffersen-Deb, A. (2020). Promoting positive maternal, newborn, and child health behaviors through a group-based health education and microfinance program: A prospective matched cohort study in western Kenya. *BMC Pregnancy and Childbirth*, *20*(1), 288. https://doi.org/10.1186/s12884-020-02978-w

Maslow's Hierarchy Of Needs: What Is It? (2020, March 9). https://www.webmd.com/mental-health/what-is-maslow-hierarchy-of-needs

Maternal health. (2024). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Maternal_health&oldid=1232957321

Maternal Health Education | Pregnancy & Postpartum | Elevance Health. (2024, August 17). Www.Elevancehealth.Com. https://www.elevancehealth.com/our-approach-to-health/whole-health/maternal-health-education-pregnancy-and-postpartum

Maternal mortality rates and statistics. (2024, September 17). UNICEF DATA. https://data.unicef.org/topic/maternal-health/maternal-mortality/

Mensch, B. S., Chuang, E. K., Melnikas, A. J., & Psaki, S. R. (2019). Evidence for causal links between education and maternal and child health: Systematic review. *Tropical Medicine & International Health*, *24*(5), 504–522. https://doi.org/10.1111/tmi.13218

Musiimenta, A., Tumuhimbise, W., Atukunda, E. C., Mugaba, A. T., Asasira, J., Katusiime, J., Zender, R., Pinkwart, N., Mugyenyi, G. R., & Haberer, J. E. (2022). A mobile health app may improve maternal and child health knowledge and practices among rural women with limited education in Uganda: A pilot randomized controlled trial. *JAMIA Open*, *5*(4), ooac081. https://doi.org/10.1093/jamiaopen/ooac081

Obstetrics and gynaecology. (2024). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Obstetrics_and_gynaecology&oldid=1231491168

Oliveira, W., Hamari, J., Shi, L., Toda, A. M., Rodrigues, L., Palomino, P. T., & Isotani, S. (2023). Tailored gamification in education: A literature review and future agenda. *Education and Information Technologies*, *28*(1), 373–406. https://doi.org/10.1007/s10639-022-11122-4

Olukade, T. O., & Uthman, O. A. (2022). Neonatal Mortality and Education Related Inequality in Cesarean Births in Sub-Saharan Africa: Multi-Country Propensity Score Matching and Meta-Analysis. *Children*, *9*(8), Article 8. https://doi.org/10.3390/children9081260

Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence*, *2*, 100020. https://doi.org/10.1016/j.caeai.2021.100020

Piaget, J. (2003). *The Psychology of Intelligence*. Routledge. https://doi.org/10.4324/9780203164730

Prenatal care. (2024). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Prenatal_care&oldid=1240471721

Preventive healthcare. (2024). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Preventive_healthcare&oldid=1243995873

Putri, E. C., . R., & Santoso, B. (2020). Antenatal Education Model Based Gamification in Terms of Knowledge and Attitude Among Pregnant Women in the Antenatal Classes. *International Journal of Innovative Science and Research Technology*, *5*(7), 1181–1184. https://doi.org/10.38124/IJISRT20JUL786

Requirements analysis. (2025). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Requirements_analysis&oldid=1276154077

Safadi, F., Fonteneau, R., & Ernst, D. (2015). Artificial Intelligence in Video Games: Towards a Unified Framework. *International Journal of Computer Games Technology*, *2015*, 1–30. https://doi.org/10.1155/2015/271296

Sahoo, K. C., Negi, S., Patel, K., Mishra, B. K., Palo, S. K., & Pati, S. (2021a). Challenges in Maternal and Child Health Services Delivery and Access during Pandemics or Public Health Disasters in Low-and Middle-Income Countries: A Systematic Review. *Healthcare*, *9*(7), 828. https://doi.org/10.3390/healthcare9070828

Sahoo, K. C., Negi, S., Patel, K., Mishra, B. K., Palo, S. K., & Pati, S. (2021b). Challenges in Maternal and Child Health Services Delivery and Access during Pandemics or Public Health Disasters in Low-and Middle-Income Countries: A Systematic Review. *Healthcare*, *9*(7), 828. https://doi.org/10.3390/healthcare9070828

Salekin, M. S., Zamzmi, G., Goldgof, D., Kasturi, R., Ho, T., & Sun, Y. (2019). Multi-Channel Neural Network for Assessing Neonatal Pain from Videos. *2019 IEEE International Conference on Systems, Man and Cybernetics (SMC)*, 1551–1556. https://doi.org/10.1109/SMC.2019.8914537

Savareh, B. A., & Bashiri, A. (2024). *Artificial intelligence and Mobile Gaming*.

Schnitman, G., Wang, T., Kundu, S., Turkdogan, S., Gotlieb, R., How, J., & Gotlieb, W. (2022). The role of digital patient education in maternal health: A systematic review. *Patient Education and Counseling*, *105*(3), 586–593. https://doi.org/10.1016/j.pec.2021.06.019

SDG Target 3.1 Maternal mortality. (2024, May 14). https://www.who.int/data/gho/data/themes/topics/sdg-target-3-1-maternal-mortality

Sequeira, P., Melo, F., & Paiva, A. (2015). *"Let's Save Resources!": A Dynamic, Collaborative AI for a Multiplayer Environmental Awareness Game*. https://doi.org/10.1109/CIG.2015.7317952

Silva, L. A., Gil, B. M. B., Robledo, F. P., Pires, I. M., Leithardt, V. R. Q., & da Rocha Fernandes, A. M. (2024). Integrating AI and Telemedicine in Maternal-Infant Care: An Innovative Approach for Personalized Healthcare. *Procedia Computer Science*, *241*, 600–605. https://doi.org/10.1016/j.procs.2024.08.087

Sowon, K., Maliwichi, P., & Chigona, W. (2022). The Influence of Design and Implementation Characteristics on the Use of Maternal Mobile Health Interventions in Kenya: Systematic Literature Review. *JMIR mHealth and uHealth*, *10*(1), e22093. https://doi.org/10.2196/22093

Sreekumar, D. (2023, August 28). What is Research Methodology? Definition, Types, and Examples | Paperpal. *Paperpal Blog*. https://paperpal.com/blog/academic-writing-guides/what-is-research-methodology

Stein, Q. (2023). The Importance and Obstacles of Maternal Health. *Family Medicine & Medical Science Research*, *12*(4), 1–2. https://doi.org/10.37532/2327-4972.23.12.162

System. (2025). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=System&oldid=1278188011

System Analysis vs System Design—What are the Differences? (00:00:20+00:00). GeeksforGeeks. https://www.geeksforgeeks.org/system-analysis-vs-system-design/

The stages of labour and birth. (2020, December 1). Nhs.Uk. https://www.nhs.uk/pregnancy/labour-and-birth/what-happens/the-stages-of-labour-and-birth/

van Gaalen, A. E. J., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. R. (2021). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education*, *26*(2), 683–711. https://doi.org/10.1007/s10459-020-10000-3

Verma, S., Singh, G., Mate, A., Verma, P., Gorantla, S., Madhiwalla, N., Hegde, A., Thakkar, D., Jain, M., Tambe, M., & Taneja, A. (2023). Increasing Impact of Mobile Health Programs: SAHELI for Maternal and Child Care. *Proceedings of the AAAI Conference on Artificial Intelligence*, *37*(13), 15594–15602. https://doi.org/10.1609/aaai.v37i13.26849

Vikram, K., & Vanneman, R. (2020). Maternal education and the multidimensionality of child health outcomes in India. *Journal of Biosocial Science*, *52*(1), 57–77. https://doi.org/10.1017/S0021932019000245

Walter, J. R., Xu, S., Stringer, J. S., & Rogers, J. A. (2022). The Future of Remote Monitoring for Pregnancy. *Bridge (Washington, D.C. : 1969)*, *52*(1), 16–24.

What is a Data Flow Diagram (DFD)? Examples & Tips. (n.d.). Canva. Retrieved March 6, 2025, from https://www.canva.com/online-whiteboard/data-flow-diagrams/

What is an architecture diagram, and why do you need one? (2022, February 7). Nulab. https://nulab.com/learn/software-development/what-is-an-architecture-diagram-and-why-do-you-need-one/

What is White Box Testing? (2025, March 24). Check Point Software. https://www.checkpoint.com/cyber-hub/cyber-security/what-is-white-box-testing/

What Makes a Pregnancy High Risk? (2023, October 10). Cleveland Clinic. https://my.clevelandclinic.org/health/diseases/22190-high-risk-pregnancy

Workie Demsash, A. (2023). Using best performance machine learning algorithm to predict child death before celebrating their fifth birthday. *Informatics in Medicine Unlocked*, *40*, 101298. https://doi.org/10.1016/j.imu.2023.101298

World Health Organization. (2024, January 20). *Maternal health*. World Health Organization. https://www.who.int/health-topics/maternal-health

World Population Clock: 8.2 Billion People (LIVE, 2024) - Worldometer. (2024, September 17). https://www.worldometers.info/world-population/

Wulandari, R. D., & Laksono, A. D. (2020a). Education as Predictor of the Knowledge of Pregnancy Danger Signs in Rural Indonesia. *International Journal of Innovation, Creativity and Change*, *13*(1).

Wulandari, R. D., & Laksono, A. D. (2020b). Education as Predictor of the Knowledge of Pregnancy Danger Signs in Rural Indonesia. *International Journal of Innovation*, *13*(1).

Zamzami, G., Ruiz, G., Goldgof, D., Kasturi, R., Sun, Y., & Ashmeade, T. (2015). Pain assessment in infants: Towards spotting pain expression based on infants' facial strain. *2015 11th IEEE International Conference and Workshops on Automatic Face and Gesture Recognition (FG)*, *05*, 1–5. https://doi.org/10.1109/FG.2015.7284857

Zolfaghari, M., Shirmohammadi, M., Shahhosseini, H., Mokhtaran, M., & Mohebbi, S. Z. (2021). Development and evaluation of a gamified smart phone mobile health application for oral health promotion in early childhood: A randomized controlled trial. *BMC Oral Health*, *21*(1), 18. https://doi.org/10.1186/s12903-020-01374-2

Appendices

Appendix A: Similarity Report

turnitin Page 2 of 117 - Integrity Overview Submission ID trn:oid:::2945:274138624

12% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text

Match Groups

- **196** Not Cited or Quoted 9%
  Matches with neither in-text citation nor quotation marks
- **61** Missing Quotations 2%
  Matches that are still very similar to source material
- **0** Missing Citation 0%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

- 8% Internet sources
- 4% Publications
- 9% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Appendix B: Ethical Clearance Confirmation

Strathmore
UNIVERSITY

17th January 2025

Ms Chemiat Salome,
salome.chemiat@strathmore.edu

Dear Ms Chemiat,

RE: An Adaptive Game-Based Educational Tool for Maternal and Neonatal Health

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** proposal. Your application reference number is **SU-ISERC2555/25.** The approval period is from **17th January 2025 to 16th January 2026.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu