Refresher Training through Gamified Activities on Maternal and Newborn Care for Frontline Healthcare Workers

Submitted in partial fulfillment of the requirements
of the degree of

Doctor of Philosophy

by

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September2025

Dedicated to my beloved parents.

Thesis Approval

This thesis entitled **Refresher Training through Gamified Activities for Front-line Healthcare Workers on Maternal and Newborn care** by **Arka Majhi** is approved for the degree of **Doctor of Philosophy**.

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Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE OF COURSE WORK

This is to certify that **Arka Majhi** (Roll No. 184350001) was admitted to the candidacy of Ph.D. degree on 12 July 2019, after successfully completing all the courses required for the Ph.D. programme. The details of the course work done are given below.

S.No	**Course Code**	**Course Name**	**Credits**
1	TD 606	Public Policy and Governance in Technology and Development	6
2	TD 621	Food Processing and Nutrition Delivery	6
3	DE 668	Instructional Design	4
4	TD 694	Seminar	4
5	TD 610	Contemporary Critical Issues in Technology and Development	0
6	HS 791	Communication Skills -I	PP
7	TD 792	Communication Skills -II	PP
		Total Credits	**20**

IIT Bombay

Date: Dy. Registrar (Academic)

Abstract

With the increasing demand for universal healthcare coverage, targeted towards mothers and children under different healthcare programmes, there has been a rapid increase in the number of Frontline Workers (FLWs) or Community Healthcare Workers (CHWs), i.e., the Anganwadi Workers (AWWs) and the Accredited Social Health Activists (ASHAs). The job training and the refresher training of these workers leave a lot to be desired. The capacity deficit of field functionaries has been identified as a major factor affecting the effectiveness of state health programmes. Given the massive numbers of field functionaries and the continuously advancing base of knowledge and techniques, conventional training pedagogy is ineffective in building and updating the capacity of the CHWs and their supervisors. With the improvement of technology and widespread availability of smartphones in cities as well as rural and tribal villages of India, access to digital training systems can potentially benefit the healthcare workers and the healthcare system to a large extent, rendering increase in immunization coverage, reduced malnutrition and infant mortality rate, countrywide. The conventional training methods are proving to be inadequate for the task. Gamification of the training material for the refresher training and use of digital tools for its dissemination offers one potential solution to this problem, which is the subject matter of the doctoral research. The child and mother care protocol, comprising the immunization schedule and medicine supplements for children and scheduled visits, checkup and medication for antenatal and postnatal mothers, is gamified through different gaming options. Digital versions of these games have been developed, which are playable on Android smartphones. Card games appear fit for this purpose, as they are easily customizable for the training content. The study compares the effectiveness of the game-based learning pedagogy and conventional classroom instruction with a group of CHWs, and discusses ways to make it an adequate refresher training tool.

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List of Abbreviations

ASHA	Accredited Social Health Activist
AWW	Anganwadi Worker
AWH	Anganwadi Helper
AWC	Anganwadi Centre
CHW	Community Health Worker
NFHS	National Family Health Survey
CNNS	Comprehensive National Nutrition Survey
ICDS	Integrated Child Development Services
IFA	Iron and Folic Acid
MWCD	Ministry of Women and Child Development
LMIC	Low and Middle income Countries
LISA	Local Indicators of Spatial Association
PHC	Primary Healthcare Centre
mHealth	Mobile Health
FDG	Focused Group Discussion
MCPC	Mother and Child Protection Card
IAP	Indian Academics of Paediatrician
ORS	Oral Rehydration Solution
ANC	Antenatal Care
GLO	General Learning Objectives
SLO	Specific Learning Objectives

MCQ	Multiple Choice Question
CINI	Child in Need Institute

Chapter 1

Introduction

Maternal and child health and nutrition are significant indicators of the growth of a nation and the well-being of its population. Healthcare systems worldwide are struggling with a shortage of Community Health Workers (CHWs) or trained health workers, especially in low- and middle-income countries (LMICs), reaching an estimated deficit of 18 million by 2030 (range 16-19) (WHO, 2020). Despite the myriad of interventions and policy actions, these are still chronic problems, particularly in nations like India, where malnutrition, morbidity, and mortality among children are severe public health concerns. Of the many government schemes addressing these issues, the Integrated Child Development Services (ICDS) scheme under the Ministry of Women and Child Development (MWCD) focuses on reducing malnutrition and overall development of children (below 6 years), as well as improving maternal health of pregnant women and lactating mothers. However, while there has been a noticeable improvement in the rate of child mortality, the nutritional scenario has been anything but good. High and persistent child malnutrition levels with tardy reduction, seen in successive health surveys, continue to be a matter of concern in India.

One of the prominent features of the state health programmes is the role played by CHWs or frontline personnel, such as AWWs and ASHAs, who are the initial interface between the health and nutrition system and the community, where they usually reside. ASHAs are state-government-employed CHWs tasked with delivering last-mile healthcare. They are not salaried but incentivized for their work, which is considered voluntary. ASHAs' activities include data collection, healthcare provision, and information dissemination in the community.

The state health programme's implementation depends on their ability to converge in community healthcare planning and actions, and deliver essential healthcare services efficiently, which in turn, depends heavily on their training, expertise, and competence (Gujral et al., 1991). Training and supervision were identified as one of the most ignored intervention-related aspects in systematic reviews of CHW success factors (Kok et al., 2015). However, with the magnitude of the issue and the growth of the number of field functionaries every year, the traditional ways of training and capacity building have faced significant limitations. It remains a challenge for LMICs to train or educate CHWs, ensuring the most vulnerable population's good health and well-being.

Capacity Building of CHWs

Refresher training of field functionaries, particularly capacity building, has been traditionally de-emphasized in terms of funding and practice. Traditionally, the field workers are trained in a physical classroom environment following the cascading model of teaching the Master Trainer of the state and districts, and then the field functionaries. Training program budgets are low, and refresher training, to keep and update knowledge, has been disproportionately impacted by budget cuts. The trainers and learners also complain about inadequate infrastructure for conducting training and assessing the knowledge gains in crowded classrooms. These are further compounded by the logistical difficulty of coordinating large-scale, face-to-face training sessions in spread-out and geographically distant locations. In these massive teaching classes, it is often difficult to pay attention to the learners or the field functionaries individually. Conventional training methods have not had the effect of motivating field workers or enabling long-term knowledge retention.

There is a pressing need to study alternative and emerging pedagogies that can bridge such gaps and render attempts at capacity building more affordable, participatory, and efficient. The rapid proliferation of digital technologies and smartphones in India, especially following the COVID-19 pandemic, has opened up new possibilities for leveraging digital tools to enhance the training of field staff. Interestingly, the post-pandemic period has witnessed a considerable surge in digital uptake, and most field functionaries now have basic digital competence and exposure to smartphones. This development has made way for building digital training solutions to suit their requirements. Research on the training and education of CHWs is scarce. Researchers have attempted to train and educate CHWs using traditional technology solutions but most of them couldn't materialize.

Why haven't the educational paradigms in training materialized?

Over the years, researchers, government programmes, and non-governmental organizations have attempted to revolutionize training approaches for CHWs in India. A wide range of technologies has been introduced at different points in time, each with varying degrees of effectiveness in promoting learning and knowledge retention. Some of these approaches, however, proved to be less adaptable to field conditions. To better understand current research progress, we can trace how technological innovations and learning have shaped CHW training systems in India.

In the 1930s, proponents of radio broadcasting claimed that it could replace teachers by providing expert instruction at scale. Researchers recently experimented with community radio like Mobile Vaani, an interactive voice response (IVR)–based mHealth intervention and multimedia content delivered through feature phones and smartphones to train CHWs (Yadav and et.al., 2017; Yadav et al., 2019; Yadav and et.al., 2019). By the 1950s, television broadcasting was thought to be an advanced educational medium, combining moving images with sound. Lectures were recorded and broadcast simultaneously to multiple classrooms. Research revealed no significant differences in knowledge gains between learners who attended face-to-face in-person sessions and those who viewed the broadcast from other rooms.

Critics might argue that, though the medium was visual, the incentive was not aligned and motivating enough for people to learn. Researchers implemented an incentive-based training approach for CHWs using basic mobile phones (Shah et al., 2017). The intervention involved preloading the phones with video modules on maternal and child healthcare. Each video was followed by a set of related questions, with their correct answers. CHWs received follow-up phone calls during which they were quizzed on the material. Correct responses were rewarded with cellular talk-time credits, serving as an incentive to reinforce learning and participation. However, evidence suggests that once the incentive is withdrawn, CHWs' interest and engagement tend to decline. The collection of offline-accessible videos functioned in a manner similar to earlier offline encyclopedic resources distributed by libraries and schools for students—useful as reference material but limited in sustaining long-term motivation without external reinforcement.

Critics have argued that the lack of interactivity might be an important aspect in such interventions. A historical parallel can be drawn from the 1980s, when the Massachusetts Institute of Technology (MIT) developed the Logo programming environment with the expectation that guiding a 'turtle' to move, similar to a remote-controlled car, would improve reasoning skills among students. More recently, in a study conducted in Dharavi, Mumbai (n = 37), instructional illustrations were found to be significantly more effective than the video-based training materials distributed by the Ministry of Women and Child Development (MWCD) for training CHWs (Tulaskar, 2020).

Researchers also tried quizzes and trivia as a mode of teaching. Answering MCQs did not teach CHWs how to create knowledge but to choose answers. It also encourages guessing, and sometimes they get some rewards for answering something they are unaware of, just by fluke. The multiple answers comprise the wrong ones, too, exposing them to the incorrect content while they read all the options. The MCQs encourage memorizing the questions to beat the system. Quizzes were often part of MOOCs.

Massive Open Online Courses (MOOCs) were also considered transformative for education. Platforms such as Coursera, EdX, IITBombayX, Swawam, and NPTEL have provided access to knowledge and delivered education at scale. However, their effectiveness remains unclear, with studies critiquing high dropout rates, limited learner engagement, and non-consistent learning outcomes across different populations. Spoken Tutorial has experimented with extending this model beyond technical domains. Content for training CHWs at scale, focused on maternal and child nutrition, as well as breastfeeding techniques for lactating mothers. While it might have delivered factual knowledge well, it has mixed results in hands-on skills. Scaling up the reach of training through technological solutions might enable wide dissemination and access to expert knowledge, but it strives to replicate the contextual, interactive, and scaffolding elements that the best trainers and professionals provide in person.

With recent advancements in artificial intelligence, researchers have experimented with deploying chatbots, voice interfaces, and AI agents to support CHWs (Ramjee et al., 2025; Sivasubramanian and Raval, 2025). These tools act as an external scaffolding by assisting with the daily tasks of CHWs, such as retrieving information for advocacy, estimating child anthropometrics through image processing, classifying images to recognize symptoms, and offering access to relevant knowledge resources. AI can help offload cognitively demanding processes and provide timely guidance. Excessive dependence on AI might limit the development of CHWs' expertise (UNESCO, 2025). The challenge lies in designing gradual phasing-out strategies, where AI scaffolding supports novices initially but reduces its assistance as competence grows, allowing CHWs to internalize knowledge, strengthen cognitive processes, and ultimately achieve mastery.

Delving into Gamification as an Innovation in Pedagogy

Gamification, applying game design in a non-game context, has been recognized as one of the most effective strategies for optimizing participation, motivation, and learning returns. Field workers, who usually go through tedious and monotonous training protocols, can gain from gamification as a way of making learning more enjoyable and interesting. Gamification offers room for competition, cooperation, and reward, which can lead to continuity and memorization of knowledge.

The perception of classroom-based training for CHWs has been that it is boring or non-engaging. It prompted many researchers to explore strategies for making training and learning more enjoyable. While learning through games may not guarantee complete comprehension of a subject, it often serves as a significant motivator. Although the literature on creating enjoyable learning experiences is extensive, there is limited direct evidence connecting fun and enjoyment in game-based learning to improved learning outcomes. However, game-based learning is believed to enhance engagement, which in turn can foster better learning. Various strategies have been employed to achieve this, including the use of diverse media, entertaining instructional methods, and hands-on constructivist approaches. The boundary between enjoyment and education is not always clear. Interestingly, in many cases, learning becomes a byproduct of enjoyable activities.

We also looked at gamification and gameful activities as an option. The four studies in this thesis outline these efforts. With the potential of gamification, we developed a digital game-based solution for field worker refresher training. [1]

The objective is to design an Android-centric game as a refresher module complementing the in-person initial core training but alleviating its limitations. This approach takes advantage of the ubiquitous usage and popularity of smartphones to deliver training content in an efficient

[1] Choice of game mechanics, drafting rules of play, and the digital game app are annexed in section A.6 and A.7

and scalable manner.

The game design borrows from traditional card games, which are simple to learn, straightforward to play, and inherently engaging. The physical card game serves as a precursor and introduction to the digital one, offering a seamless transition for those who are upcoming adopters of smartphones and other technologies. The card game format also facilitates the easy incorporation of key elements of gamification, such as rules, procedures, and structured gameplay, making it an ideal choice for this situation.

Health module as Scope of Gamification

During the course of this research, it became evident that gamification requires a well-defined and unambiguous set of rules or protocols for participants to follow. In this regard, the procedures and protocols within the health module, like immunization schedules and medicine supplements for children and mothers, were found to be more clearly codified compared to those related to nutrition. Given this distinction, the gamification efforts were deliberately confined to the refresher training syllabus for ASHA workers, pertaining to health, ensuring clarity and alignment with established health protocols.

ASHA and Anganwadi Workers: Team Building

ASHA workers and Anganwadi workers (AWWs) work together to organize Village Health and Nutrition Days (VHNDs), where services like immunization, antenatal care (ANC), postnatal care (PNC), and nutrition support are provided. They also conduct home visits to ensure that pregnant women and children receive proper care and follow-up. Both workers play a key role in mobilizing the community to participate in health programs and address vaccine hesitancy. Their combined efforts significantly contribute to improving immunization coverage, reducing maternal and child mortality, and raising awareness about maternal and child health, especially in underserved communities. They are essential to the success of national health programs like the National Health Mission (NHM) and Poshan Abhiyaan (Nutrition Mission).

The dynamics of cooperation and competition come into play when AWWs join teams with ASHA workers, either collaborating or competing with each other. This interaction provides valuable insights into inter-cadre teamwork and coordination. It not only increases participation but also helps both cadres better understand each other's roles and responsibilities in community healthcare delivery.

Field Trials and Methodological Considerations

The first field trial [Study 1] (n=100 sampled and 86 of them retained) was conducted in urban areas of Kolkata and rural areas of West Bengal. We conducted play sessions, tests, and interviews in Bengali, which is the local language. We worked in partnership with an NGO named CINI, which also acts as a State Training Centre (STC) for training the ASHAs of the districts around.

The second field trial [Study 2] was conducted at three places. Prior notification of conducting these field testing sessions was given to the ASHA and AWW coordinators and Health Officers of Burhanpur Urban (Burhanpur, Madhya Pradesh), Joka village (Kolkata, West Bengal), and Mandala village (Slum near BARC, Mankhurd, Mumbai). Out of 400 CHWs selected through convenience sampling, n=368 (184 ASHAs and 184 AWWs) were retained till the end of the study. We conducted play sessions, tests, and interviews in Hindi, Bengali, and Marathi, respectively, which are the local languages.

The third field trial [Study 3] was conducted at different places in Madhya Pradesh, comprising urban, rural, and tribal areas. 90 participants (45 ASHAs and 45 AWWs), each from three groups, were retained till the end of the study, totaling n=270 participants across three groups.

The last field trial [Study 4] was conducted at different parts of Burhanpur, Kolkata, and Mumbai. We conducted field testing with n=198 ASHAs, or 94 each from two intervention groups, spread across 3 locations. We conducted play sessions, tests, and interviews in Hindi, Bengali, and Marathi, respectively, which are the local languages.

Some ASHAs, particularly those with limited formal education, faced challenges reading Hindi numbers on cards and filling out survey questionnaires. To address this, numbers were changed to English while retaining Hindi words. However, ASHAs educated in Madrasas, familiar only with English and Urdu numbers, required English translations to complete forms, but could still play cards using other information. Consequently, all numbers in the cards and the app were updated to English. During questionnaire reviews, discrepancies were found, such as ASHAs skipping Rotavirus-related questions. This was due to Rotavirus vaccines not being operational in Madhya Pradesh and thus being excluded from training materials. Additionally, confusion around the term "booster" for the PCV vaccine arose, as it was not used in their training schedules, though most ASHAs eventually understood and answered correctly.

Large-scale field trials in multicultural linguistic and geographic settings have guided the development and piloting of the gamified training module. The field trials have provided information about the operational challenges and potentialities entailed in implementing gamification in a field training program. An instance would be how the interrelation between teamwork and collaboration was brought out through observations of ASHAs' and AWWs' interaction when playing the game in cooperation. Additionally, the design process involved iterative prototyping and field worker feedback to ensure that the game was both culturally appropriate and easy to use.

1.1 Dissertation content and structure

In this research, we conducted the experiments in phases of studies, each addressing different but connected aspects of training and knowledge enhancement for Community Healthcare Workers (CHWs) in India. The first phase was on comparing physical and augmented reality (AR)-based playful activities for refresher training, which was conducted in rural and semi-urban areas of West Bengal. This phase provided the foundation for the effectiveness of game-based training over traditional methods. The second phase expanded the scope by integrating digital and physical card games, with a larger cohort of CHWs from various states, pan-India, to test for retention of knowledge and interest in the long term. The third phase shifted focus to the use of game-based tools for data collection, for child malnutrition mapping, and was piloted in various urban and rural locations to identify the scalability and flexibility of these tools. Each phase built on the findings of the previous one to create a cohesive narrative that addressed the issues of training, retention, and implementation. The four-study format thesis structure allows for the exploration, analysis, and presentation of each phase separately. This allows for integrating various methodologies, from qualitative co-design work to quantitative quasi-experimental studies, and providing an overall picture of game-based training tool effectiveness. Through the four separate studies, the dissertation covers the multifaceted nature of the issue and thus contributes to the body of knowledge on gamified training methodologies for CHWs in low-resource settings.

The four studies present a detailed discourse on the implementation of gamified learning, assess its effectiveness, and address the training demands of CHWs. These studies respond to the gaps in the training and performance of CHWs, who are the sole contact points between the health system and rural communities. The studies stress the necessity for interactive and user-oriented learning methods and emphasize the facilitation of engagement and motivation to promote better learning outcomes. They also highlight the importance of reinforcement learning and feedback mechanisms in facilitating long-term retention of health information among CHWs. The studies differ with respect to their focus on specific game modalities. While the first study focuses on the comparative effectiveness of physical and computer games, the second and third studies focus on the long-term retention gains of smartphone-based games. The fourth study expands the scope by covering how location-based games can be used in data gathering. This variety of approaches illustrates the adaptability of gamified learning and how it can be used in different training needs and settings. The findings of these articles give valuable insights regarding the potential of game-based training in enhancing knowledge acquisition, retention, and interest among CHWs and the utility of these instruments in practical applications of data collection and healthcare delivery.

The first study, "Physical and Augmented Reality-based Playful Activities for Refresher Training of ASHA Workers in India", shows the drawbacks of the traditional classroom training model and suggests the concept of playful, interactive training tools. Through a comparison of physical playing cards with an AR-based smartphone game, the study establishes that AR-based training results in significant knowledge retention and interest gains among CHWs. The immersive and interactive nature of AR games makes them particularly appropriate for visual learners, and physical card games are appropriate for auditory learners who acquire knowledge from verbal communication when playing the games. This study points to the necessity of conforming training strategies to the different learning styles of CHWs to ensure that training programs are not only engaging but also effective.

Following these findings from the first study, though AR-based games were better, physical card games also have potential in training CHWs. We further developed the card game for both digital and physical play and tested it with CHWs. The second study, "Refresher Training through Digital and Physical, Card-Based Game for Accredited Social Health Activists (ASHAs) and Anganwadi Workers (AWWs) in India", further explores the relative effectiveness of physical and digital card games. The study finds that while digital games yield higher short-term knowledge gains, long-term knowledge retention is equally high, with no significant difference between digital and physical play modes. This suggests that both modalities are viable options for refresher training, with digital games having the added advantage of scalability and accessibility. The study also highlights the necessity for ongoing reinforcement in an attempt to preserve knowledge retention, as the control group, without training, performed significantly worse than the game-based groups. These results show the importance of continuous training and support to support CHWs in delivering quality healthcare services.

Following these findings from the second study, we tried deploying and testing both the modalities, physical and digital card games, in different locations to rigorously test the product and check if the results are generalisable. The third study, "Replay, Revise, and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India", examines the long-term effect of smartphone-based refresher training. The study contrasts digital and physical card games with conventional classroom teaching and finds that both game-based methods fare better than conventional training in knowledge retention. While the digital game shows higher short-term knowledge gain, long-term knowledge retention is similar for both digital and physical gameplay modes. The qualitative answers provided by CHWs indicate a strong preference for digital games due to their convenience and interactivity, yet highlight the need for hard copies of printed materials for purposes of learning and reference when undertaking home visits. This study underlines the imperative of including game-based training as part of existing programs while satisfying the practical needs and wants of CHWs.

We then tried to explore whether the training games, apart from imparting healthcare knowledge, can also help in collecting child anthropometric data of children, through crowdsourcing efforts of CHWs, helping to create a malnutrition hotspot map of the community, and measure the efficiency of the CHWs, while maintaining engagement in the learning process. The fourth study, "Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location-Based Games in India", shifts the focus from training to actual field implementation of skills of CHWs in collecting data. The study introduces a geospatial game to enhance the efficiency and engagement of CHWs in carrying out child anthropometric data collection. The study shows that the game-based approach can significantly increase measurement efficiency and encourage CHWs to reach underserved areas, leading to broader data coverage. However, the study also introduces challenges of maintaining long-term engagement, as the initial excitement about the game-based application diminishes over time. This demonstrates the necessity of ongoing support and reinforcement to ensure motivation and the ongoing effectiveness of game-based tools in real-world settings.

Keeping in view the findings of these articles, some key themes emerge. Firstly, game-based training methods, with digital and AR capabilities, are better than classroom training in facilitating learning and knowledge retention among CHWs. Their interactive and immersive nature makes them highly engaging, responsive to different learning styles, and makes training fun and effective. Second, while digital games offer access and scalability, physical card games might also be an appropriate choice in resource-constrained contexts, or/where mobile phone access is restricted. The choice between them on which mode to deploy must be tailored to the specific requirements and contexts of the targeted population. Third, these studies focus on knowledge gain and knowledge retention over time through game-based training. While these tools may have the ability to maximize short-term knowledge acquisition, long-term effectiveness is contingent upon regular use and reinforcement. This suggests that training classes should incorporate regular refresher classes and provide CHWs with access to supplemental material, such as printed brochures, to enhance continued learning and reference. Finally, the application of game-based tools in crowdsourcing geolocated anthropometric data demonstrates their capacity to augment the efficiency and accuracy of healthcare delivery. By encouraging CHWs to reach underserved populations and gather detailed data, these tools support healthcare planning and make the intervention more effective.

Overall, the evidence from the following articles provides strong support for game-based training methods' ability to improve the knowledge, performance, and engagement of CHWs in India. These game-based trainings are an effective alternative to traditional training methods, counteracting the challenge of limited literacy, resource constraints, and poor retention. They are, however, dependent upon careful planning, ongoing assistance, and alignment within existing healthcare structures. Future research must consider the long-term outcomes of game-based training, investigate how levels of engagement need to be sustained, and address the broader impact of these tools on the provision and outcome of healthcare within resource constraints.

Study-1 Physical and Augmented Reality based Playful Activities for Refresher Training of ASHA Workers in India			
Aim	**Methods**	**Results**	**Conclusions**
To compare the effectiveness of physical and augmented reality (AR) card games for improving knowledge gain and retention on child immunization among ASHA workers.	Focus group discussions (FGDs) and participatory design exercises with CHWs. Field trials were conducted to evaluate the effectiveness of both physical and AR-based games.	AR-based games demonstrated higher engagement, knowledge gain, and retention compared to physical card games, mainly due to their interactive and intuitive nature.	AR-based games were found to be more effective in learning enhancement and knowledge retention, suggesting potential as a complementary training tool for ASHA workers.
Study-2 Refresher Training through Digital and Physical, Card-Based Game for Accredited Social Health Activists (ASHAs) and Anganwadi Workers (AWWs) in India			
Aim	**Methods**	**Results**	**Conclusions**
To investigate the effectiveness of digital and physical card-based games in enhancing knowledge of child immunization among community healthcare workers (CHWs) in India.	A quasi-experimental study with 368 participants (n=92 for each group: digital, physical, traditional classroom, and control). Quantitative gameplay data and qualitative feedback were collected through interviews.	Both digital and physical card games showed significant knowledge improvements compared to traditional classroom and control groups. Digital gameplay demonstrated slightly higher knowledge retention.	Game-based refresher training can be a scalable, cost-effective, and engaging tool for improving CHWs' knowledge and practices in resource-constrained settings.
Study-3 Replay, Revise, and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India			
Aim	**Methods**	**Results**	**Conclusions**
To assess the differences in knowledge gain and retention among digital, physical, and traditional classroom training methods for CHWs.	270 CHWs (n=90 per group) were divided into three groups: digital game, physical card game, and traditional classroom training. Pre- and post-intervention tests and retention tests after six months were conducted.	All groups demonstrated significant knowledge improvement, with digital gameplay yielding higher post-intervention scores and superior long-term knowledge retention.	Smartphone-based training outperformed both physical and classroom methods, indicating its potential for improving long-term knowledge retention through frequent, interactive learning sessions.
Study-4 Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location Based Games in India			
Aim	**Methods**	**Results**	**Conclusions**
To evaluate the effectiveness of location-based games for improving CHW engagement, data collection accuracy, and measurement efficiency in crowdsourcing child anthropometric data.	Two groups (n=94 per group) were compared: one using a game-based data collection app and the other using a traditional non-game app. Data accuracy, speed, and engagement were measured through gameplay and analytics.	The game-based approach showed significant improvements in data accuracy, engagement, and measurement efficiency compared to the traditional data entry method.	Location-based games demonstrated the potential to enhance CHWs' engagement and improve the quality of anthropometric data collection, aiding evidence-based decision-making for child nutrition monitoring.

Table 1.1: Doctoral Dissertation at a glance: Summary of Aims, Methods, Results, and Conclusions from Four Studies

1.2 Research Questions

This research addresses several key questions across the four studies, focusing on the effectiveness of game-based training, knowledge retention, user engagement, and data collection efficiency. These questions aim to explore the potential of content gamification and digital tools in improving healthcare training and data collection processes for CHWs, contributing to the growing body of evidence supporting innovative pedagogical approaches in resource-constrained settings. These research questions are as follows:

1. **Effectiveness of Game-Based Training**

   RQ1 To what extent are game-based training methods more effective than traditional classroom-based refresher training for community healthcare workers (CHWs) in terms of knowledge acquisition and retention?

   RQ2 How do digital and physical gameplay modalities compare in improving CHWs' knowledge and performance?

2. **Knowledge Retention**

   RQ3 Are there significant differences in long-term knowledge retention between physical and digital gameplay modes for CHWs?

   RQ4 How does knowledge retention from game-based training compare to that achieved through traditional training methods after an extended period?

3. **Engagement and User Experience**

   RQ5 Does the incorporation of augmented reality (AR) into training enhance CHWs' engagement and learning outcomes compared to traditional physical card-based training methods?

   RQ6 How do CHWs perceive and engage with digital and physical game-based training tools in terms of ease of use, motivation, and satisfaction?

4. **Crowdsourcing and Data Collection Efficiency**

RQ7 How does measurement efficiency—encompassing accuracy, speed, and overall effectiveness—differ between game-based and traditional non-game data entry methods for crowdsourcing child anthropometric data?

RQ8 Can game-based methods enhance the engagement and sustained participation of CHWs in data collection across various spatial and temporal dimensions?

Chapter 2

Background

2.1 Current status of child immunization

Immunization saves 2-3 million lives each year from diseases that vaccines could prevent (Andre et al., 2008). Across the world, about 14.5 million children under 12 months missed the necessary vaccination, and 1.6 million of them were Indian (WHO, 2024). A study on NFHS-4 data found that the immunization coverage of children in 163 districts in India was less than half (Panda et al., 2020). 47% of children belonging to the lowest wealth quantile households in India are not fully immunized, and any health insurance does not cover 71% of families (Indian Institute Population Sciences and Ministry of Health and Family Welfare, 2016). As a result, they end up spending significant amounts on healthcare, pushing almost 32-39 million people annually to dip below the poverty line (van Doorslaer et al., 2006; Garg and Karan, 2009).

A study (Panda et al., 2020) performed LISA and spatial regression model on NFHS-4 data. Through this study, we found that mothers receiving ante and post-natal care had better chances of fully immunizing their children. It also found a strong association between full immunization of children and women empowerment indicators like mothers' literacy and women being the family's authority. However, despite vaccination camps being conducted free of cost in Government Hospitals and all rural or urban Primary Healthcare Centres (PHCs) in India, many children are still not vaccinated. The study also found that it is mostly ignorance and unawareness among family members regarding vaccination that increases the likelihood of undernutrition in children and results in child mortality and morbidity. The study also suggests the necessity of sensitizing the population, which would improve access to community healthcare. Pockets of the population with poor healthcare access require more targeted steps to bridge the immunization gap. mHealth technologies could help improve health outcomes and decrease health inequalities (Peek, 2017).

2.2 Knowledge Gap of healthcare workers and mothers

We conducted a focused group discussion with mothers in a rural village in South 24-Paraganas district in West Bengal. We found that, due to the knowledge gap among healthcare workers, the mothers and children in the community are usually left unaware of medical care, healthcare delivery, checkup services, family planning, etc. Studies conducted in other parts of India also show similar results. A study (Mani et al., 2020) found mothers' low awareness of tetanus, immunization, iron, and folic acid (IFA) tablets. More than half of the pregnant women were unaware of availing pregnancy care services at ANC visits, such as blood pressure and weight measurement, and abdominal examination. Knowledge regarding high-risk conditions in pregnancy and danger signs in pregnancy was also low. Few mothers knew about the various components of institutional delivery and maternity benefit schemes. The designed game would try to bridge the knowledge gap of the community healthcare workers in the above-mentioned topics.

2.3 Access to mobile phones and internet services

According to a press release (Telecom Regulatory Authority of India, 2021), out of the 1205.64 million telephone subscribers as of June 30, 2024, in India, 44.66% (538.51 million) were rural telephone subscribers. Out of them, 99.44% (535.53 million) were rural wireless telephone subscribers, making 45.75% share of the total wireless subscribers. Based on NSS 75th Round, Household Social Consumption Education Survey conducted between July 2017-June 2018 (MoSPI, 2015), it was found that 35.8% households (24.8% rural and 51.3% urban) had access to internet. The rise in smartphone ownership among healthcare workers in India opens up an opportunity to utilize mHealth approaches to bridge the gap between healthcare access and engagement with the beneficiaries of the target population (Ganapathy and Ravindra, 2008; Bassi et al., 2018; Madanian et al., 2019).

2.4 Introductin to mHealth

Mobile Health or mHealth is defined as "medical and public health practice supported by mobile devices" (WHO, 2011), thus having the potential to overcome the limitations of the traditional methods of receiving child and maternal healthcare through job cards or printed paper brochures. mHealth is a means to disseminate healthcare information cost-effectively and personalized to socioeconomic and cultural needs to fit the context.

Researchers from developing countries have provided suggestions for designing effective mHealth interventions (Kumar and Anderson, 2015). These include communicating with the community through radio and text messages (both automatic and human-aided). Studies have been conducted to motivate health workers and increase their knowledge by deploying short videos on mobile phones (Ramachandran et al., 2010). Another study (Kumar and Anderson, 2015) from India found that watching short films on mother and child care empowered Health Workers and mothers to manage pregnancies proactively. Shah. et al. (Shah et al., 2017) from India did a similar study on an incentive-based approach for training AWWs through mobile-based videos. The AWWs' feature phones were loaded with videos related to mother and child healthcare. A few questions with their correct answers related to the content of the video were appended to the video. After watching these videos, AWWs were supposed to call a toll-free number, where they would be quizzed on the same questions as shown in a particular topic video. AWWs were awarded cellular talk time as an incentive for answering correctly. Another study (Pérez et al., 2020) from India found that 'Tika Vaani', an IVR-based mHealth solution to improve knowledge on immunization, has shown significant results in improving healthcare knowledge if the content is customized to meet the needs of less-literate users.

2.5 mHealth interventions through e-Learning, Serious Games and Gamification

e-Learning is a teaching and learning approach through an educational model focusing on improving access to training, communication, and interaction by adopting electronic media and devices for promoting novel understanding and enhancing learning (Sangrà et al., 2012). 'Blended Learning' happens when e-learning and face-to-face teaching are combined. 'Educational game' pedagogy requires learners' participation while performing competitive activities following previously set game rules. A Cochrane review (Akl et al., 2010) studied two physical games for educating healthcare professionals and confirmed games as an effective strategy for teaching. The application of games focusing on 'serious intent' has been observed in various domains like health, training, defense, education, military, aviation, city planning, politics, and ecology with multiple approaches () (Alvarez 2012). Researchers have used similar terms like Game-Based-Learning, Games-for-Good, Alternative-Purpose-Games, (Sawyer and Smith, 2008), and Edugaming (Angarita et al., 2005) while describing similar interventions.

Clark Abt first outlined the idea of 'Serious Games' in his book, published in 1970, named 'Serious Games.' He described 'Serious Games' as the games that "have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement" (Abt, 1970). Serious Games combines learning theory and empirical outcomes to improve skill learning and game design principles. Interventions through serious game design can enhance cognitive, social, and health-related skills beyond the game context (Ritterfeld et al., 2009; Giunti et al., 2015). The number of articles and systematic reviews on serious games in healthcare education is growing (Graafland et al., 2014; de Ribaupierre et al., 2014; Laamarti et al., 2014; De Wit-Zuurendonk and Oei, 2011).

The games created with the serious purpose of providing healthcare education delivered through digital devices are Serious Games. Serious Games provide a gaming experience through rules, engines, and mechanics. However, gamification tries to create a similar experience through applying game mechanics and involving fun while performing mundane activities, while developing motivational and cognitive abilities. Deterding et al. defined gamification as the "use of game design elements in non-game contexts" (Deterding et al., 2011b,a; Deterding, 2011, 2012). Gamification potentially allows higher involvement of the player in setting up the objectives and outcomes, thus personalizing the intervention and making it cost-effective (Gentry et al., 2019). The increase in inequality of access to resources for healthcare, lack of adherence to treatment (Vicente et al., 2014), and increased healthcare cost (Lenihan, 2012) generated the need for applying gamification in digital healthcare services. Self-determination theory suggests using intrinsic and extrinsic motivations in the context of game design (Ryan and Deci, 2000). Extrinsic motivators are game elements such as badges, points, progress bar, and leaderboards (Ryan and Deci, 2000). At the same time, intrinsic motivators are the feelings of 'mastery' or accomplishment towards the goal, 'autonomy' or the freedom of a sense of play, and 'relatedness' or connecting players to the goal and passion (Deterding et al., 2011b).

2.6 Educational Theories and Serious Gaming

In his book (Knowles, 1980), Malcolm stresses the factors supporting adult learning. Serious games and gamification techniques can also help achieve those goals.

- With every experience faced, there is a tendency to move from dependency to autonomy. Games facilitate this by providing an active learning environment through independence in moves or choices made in games.

- Past learning is used in dealing with our current problems. Games challenge us to deal with different situations as per our prior knowledge.

- With age, people tend to be more focused on the task goal. Games train us to be goal-oriented by targeting small tasks and completing levels.

- With age people tends to learn from tasks, based on practical problems and less on educational content. Games facilitate learning through design problems, which are inspired by practical problems.

Learning through games supports the 'cognitive theory of multimedia learning' (Mayer, 1997), which says that learning happens better when both visual and auditory senses are involved. Siemens proposes that learning is not a linear process, but meandering through changing environment (Siemens, 2005). Serious Games also follow similar mechanisms. Researchers (Mey, 2005; Gee, 2012) showed that games are compelling as learning happens within meaningful contexts.

Training through Serious Games has resulted in more extended training engagement and improvement in learning gains. Experiential Learning Theory (Kolb, 1984) suggests that after gaining knowledge, every learner observes, reflects, and analyzes it, creating abstract concepts in mind and actively experimenting with them by applying their learnings to see the results. Serious Games can target every stage of this process and support the creation of knowledge through the experience of gameplay. For combining learning and gaming, Ritterfeld suggests three ways (Ritterfeld and Weber, 2006).

- Reinforcement model: Learning rewarded with entertainment

- Motivation model: Entertainment encourages learner's interest and attention

- Blended model: Process and result of learning itself becomes exciting

The blended approach seems to be most effective because it provides intrinsic satisfaction of learning (Breuer and Bente, 2010) and provides fun while learning (Koster, 2010).

To achieve predefined learning objectives in mind, a Serious Game in its design phase needs to follow a grounded design approach (Hannafin et al., 1997) and align with educational theories. Choosing behaviorism or constructivism while designing the game can influence the playful activity's learning theories and instructional strategies (Gunter et al., 2008). The learning approach defines the characteristics of the training environment. It also controls the pace and frequency of interactions intended for critical learning through the Serious Game targeted toward the learning outcomes of the learner.

2.7 Theoretical Framework: Why aren't CHWs Learning?

The challenges in CHW training are often attributed to institutional inertia, limited commitment from state health systems, or overhyped technological solutions. Another perspective is offered by the framework of fast and slow thinking by Daniel Kahneman (Kahneman, 2011). According to dual-process theories of cognition, humans operate through two interacting systems of thought.

System 1 (S1) thinking is fast, intuitive, and automatic. It processes information rapidly, recognizing patterns based on prior experiences, and draws on long-term memory without conscious effort. System 2 (S2) thinking, in contrast, is slow, deliberate, and analytical; it monitors for errors, walks through procedures step by step, and allows for meta-cognition—thinking about thinking. While S2 is essential for novel or complex problems, much of real-world problem-solving relies on the well-developed capabilities of S1.

Expertise emerges from repeated engagement, practice, and reflection, which gradually consolidates knowledge into long-term memory. Over time, S2-mediated processes help structure experiences, allowing S1 to recognize patterns and make decisions automatically. In effect, S1 functions as a highly efficient, largely unconscious problem-solving system; most decisions and actions are executed seamlessly, without deliberate analytical effort.

For CHWs, this framework underscores the importance of experiential, practice-based, and reflective learning. Simply providing information is insufficient. Training must be structured to repeatedly engage CHWs in meaningful tasks, allowing them to internalize procedures and knowledge in long-term memory. This enables S1-driven recognition and decision-making, making fieldwork both effective and adaptive to complex, real-world situations.

2.8 Designing Implications: Training Tools for CHWs

Effective learning design requires a careful balance of cognitive load. Extraneous load should be minimized through clear and intuitive materials, such as well-structured interfaces, simple visuals, and minimal distractions. At the same time, intrinsic load must be matched to the learners' prior knowledge. This means introducing concepts gradually, revisiting familiar ground at the start, and avoiding too much new material at once. Germane load should be encouraged by presenting moderately challenging content that prompts learners to think more deeply and connect ideas.

Learning happens through effortful practice. Learners need repeated opportunities to attempt tasks, make mistakes, and receive timely feedback. This cycle helps strengthen memory, gradually shifting performance from deliberate reasoning to more automatic responses. Confidence is built through iteration. Small improvements over time, reinforced with feedback, allow learners to see their progress. This steady reinforcement motivates continued engagement and helps fragile skills become more stable and reliable in practice. Effective design must allow space for productive struggle. If tasks are over-automated or solutions are given too quickly, learners may miss the chance to develop resilience and adaptive strategies. Allowing them to work through difficulties, even when the process feels slow, is key to creating learning that lasts.

Constructivism views learners as active builders of their own knowledge, but discovery learning does not always work as intended. The challenge lies in how scaffolding is implemented. If support is removed too quickly, learners may feel lost and unable to progress. Consider the analogy of arriving in a new city without GPS. You could rely on S2 to carefully follow road signs, but this is effortful and slow. With GPS, you can offload that cognitive effort, but if you always rely on it, you never truly learn the city. The best approach is a balance: guidance at first, followed by gradual phasing out so learners can eventually navigate on their own.

This highlights the limits of working memory. S2 has fewer resources and cannot handle too many complex tasks at once. The goal of instruction is to support learners until the knowledge becomes internalized and shifts into S1. Experts often forget what it feels like to be a novice because their own S1 knowledge is automatic and effortless. Learners struggle with basics, and if these are not mastered through repeated, effortful practice, moving on to advanced topics becomes overwhelming. Effective learning design therefore requires balancing support, practice, and the gradual transition from effortful reasoning to automatic mastery. CHWs should understand information and extract meaning from the game's content. Further, they might construct knowledge by applying the learning to overcome the game's situations, ideally cascading later in their daily practices.

2.9 Learning: A Social Activity

Much of the technology-driven hype in education stems from the assumption that the primary barrier to learning is limited access to information. While this may hold true in resource-constrained contexts, in most cases, access alone is insufficient. Effective learning requires skilled instructors and a community of peers with whom learners can engage and collaborate. Social Learning Theory (Bandura, 1977) states that learning is a social activity where we learn by observing, imitating, and modelling others. For community health workers (CHWs), this social dimension is particularly important: while their role emphasizes connecting with the community, they must also engage with peers to foster a collaborative and socially supported learning environment.

Chapter 3

Methods

3.1 Ethics Declaration

The study procedure was approved by the IIT Bombay Institutional Review Board (IRB) (Proposal Number: IITB-IRB/2022/051), and the IRB approval is attached in the Appendix (Figure: E.1). All participants provided informed consent prior to data collection. We conducted the studies by relevant guidelines and regulations set by the Institute Ethics Committee, which strictly adheres to the Declaration of Helsinki (WMA, 2013) developed by the World Medical Association.

Participation in the playtesting activity was voluntary, with an option to quit anytime during the research. We tried to compensate CHWs for the valuable time and expertise they brought in through knowledge gain and non-monetary collaboration. Their contribution to our research was immeasurable materialistically. We served tea, snacks, and sweets as a token of gratitude. However, we have not given the participants any monetary or materialistic compensation.

3.2 Evaluation method

This research study assessed knowledge gain, retention, and satisfaction after playing the designed game with the intervention group. We compared it with a control group using the traditional mode of the classroom refresher course. The evaluation of the gameplay intervention program generally follows the Kirk Patrick Model of Evaluation (Kirkpatrick, 1950). This model considers evaluation across four levels. We limited the scope of this research study to conducting level 1 and level 2 evaluations only, as levels 3 and 4 evaluate the prolonged effects of the intervention program.

We conducted a baseline knowledge evaluation before the intervention. Then, we conducted 4-5 physical and digital card play rounds. It was followed by a post-test using the questionnaire survey. We provided a deck of cards to every CHW group who lived nearby and installed an Android app for other groups. They were encouraged to play when they met for about an hour every day for a week. Master trainers trained the control groups through regular classroom training. After a few weeks, we tested the knowledge levels through a questionnaire survey.

1. Kirk Patrick Level 1 evaluation (Reaction): CHWs' reaction toward the game, gameplay experience, enjoyment, and satisfaction after playing a few game rounds will be recorded through feedback forms. The standard SUS questionnaire for evaluating usability covers most Level 1 questions. The responses would provide inputs for further modification of the game. We translated the GEQ or Game Experience Questionnaire (Ijsselsteijn et al., 2013) into Indian languages. We started with Marathi, Hindi, and Bengali, as the respondents were majorly into these three languages.

2. Kirk Patrick Level 2 evaluation (Learning): A pre-and post-questionnaire on both intervention and control groups will assess the delta learning by measuring the change in the CHWs' knowledge of child immunization and pregnancy care. To compare if the delta learning is significantly different in one of the cases, we conducted a paired t-test (considering normal distribution). We further compared the post-test scores to delayed post-test scores conducted a few weeks later to compare knowledge retention. We used t-tests to find significant differences.

Apart from learning gains and knowledge retention tests, we performed usability testing and other qualitative evaluations of this teaching and learning method.

1. Usability Testing of the designed game (Jakob Nielsen)

    (a) Learnability : How easy is it for a new player to learn how to interact with the interface of the digital game

    (b) Memorability : If the player comes back after some time to play the same game, how easy is it to regain proficiency or to remember what they have learned, the first time they played the game

    (c) Efficiency : Once players have used the interface or the system, how quickly can they perform different tasks

    (d) Accuracy : How often do players make mistakes related to the rules

    (e) Satisfaction : How is the experience of playing the game? Are the players having fun, enjoying, feeling skilled, gaining mastery, providing context for social interaction, etc?

3.3 Instrumentation

3.3.1 Knowledge Questionnaire

The instrument used in this study had three sections. All participants consented to this research by reading the first section of the questionnaire and signing it before every survey/test. The second section was the demographic data sheet to identify potential group variances. The demographic data sheet consisted of a checklist and gap-fill questions, such as age, highest educational grade/degree, and years of experience as an ASHA. The third section was 40 Multiple Choice Questions (MCQ) on all four silos, Children below 1 year, above 1 year, ANC and PNC. Questions related to infants and children were on immunization and medicine supplements. This test evaluates the participants' knowledge at the baseline, gained through intervention, and retention after a week of practicing the playful activity. A reference to the 3-page questionnaire is in the Appendix section: (Figure: B.1 , B.2, and B.3). This questionnaire was initially prepared in English and then auto-translated to Indian languages by Google translation services, followed by human corrections. Most of the respondents' mother tongues are comprised of Hindi, Marathi, and Bengali, so we translated the questionnaire into these languages.

3.3.1.1 Game Experience Questionnaire

We tried to conduct the game experience survey through the GEQ (Game Experience Questionnaire) (Ijsselsteijn et al., 2013). The questionnaire contains 33 questions assessing gaming experience on seven components: Immersion, Flow, Competence, Positive and Negative Affect, Tension, and Challenge. There are approximately five questions per item to make it a robust experience measure. The questions generally capture the feelings that they experienced while gaming. The answers are on 5 5-point Likert scale, which ranges from "not at all" at the low end to "extremely" at the high end. The GEQ is available in global Western languages like English, Dutch, Finnish, and German (Ijsselsteijn et al., 2008). In this research, we made an attempt to translate it into Indian languages. We started with Marathi and Hindi as the respondents were mainly into these two languages. The translation process of GEQ was similar to the translation process of the main evaluation questionnaire. Firstly, we translated the English texts into Marathi with the help of the Google Translate service and the IndiaTyping service to get two linguistic variations. Then, a human was involved in correcting the translation of the questions individually. As Indian languages are cultural and gender-sensitive, we considered that the questions were asked to an elderly lady formally or respectfully. We chose the vocabulary appropriate for the rural respondent, thus avoiding urban vocabulary. For simplicity of understanding, we used English words in Marathi texts, which local people commonly use. A reference to the GEQ and the translation process (Figure: B.4). Later, the GEQ is now in the process of translation into 16 Indian languages: Bengali, Gujarati, Hindi, Kannada, Malayalam, Marathi, Tamil, Telugu, Odia, Punjabi, Urdu, Assamese, Nepali, Bhojpuri, Konkani, and Maithili. The translated questionnaires are going through rounds of human correction phases. We decided to exclude the social presence module (player's social engagement with characters) and the Post-game module (fatigue after a long gap in playing) from this study as they were beyond the scope of this research.

3.4 Experiments in Four Studies

The course of this experimental research has not been linear but instead characterized by discontinuities and leaps. The author has been lucky enough to have the effort come full circle in reputable journals. Due to the evolving and iterative work, we chose the 'four-publications' format for this doctoral thesis to present flexibly but still structurally. Each chapter uses the conventional academic approach of an introduction, methodology, results, and conclusion. The four summaries of publications are not chronological in order, but mostly overlap. However, it illustrates how the gamification efforts developed while focusing on different aspects. Towards the end of the dissertation, there is a summary of the reflections connecting the dots from all the studies.

The papers presented in this thesis collectively explore innovative, gamified, and technology-enabled strategies to enhance the knowledge, engagement, and data collection efficiency of Community Healthcare Workers (CHWs) in India. While each study is rooted in a different facet of public health intervention—refresher training, immunization schedules, geospatial mapping, and anthropometric measurement—the overarching narrative revolves around leveraging Human-Computer Interaction for Development (HCI4D) to address systemic inefficiencies in CHW training and performance evaluation.

The first publication-'Physical and Augmented Reality based Playful Activities for Refresher Training of ASHA Workers in India' [Publication 1 - (Chapter 4)] compares a physical card-based game to Augmented Reality game for training ASHA workers. The publications—'Refresher Training through Digital and Physical, Card-Based Game' [Publication 2 - (Chapter 5)] and 'Replay, Revise, and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India' [Publication 3 - (Chapter 6)] —demonstrate the efficacy of gamified interventions in improving knowledge acquisition and retention among CHWs. Publication 2 compares traditional classroom training with physical and digital card-based gameplay, showing significant short-term and long-term knowledge improvements, particularly in the digital group. Publication 3 further supports these findings by revealing that digital interventions offer a significantly higher learning curve and immediate knowledge gain. However, both card-based formats outperformed traditional training in long-term retention. These works highlight the role of interactivity, multimodal content, and learner-centered design in strengthening the capacity building of CHWs. The paper—'Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location-Based Games in India' [Publication 4 - (Chapter 7)]—extends the concept of game-based learning to the domain of real-time public health data collection. Here, the focus shifts from theoretical knowledge to practical task efficiency. Compared to standard data entry apps, the study evaluates how a location-based mobile game improves CHWs' measurement accuracy and engagement in collecting child anthropometric data. The intervention group performed significantly better and demonstrated broader spatial coverage and motivation, reinforcing that gamification can transform routine monitoring tasks into engaging activities.

Chapter 4

Study 1: Comparing Physical and Augmented Reality-based Playful Activities for Refresher Training of ASHA Workers

This study seeks to design and evaluate playful refresher training activities for CHWs on immunization schedules and maternal-child healthcare practices. It compares a physical card game and an Augmented Reality (AR)-enabled smartphone application. Hypothesis (**H1**): ASHAs playing the AR-based digital version would show a higher improvement in knowledge of immunization and long-term retention compared to the group using the physical card-based game. Because of the immersive and interactive nature of the AR-based gameplay, Hypothesis (**H2**): There will be higher engagement, especially with visual and auditory learners, as compared to the physical card-based game.

This study aims to empirically validate the pedagogical potential of immersive technologies like AR in public health training, address gaps in CHW knowledge through scalable learning tools, and contribute a novel perspective to digital education research in low-resource settings. The study proposes an inclusive training methodology easily adapted across diverse public health topics and geographies by making learning interactive, language-independent, and play-based.

4.1 Study-1 Details

Parts of this section are from a published research Study [1] annexed in the Annexure 10.5

1. **Introduction**

   Research conducted on training CHWs using technology through means of texts, voice messages, videos, and quizzes has shown mixed results (Section 2.4). The gap often missing in their current way of classroom learning is long-term interaction and interactivity. While discussing with CHWs, we found that most of them like to learn while they do something tangible with their hands or get instant feedback. Augmented Reality can address this gap (Billinghurst and Dünser, 2012; Dunleavy et al., 2009; Wu et al., 2013) through layering a virtual world over the physical world through a smartphone screen, which enables to learn by doing (Azuma, 1997). With the increasing use of mobile devices, the use of interactive and gaming style learning strategies Peek (2017) offers new opportunities for training in AR Santos et al. (2014); Sarkar et al. (2020). AR provides an opportunity to transform an average room into an interactive learning lab, in which child profiles and vaccine cards interact, and choices made by the player have consequences in that world.

[1] **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2022. Physical and Augmented Reality-based Playful Activities for Refresher Training of ASHA Workers in India ", *CHI 2022: Asian CHI Symposium 2022* (Best Paper and Best Presentation award in Long Paper category) https://dl.acm.org/doi/10.1145/3516492.3558788

2. **Methods**

We conducted the study in multiple stages, i.e., conceptualization of a training game, content validation, game design, development, field testing, and comparative assessment.

(a) **Focused Group Discussion with CHWs**

We began with a focused group discussion (n=14). We observed a knowledge gap among CHWs and felt difficulty in remembering and recollecting the details of the immunization schedule. It includes the names of vaccines and the time of administering them. CHWs also reported that their original training was too lectured or rushed. We realized that the issue was about the format in which the information was presented. It led us to find more visual and interactive ways to help retention and understanding.

(b) **Co-Design with CHWs**

We chose to design along with the ASHAs. We hosted small co-design sessions where ASHAs reviewed sample illustrations, suggested modifications and made them draw. Their inputs directly influenced the choice of imagery, terminology, and the flow of the physical and AR-based games. This collaborative approach ensured that the final tools were intuitive and familiar. It also helped build a sense of ownership among the ASHAs, making them more invested in learning.

(c) **Gamified Activity - Physical Card Game**

We developed a deck of 20 cards, which was used across both the physical and AR-based interventions to keep the content consistent and comparable. The detailed process of designing the card deck is discussed in Section 3.3 of the publication in the Annexure 10.5. Players received a random mix of cards in the Physical Card Game version. The task in the game is to simulate an experience of examining the child profiles and administering them with age-appropriate vaccines. Players receive points for correct matches and can challenge each other's combinations. The activity encouraged peer validation, discussion, and friendly competition. Each round took about 15 minutes and was played by 2–5 people.

(d) **Gamified Activity - AR-based Digital Game**

The AR-based game or digital version added an interactive twist. CHWs placed printed stickers on the walls representing children and mothers. When scanned with a smartphone using the AR app, a 3D model appeared, showing age and other key details. Players then scanned the appropriate vaccine cards to administer them virtually. The game rewarded correct matches with laughter and positive reinforcement. Mistakes led to crying sounds and point deductions. This instant feedback made the experience memorable and emotionally engaging. Players can play the AR game solo or in teams. In multiplayer settings, we observed role-playing dynamics, with some participants taking the lead in scanning while others handled cards or helped strategize.

(e) **Rules of Play**

The rules of play for both physical and digital versions of the game are explained in detail in Sections 3.4 and 3.5 of the publication in the Annexure 10.5

(f) **Evaluation**

To test both tools, we collaborated with an NGO involved in ASHA training. We aligned our interventions with their existing schedule and conducted five sessions. Each group of participants went through either the physical or digital version of the training. ASHAs were informed of the purpose of the study and agreed to it through SMS or WhatsApp. The process was not mandatory, and they were free to exit anytime. Of the initial 100 ASHAs recruited for the study, 86 went through all phases. Most were between 30 and 50 years old and had a secondary school level of education. They were all proficient in Bengali, although almost a dozen had difficulty reading or writing it.

We used a simple questionnaire consisting of 10 questions focused on the immunization schedule to measure knowledge gains. We conducted the questionnaire survey both before and after the training. Questions covered topics such as the timing of vaccines, matching vaccines to ages, and interpreting information from the MCP card. We divided the participants into two groups: one experienced the card game (n=42), and the other used the AR app (n=44). We analyzed the change in their scores using paired t-tests within groups and two-sample t-tests between groups (Dimitrov and Rumrill, 2003).

3. **Results**

The results showed that the AR-based and physical games significantly increased the

ASHA workers' knowledge of child immunization schedules. The AR-based game was more interesting and effective in retaining knowledge significantly, even after three months. The intuitive and interactive nature of the interface of the AR game enhanced its appeal among the participants, making learning more effective. We also found that AR-based gaming was effective for visual learners. However, physical card-based gameplay was liked by auditory learners or those who support verbal cues during playtime.

Intervention	Pre-test score	Post-test score	Difference in Score
IG-1 (n=44)	2.7 (SD=1.1)	9.2 (SD=2.1)	6.5
IG-2 (n=42)	2.8 (SD=1.4)	6.2 (SD=1.8)	3.4
Difference of difference			Difference in Score
(IG1post - IG1pre) - (IG2post - IG2pre)			3.1

Table 4.1: Study 1: Summary of means of pre-test and post-test scores and their difference. Learning through Mobile App (Intervention Group 1 or IG 1). Learning through Physical Card (Intervention Group 2 or IG 2)

We divided the participants into two groups: one used the physical card game, and the other used the AR app. Before starting, we asked each ASHA to complete a short quiz covering key points of the immunization schedule. We repeated the same quiz right after the session. On average, ASHAs who played the physical card game improved their scores by about 3.4 points. Users of the AR app improved by over 6.5 points. We observed a statistical difference between the two groups.

4. **Discussion**

   (a) **Counterintuitive Findings in Playful Learning**

   Both modalities showed overall effectiveness, but the study shows a few counterintuitive findings.

      i. **Short-term vs Long-term knowledge retention**

      The AR-based game showed effective, immediate knowledge gains. However, the physical card game showed better knowledge retention. This reflects Kahneman's dual-process theory (Kahneman, 2011). AR-based game engaged

System-1 through fast, intuitive cues like the crying or laughing baby, signalling a right or wrong move. Whereas playing with physical playing cards demanded carefully weighing arguments and perspectives to make a thoughtful decision through taking turns, discussion, and rule-based negotiations. System-1 supported immediacy and memorability, but System-2 supported deeper understanding and codifying the content. An ASHA who had been in the physical card play group stayed silent through the first play round, later started correcting her peers mid-game, saying, "No, not at six months, the vaccine comes later—let me explain properly," suggesting that peer interaction and slow reasoning supported knowledge retention.

ii. **Low literate CHWs performed better with AR than physical cards**

Another counterintuitive finding was that participants with lower literacy or limited smartphone exposure often showed higher comfort with AR-based gameplay than with physical cards. The conjecture is that in the digital version, the multimodal cues reduced the cognitive burden of textual recall. This is consistent with embodied cognition (Wilson, 2002). During playtesting, an ASHA burst out laughing at the crying baby sound and remarked, "Now I will never forget this mistake—the baby scolded me," while making a sarcastical sad facial expression. It shows that sensory feedback can act as a strong anchor for memory. Conversely, literate participants often preferred the tactile and visual-symbolic reasoning of the cards, where they could compare options.

iii. **Constructive and Social Learning pathways**

While the AR-based game offered a learning loop through trial and error, the physical card game offered social play, elements of collaboration, competition, and correction. This exhibits the factor of relatedness in Self-Determination Theory (SDT) (Miller et al., 1985). ASHAs frequently joked and teased one another and took the game in good spirits. One of them said, "In this game, mistakes are fun, not shameful." This environment of safe social space aligns with Vygotskian ideas (Vygotsky, 1978) where scaffolding from colearners turns mistakes into a shared learning opportunity. Facilitators of the experiment observed that the physical card gameplay group had more laughter and intense debates, as compared to the digital group. This suggests that a technologically complex method or solution does not necessarily translate linearly into engagement or effectiveness. Instead, each form of gameplay was supported by different motivational and cognitive pathways. AR-based gameplay supported competence through feedback, whereas the physical card version supported relatedness through collaboration, and both were complementary to each other.

(b) **Knowledge Graph**

By about 10-15 rounds, the novelty and challenge dipped since the scenarios were stereotypical. It suggests incorporating more realistic, diversified scenarios and adaptive gameplay for long-term interest. Peer collaboration in both versions also allowed for discussion, dispelling misconceptions, and learning together, pointing out the social facet of learning through play.

(c) **Co-Design**

The intervention became contextually grounded and language-independent by involving ASHAs in the participatory co-design process, by selecting illustrations and developing rules.

(d) **Institutional Support**

The co-design and field-testing were supported by the Child in Need Institute (CINI), which also serves as the State Training Centre for ASHAs in West Bengal. CINI's long presence in communities and the trust it has built through its social work enabled us to reach remote areas and work closely with people who might otherwise have been difficult to engage. This experience shows how important institutional support is for enabling access and ensuring interventions are welcomed in community settings.

5. **Conclusion** This study began with the conjecture that training can be more effective and enjoyable if it is more game-like. Based on what we observed and measured, we found that both tools—the physical card game and the AR app—made learning more interactive, memorable, and enjoyable for ASHAs. The AR app, in particular, showed greater improvement in test scores and generated strong emotional responses that seemed to deepen retention. These findings matter because ASHAs often have limited time and resources for refresher training. If we can make those brief windows more impactful using tools they enjoy, we can improve their knowledge and empower them in their vital

roles.

This study demonstrated the potential of AR-supported learning tools to enhance healthcare training for CHWs by providing interactive, immersive, and visually rich learning experiences. The findings suggest that AR-supported learning tools can overcome the limitations of traditional training methods. Future efforts must prioritize refining AR game design for low-literacy users and scaling up this intervention in different healthcare settings. The content of the current game is limited to a fixed number of scenarios. However, in reality, there can be infinite possibilities. Adding more complicated narratives might make the game's content more comprehensive, but make the gameplay more difficult. We also plan to follow up with ASHAs months after training to see if their knowledge stays with them and helps in their fieldwork. The long-term impact is the actual test of any training tool. With further refinement and support, tools like these can become part of mainstream ASHA training across states, translated into different languages, and used in both online and offline formats.

4.2 Study-1 Reflections

This study reaffirms our conjecture that experiential, game-based refresher learning tools can improve capacity-building efforts. By shifting the mode of training from passive to active engagement, we can create an effective learning system for frontline health workers.

Critics have argued that using Augmented Reality (AR), a relatively new technology, may have induced a novelty effect that influenced learning outcomes in this study. It leaves us wondering if the observed improvements in knowledge were due to the pedagogical value of the intervention or the new technology. The preceding experiment also lacked a placebo or no-intervention control condition, limiting the ability to control for the sole effect of the intervention. To surmount these problems, the subsequent study, described in Study 2, was designed to eliminate AR and examine the learning effect of a simple card-based game delivered in digital and physical formats. We added a placebo group to enable a more controlled comparative design and better identify the isolated effect of the intervention versus usual practices.

Chapter 5

Study-2: Refresher Training through Digital and Physical, Card-Based Game for Accredited Social Health Activists (ASHAs) and Anganwadi Workers (AWWs) in India

This study was built on the findings of the previous research by expanding the comparison to include both digital and physical versions of the same card game, following the same rules of play for refresher training in immunization knowledge. The objective was to evaluate the comparative effectiveness of these two game modalities in improving knowledge retention and engagement over time. Building upon the learnings from the previous experiment in Study 1, this experiment is four-armed and compares the impact of four training groups: (i) A smartphone-based digital card game, (ii) A physical card-based game mimicking similar mechanics, (iii) Traditional classroom teaching, (iv) A control group receiving no training.

The intervention is designed around the national immunization schedule, integrating age-appropriate vaccination logic into the game mechanics. We categorized vaccines into children's age groups: Below 1 year, above 1 year, and mothers' phases: Antenatal care, and Postnatal Care. The research questions are as follows: **RQ1:** Does knowledge gain and retention differ significantly among CHWs trained using digital games, physical card games, and traditional classroom methods? **RQ2:** Is there evidence of a novelty effect that fades over time?

5.1 Study-2 Details

Parts of this section are from a published research Study [1] annexed in the Annexure section 10.5

1. **Introduction** The prevailing concerns on training CHWs are already discussed in the chapter 1. This study examines how effective card-based games—digital and physical—can be for CHWs as refresher training tools on immunization. We also wanted to find whether these games helped participants retain information over time and how they compared with conventional classroom instruction. Throughout the design process, we involved CHWs to ensure the games reflected their learning needs and constraints. We prototyped and piloted a card game-based refresher training solution for CHWs, particularly focusing on child immunization. This game will try to make learning more interactive and engaging, and allow the CHWs to practice decision-making in a social, dynamic setting.

2. **Methods**

   We initially recruited 400 CHWs—200 ASHAs and 200 AWWs to account for possible dropouts. By the end, 368 were selected among the ones who retained, divided into four groups of 92 each, with equal numbers of ASHAs and AWWs. Group 1 (IG-1): Trained with the digital card game on smartphones, Group 2 (IG-2): Trained with physical cards, Group 3 (IG-3): Received a traditional classroom session with the same content, and Group 4 (CG): Control group with no training during the study period.

[1] **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Refresher Training through Digital and Physical, Card-Based Games for Accredited Social Health Activists (ASHAs) and Anganwadi Workers (AWWs) in India. CHI PLAY Companion '24, October 14–17, 2024, Tampere, Finland (https://dl.acm.org/doi/10.1145/3665463.3678819)

All groups underwent a baseline test. The three intervention groups received their respective training formats. A post-test followed. After three weeks, we conducted a final delayed retention test (DRT) to measure how much they remembered. We trained the control group only after completing all evaluations to ensure fairness. Before participating, we gave all CHWs verbal and written explanations about the study's purpose and process. We designed digital and physical card games to help CHWs memorize the sequence and dosage of immunizations and supplements required for children and mothers. We used questionnaire surveys to check knowledge gain and retention. Focus group discussions with CHWs captured engagement levels, user satisfaction, and feedback on the training experience. Data analysis included paired t-tests for knowledge score comparisons and thematic analysis for qualitative data.

We built the training game using 60 cards (Appendix C). The process of designing the card deck is discussed in Appendix A.4. We printed the playing cards on card paper for the physical version, and the digital game mimicked the same format and rules of play, discussed in Section A.7. The players played the game in teams of four. Each player received 15 shuffled cards. The goal was to place cards in the correct chronological order based on the child's or mother's age and stage of care. Players took turns placing cards, and correct moves awarded bonus turns. The game ends when one player finishes their cards in their hand. The digital game automated the process of shuffling, distribution, and ensuring rules are followed. This reduces the cognitive load on the players. Instant feedback gives them the opportunity to learn and reflect.

We used a pen-and-paper questionnaire (Appendix B) comprising 40 multiple-choice questions covering the MCP card's contents. Each question had a single correct answer. Public health experts reviewed the questions and pilot-tested them with a small CHW group. Each survey phase—pre-test, post-test, and DRT—used the same question pool but in different orders to reduce memory bias. We translated the questionnaire into local languages to include the diversity of participants across India in the evaluation. We conducted interviews and informal discussions with CHWs to obtain qualitative feedback on their gameplay experience.

Figure 5.1 visualizes the dispersion of the scores of each group through a series of box plots.

Test phase	Intervention Group-1 (IG-1) Digital Card Game Mean (SD)	Median (min-max)	Intervention Group-2 (IG-2) Physical Card Game Mean (SD)	Median (min-max)
Pre-test	25.80 (4.81)	26 (15-36)	24.35 (5.02)	24 (16-35)
Post-test	33.83 (4.03)	34 (25-40)	32.12 (4.36)	32 (21-40)
Late Post-test (After 3 weeks)	30.55 (4.04)	31 (23-39)	30.43 (4.20)	30 (23-39)
Test phase	**Intervention Group-3 (IG-3) Digital Card Game Mean (SD)**	**Median (min-max)**	**Control Group (CG) Physical Card Game Mean (SD)**	**Median (min-max)**
Pre-test	25.35 (4.30)	25 (15-34)	24.61 (5.65)	24 (10-35)
Post-test	28.05 (3.73)	28 (19-36)	27.64 (3.69)	28 (19-36)
Late Post-test (After 3 weeks)	26.25 (3.32)	26 (19-33)	24.67 (4.10)	25 (15-32)

Table 5.1: Study-2: Test Scores

3. **Results** We used a paired t-test to compare scores within each group. The statistical tests confirmed that the digital and physical game groups had significantly better outcomes than the classroom and control groups ($p < 0.05$). Differences between digital and physical game groups were also statistically significant, with the digital card game demonstrating better immediate knowledge gain. However, there was no significant difference between long-term knowledge retention among the digital and physical card game groups. The research found that digital and physical card games are both effective refresher training instruments for CHWs, with digital games having the additional advantage of scalability. The results indicate the imperative of blended training approaches combining traditional and digital learning modalities to cater to heterogeneous learner needs. The results emphasize the potential of game-based training to improve the knowledge and performance

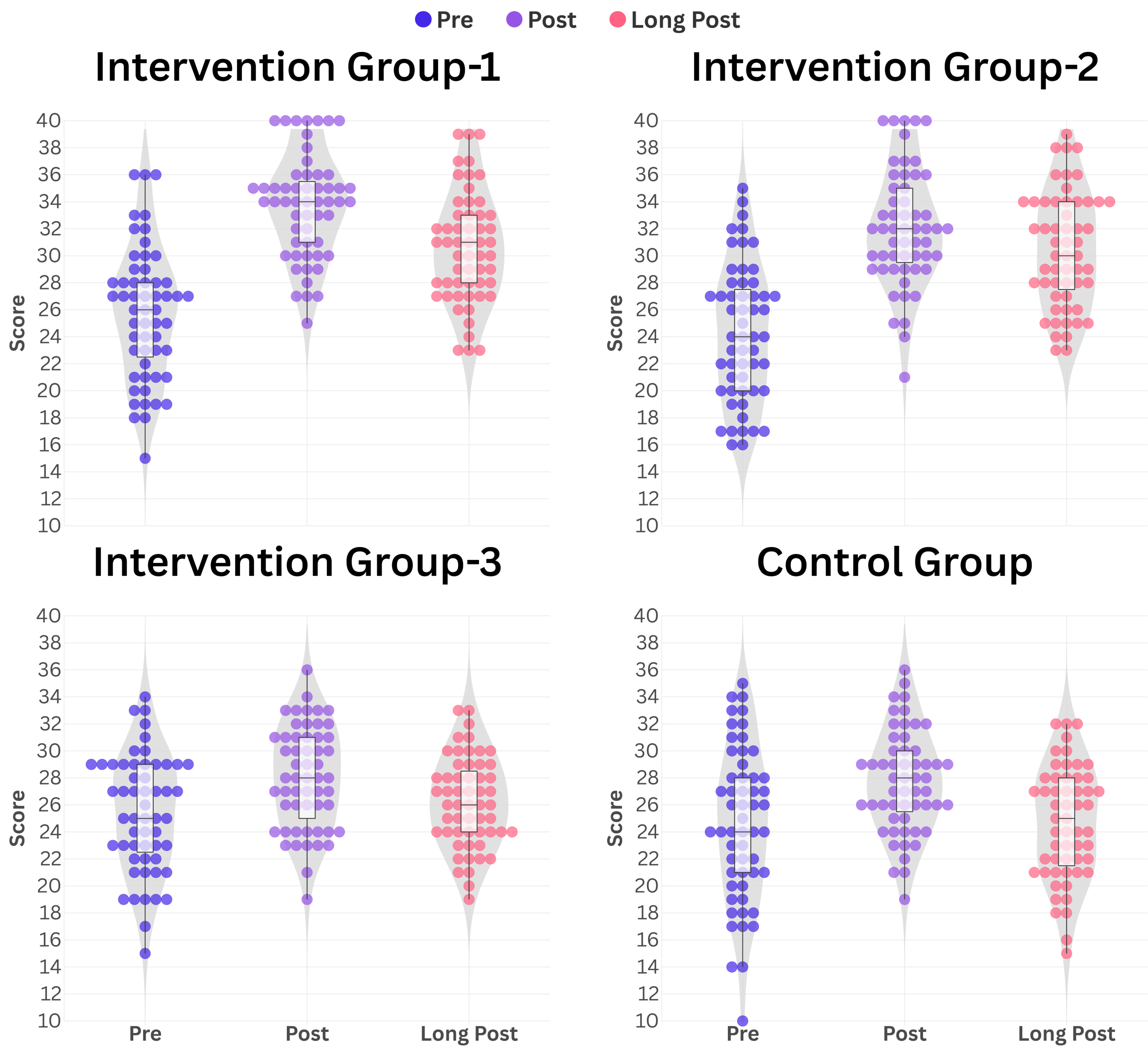

Figure 5.1: Study 2 : Results from comparing the scores of IG1 (Digital Card Games group), IG2 (Physical Card Game group), IG3 (Classroom group) and CG (Control Group)

of CHWs, particularly in resource-scarce environments.

After analyzing the test scores, we found that CHWs who played the games—either digitally or with physical cards—performed significantly better than those in the classroom training group. The control group showed slight improvement and remained flat across all three testing phases. Between the two game formats, the digital group had slightly higher scores on average, especially in the delayed retention test, although the difference was not statistically significant.

When the digital card game results were compared to the results of the AR group of the previous study (though the sample size and context were different), we found the digital card game to be better in both immediate knowledge gains and retention.

4. Discussion

Counterintuitive Findings in Playful Learning

Although digital and physical card games both significantly improved knowledge, several observations challenged conventional assumptions about game-based learning for CHWs.

(a) **Familiarity with Technology reduced Cognitive Engagement**

Some CHWs with prior experience with smartphones performed poorly in the digital game compared to expectations. FGD revealed that they relied on rapid chances and mindless tapping of cards, rather than carefully evaluating the sequence of the immunization schedule. A CHW remarked, “I thought I knew the order because I use phones every day, but I kept placing cards wrong because I was rushing.” This could be explained by Cognitive load theory (Sweller, 2022), which suggests that familiarity with technology often leads to surface-level engagement and overdependence on interface cues. However, CHWs with minimal digital experience approached the game more purposefully, taking extra time to reason through each card placement, which improved knowledge retention. This is supported by dual-process theory (System-2 thinking) (Kahneman, 2011), highlighting the benefits of conscious or thoughtful learning.

(b) **Highly competitive groups bargain Accuracy for Speed**

Another counterintuitive finding was that highly competitive teams of CHWs sometimes showed lower overall accuracy during early rounds of digital-based card play. While competition increased engagement and motivation, it occasionally triggered speed-over-accuracy strategies. CHWs prioritized finishing first over correctly sequencing cards. Meanwhile, we observed that CHWs playing with physical cards were less competitively driven and more collaborative in their approach. They achieved higher correctness by playing at a slower pace. This can be explained by Self-Determination Theory (Miller et al., 1985) principles. Intrinsic motivation and social relatedness can override extrinsic incentives like competition in supporting effective learning.

Learning - A Social Experience

The results suggest that when CHWs engage in game-based learning, they are not just having fun but learning in a way that retains them. The interactive and hands-on nature of the digital and tangible card games increased the interactivity and engagement of the training. It aligns with the Social Learning Theory (Bandura, 1977) that learning is a social activity where we learn by observing, imitating, and modeling. We learn better when peers are actively engaged in the learning process.

Number Literacy and Content Standardization

Several issues came up during testing. A few CHWs struggled with numeric literacy, especially those who had studied in madrasas, where English numerals were more familiar than Hindi. We responded by changing card numbers to English digits. We also found that some vaccines mentioned in our materials were not administered in all districts, which confused participants during the evaluation. A handful of participants attempted to refer to printed job aids during testing. We removed these cases from the final analysis. To prevent bias, we randomized the order of questions in later survey rounds.

Learning Experience through Games

During informal feedback sessions, most of the CHWs indicated that they enjoyed playing the game. They found it better than classroom sessions and more relevant to their work. Some teams were very competitive, which helped reinforce memorization of the order of the cards. The findings point to a broader potential shift in how we might train CHWs. Physical card games were easy to adopt as they did not require high-tech hardware or advanced literacy. They can be designed locally for local health agendas and scaled up with little technology. They offer a practical, scalable solution to this problem, even at their simplest.

5. Conclusion

This study shows that learning through games with smartphones or paper cards can be a robust and feasible method for training community health workers. Both formats helped CHWs learn and retain key health information better than classroom sessions. With rising smartphone access, digital tools offer slightly better outcomes and added flexibility, which has the advantages of scalability and long-term retention. This strategy can help bridge long-standing training gaps and improve public health outcomes across India by scaling the solution. Physical card-based games can be an alternative at places where access to digital infrastructure is scarce. The findings also suggest that training approaches combining physical and digital game-based learning can be more effective.

5.2 Study-2 Reflections

The findings of this study show that both digital and physical card-based game interventions significantly outperformed the traditional classroom training and control group in immediate knowledge gain. The digital version of the game demonstrated better outcomes in retention, although the statistical significance between digital and physical modes remained marginal.

Competitive and collaborative elements also improved peer learning and social reinforcement, which are the core components of community work. Gamification also improved intrinsic motivation and increased the participants' confidence, an element typically missing in training programs scheduled on the calendar. The initial rounds of digital play show the novelty effect. Players showed increased interest owing to fresh technology and instant feedback. However, as the players adapted to the given limited set of scenarios, interest started to level off. This insight indicates the requirements of repeated revisions to the content and the introduction of more varied, context-dependent challenges so that CHWs can have long-term interest and learning benefits.

Critique of these two experimental studies highlighted that the sample populations selected were unlikely to be representative of the broader demographic and contextual variability of Community Healthcare Workers (CHWs) in India. In response to this limitation, the experimental design of the subsequent experiment sought to expand the geographic and contextual reach by implementing the intervention in several demographically varied sites.

There were practical challenges in executing multi-arm study designs, particularly in geographically constrained or community-based settings. There were risks of intervention spillover and sample contamination. To mitigate these risks and enhance the simplicity of implementation, the study design of the subsequent experiment was condensed to three arms, excluding the placebo or no-intervention group. This adaptation allowed for better comparisons without interfering with the intervention and data collection process.

Chapter 6

Study-3: Replay, Revise, and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India

This study is similar to the previous study. However, in this study, the experiment was conducted in various locations in Madhya Pradesh, improving the representativeness of the population. We chose rural, tribal, and urban areas of Madhya Pradesh and Maharashtra. Mostly Hindi versions of digital and physical cards and questionnaires were used, but in some places bordering Maharashtra, we also used the Marathi version questionnaire.

6.1 Study-3 Details

Parts of this section are from a published research Study [1] annexed in the Annexure section 10.5

1. **Introduction**

   The prevailing concerns on training CHWs are already discussed in the chapter 1.

   This study investigates the comparative effectiveness of three refresher training approaches: standard classroom training, a physical card game, and a smartphone digital game.

   This study particularly wants to address the following research questions:

   - RQ1: Is gaming an effective replacement for standard classroom-based refresher training in enhancing CHW knowledge?
   - RQ2: Do digital and physical gameplay modalities differ significantly in terms of the immediate gains in knowledge?
   - RQ3: Do the two modalities differ significantly regarding long-term knowledge retention?

2. **Methods**

   We built the training game using 60 cards (Appendix C). The process of designing the card deck is discussed in Appendix A.4. We printed the playing cards on card paper for the physical version, and the digital game mimicked the same format and rules of play, discussed in Section A.7. We developed a digital version of the card game as a smartphone application with the same content and rules of play as the physical game. We calculated the sample size using G*Power software (d = 0.5, 1-β = 0.95, α = 0.05), leading to a required sample of 88 participants per group. Considering attrition, we initially recruited 95 participants per group. 90 participants per group retained, totaling 270 participants. Each group had an equal distribution of ASHAs and AWWs (45 each).

[1] **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Replay, Revise and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India ", *HCI International 2024, Washington DC, USA* https://link.springer.com/chapter/10.1007/978-3-031-61966-3_34)

A quasi-experimental design was conducted. We divided the participants into three groups:

- IG1: Digital card game (smartphone-based)
- IG2: Physical card game
- IG3: Traditional classroom training (control group)

We conducted three assessments for each group: a baseline pre-test, a post-intervention test, and a delayed post-test after three weeks. All tests included 45 multiple-choice questions (Appendix B) focused on immunization and healthcare scheduling, shuffled across instances to reduce recall bias. We performed quantitative analysis to evaluate intra- and inter-group differences.

3. **Results**

Immediate knowledge gain was significantly greater in the digital card game group, while there was no significant difference in knowledge retention between physical and digital card game-based groups. Traditional classroom training showed significantly low retention of knowledge. The qualitative feedback indicated that CHWs liked the digital version of the card game due to its convenience and interactivity, but had reservations about distractions and the requirement of printed versions for reference.

Experimental Study Results	**Intervention Group-1 Test Scores**		**Intervention Group-2 Test Scores**		**Intervention Group-3 Test Scores**	
Test phase	Mean (SD)	Median (min-max)	Mean (SD)	Median (min-max)	Mean (SD)	Median (min-max)
Pre-test scores	24.85 (3.34)	24.16 (18-33)	24.28 (2.88)	24.13 (19-30)	25.02 (3.19)	24.69 (19-32)
Post-test scores	35.62 (3.57)	35.56 (28-42)	31.86 (4.1)	31.48 (24-42)	30.01 (4.32)	29.71 (19-39)
Delayed Post-test scores (After 3 weeks)	31.75 (4.69)	32.23 (22-41)	30.62 (4.1)	30.82 (21-40)	26.46 (3.54)	26.75 (19-34)

Table 6.1: Study-3: Study Results

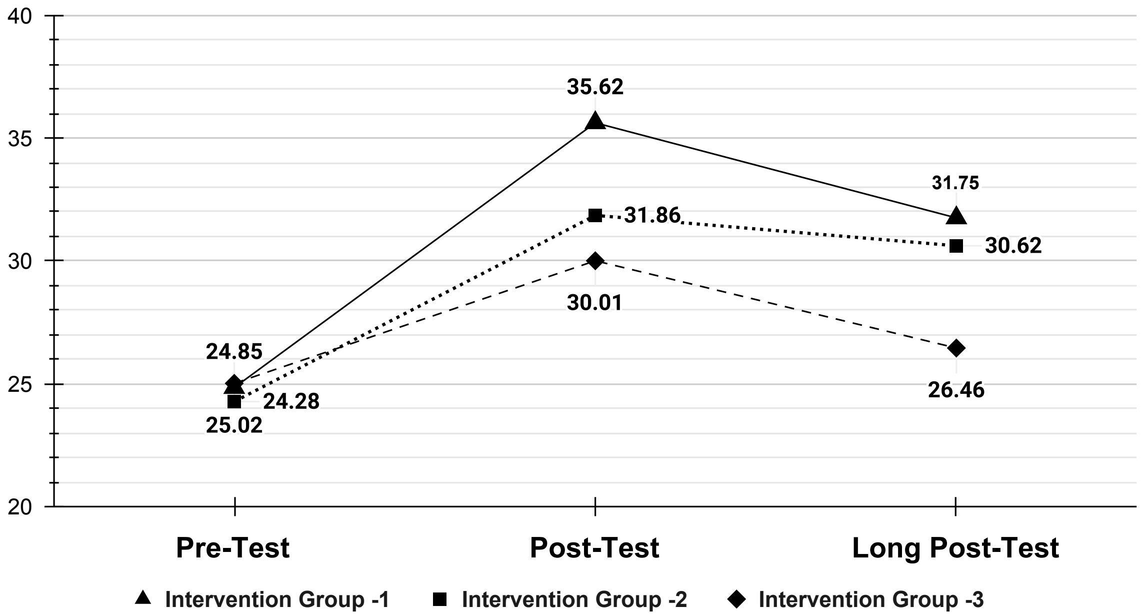

Figure 6.1: Study 3: Line chart showing trends of change of mean value in the pre-test, post-test, and delayed post-test

Pre-test scores did not differ significantly across the three groups ($F = 0.84$, $p = 0.44$), testifying to an equal baseline. Post-intervention scores differed significantly ($F = 22.96$, $p < 0.00001$). Tukey's HSD test revealed that IG1 performed significantly better than both IG2 ($F = 6.36$, $p = 0.00004$) and IG3 ($F = 9.39$, $p < 0.000001$). We did not observe a statistically significant difference between IG2 and IG3 ($F = 3.03$, $p = 0.085$).

After three weeks, delayed post-test scores varied significantly ($F = 20.62$, $p < 0.00001$). IG1 and IG2 scored significantly higher than IG3 ($p < 0.05$). No significant difference existed between IG1 and IG2 ($F = 1.84$, $p = 0.4$), indicating equivalent retention. There were significant gains from the pre-test to the post-test for all groups. IG1 gained the most in scores, followed by IG2, then IG3. While IG1 gained the most immediately, its delayed retention dropped more significantly than IG2, which retained more steadily. IG3 consistently had the lowest scores at every phase.

4. Discussion

This study validates the hypothesis that gamified training methods, particularly smartphone-based interventions, can outperform traditional classroom training in immediate knowledge acquisition. However, the performance of digital and physical card games converged when we checked knowledge retention over three weeks. This insight underscores the potential of both gamified methods as viable tools for CHW refresher training.

Counterintuitive Findings in Playful Learning

Although digital and physical card games both significantly improved knowledge, several observations challenged conventional assumptions and revealed nuanced interactions between digital literacy, local context, and learning behavior.

(a) **Technical Constraints hinders Germane Cognitive Processing**

CHWS from the rural and tribal areas who were in the intervention group with the digital card game sometimes performed slower than those who were intervened with the physical card game, despite their prior smartphone experience. Interviews from the feedback session and careful introspection pointed to the limited network connectivity and small smartphone screens caused cognitive friction, slowing down engagement. This behavior can be explained by Cognitive Load Theory (Sweller, 2022). Frictions from technical constraints can hinder germane cognitive processing. One ASHA from a tribal block remarked, "I know how to use a phone, but tapping through this many screens was confusing. I liked spreading the cards on the table better." However, physical cards enabled better reasoning and collaborative discussions, which led to a reduction in extrinsic cognitive load and supported distributed cognition (Hutchins, 1995) through visible sequencing and scaffolding from coparticipants.

(b) **Switching to Physical Cards**

There were many instances where the CHWs in the intervention group with the digital card game voluntarily opted to switch to physical cards for peer learning or practicing at home, even when they had access to the digital card game. One CHW commented, "I liked the app, but with the real cards, I could show my friends and explain everything. It stays in my memory better." This behavior can be explained by the principles of Social Constructivism (Vygotsky, 1978). Collaborative dialogue between co-learners and tangible artifacts helps in co-creating knowledge. These findings have important implications for public health training programs. Gamified learning can provide a scalable, interactive, and efficient way of training. However, hybrid models that combine digital and printed materials may more appropriately address the varied needs and constraints of CHWs.

(c) **Drop in Retention of Knowledge among Digital Play Group**

CHWS who were in the intervention group with the digital card game sometimes showed a sharper drop in retention than the intervention group with the physical card game. The novelty and interactivity of the app generated intrinsic motivation (Miller et al., 1985), but in some cases also promoted overconfidence and choosing quick strategies, reducing careful thinking. A participant reflected, "I wanted to finish first, but then I realized I had misplaced some cards—I remembered better after playing slowly with my friends." This can be explained by Kahneman's dual-process theory (Kahneman, 2011). System 1-driven quick moves in the game can result in immediate gains through game scores, but shallow knowledge retention without slow reflecting and reasoning driven by System 2.

(d) **Context-Dependent Perception of Games**

We observed that urban CHWs sometimes treated the digital game as a leisure activity. However, rural and tribal CHWs engaged with it as a formal learning tool. One rural CHW explained, "Playing on the phone with my community CHWs felt serious here, but when I go for training and play it with the city CHWs, it seemed like a game to pass the time." This underscores that learning outcomes are co-determined by social, cultural, and environmental factors, and not merely by the modality itself. This can be explained by Situated Learning Theory (Lave and Wenger, 1991).

5. Conclusion

The research concludes that refresher training using smartphones could be an effective method for refresher training, by enhancing the knowledge retention of CHWs. Though the digital game showed a higher short-term gain in knowledge, long-term retention was almost similar in both digital and physical card games. Evidence also shows that game-based training can complement conventional training programs in low-resource contexts. Future research can investigate long-term effects, motivational determinants of the use of games, and integration of gamified learning into routine CHW workflows.

6.2 Study-3 Reflections

The experiment results show that game-based learning interventions—both physical and digital—are significantly more effective than traditional classroom-based methods in enhancing knowledge acquisition among CHWs. Post-test results showed the highest gain in the digital gameplay group (IG1), followed by the physical card group (IG2), with the classroom training group (IG3) showing the least improvement. These findings validate our first hypothesis that interactive and engaging formats, such as games, can be superior alternatives for refresher training, especially when aiming for immediate knowledge enhancement.

In terms of long-term retention, measured three weeks after the intervention, the digital and physical groups performed significantly better than the classroom group. The difference between digital and physical modes was not statistically significant. Participants' feedback from the focused group discussions supported major sociocultural determinants of learning. While some CHWs enjoyed the interactivity and independence offered through the smartphone game, others employed physical cards as they were tangible, simple to work with, and could serve as counseling tools while conducting field visits. Smartphone distraction, especially when shared among the CHWs, also constituted a significant challenge.

These findings validate the imperative for the creation of educational interventions for effectiveness as well as contextual appropriateness. Physical card play, while less technologically advanced, is more accessible and can be more easily integrated into the everyday routines of CHWs. Digital smartphone-based games, however, incorporate automation of feedback, progression tracking, and scalable opportunities to disseminate, especially when presented by public health platforms or app stores.

At a policy level, the research suggests that investment in low-cost, culturally targeted, gamified training interventions can improve the quality and consistency of health services delivered by CHWs. These interventions can act as reinforcement strategies following in-class training, filling the knowledge gap and building confidence, hence driving better health outcomes at the community level. Looking to the future, the results endorse a hybrid training paradigm that leverages the complementary strengths of physical and digital interventions.

Building upon the insights gained from the three preceding experimental studies conducted across diverse locations in India, this research sought to investigate the practical implications of gamified training interventions. While earlier studies focused primarily on knowledge acquisition and retention, our objective in the subsequent phase was to explore how such interventions influence the day-to-day practices and performance metrics of Community Healthcare Workers (CHWs). Specifically, we aimed to assess the extent to which game-based training modalities, particularly those with location-based mechanisms, translate into measurable improvements in CHWs' routine field activities. We addressed this inquiry in detail in the fourth experimental study, presented in Study 4.

Chapter 7

Study-4: Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location-Based Games in India

The role of ASHAs and AWWs, as CHWs, is to perform timely anthropometric measurements and care for children and mothers in the community. However, the current data collection practice has inefficiencies like infrequent updates, a lack of spatial granularity, limited CHW engagement, and the use of manual registers or inconvenient smartphone apps. These lead to incomplete and outdated community health datasets. It affects decision-making in health interventions across state-run programmes. By leveraging the motivational affordances of serious games, such as reward mechanisms, narrative progression, and collaborative competition, this study aims to improve and sustain participation and provide an accurate geospatial mapping of malnutrition indicators.

Our primary objective is to evaluate whether CHWs using a game-based, smartphone-supported data collection application exhibit higher measurement efficiency than those using a traditional, non-gamified data entry application. The primary hypothesis (H1) is that game-based data collection will result in statistically significant improvements in performance metrics over traditional methods. A second hypothesis (H2) examines whether these enhanced performances are sustained in the long term, indicating the enduring impact of the intervention beyond novelty effects.

We conducted a quasi-experimental design (QED) study across two arms: an Intervention Group (IG, n=94) using the game-based application and a Control Group (CG, n=94) using a regular data entry app. Both groups are assessed in three phases—baseline, post-intervention (after one month), and delayed retention (after three months).

The game incorporates geospatial incentives to motivate data collection from underserved and underrepresented areas and uses real-world feedback systems to sustain engagement and motivation. The game focuses on playful learning, peer-to-peer coordination, and reflective practice to align the intervention with the daily realities and constraints of CHWs in low-resource environments.

7.1 Study-4 Details

Parts of this section are from a published research Study [1] annexed in the Annexure section 10.5

1. **Introduction**

   The prevailing concerns on training CHWs are already discussed in the chapter 1.

   Most CHWs are poorly trained and lack digital tools and skills for adequate and sustained data collection. CHWs' access to smartphones opens up new opportunities to leverage digital tools for improved health surveillance. Healthcare planning and intervention depend upon timely and accurate data collection. Conventional data entry computer software is often incapable of facilitating extended CHW participation due to usability and a lack of contextual appropriateness. Previous resistance to digital tools like the Poshan Tracker points to the need for user-centered design principles that emphasize simplicity, training, and user participation.

   This study examines the use of geolocation-based games to enhance the quality and engagement of CHWs in collecting child anthropometric measurements. Recognizing the value of CHWs in providing community-level health interventions, this study examines how gamified data collection tools can improve the frequency and quality of anthropometric measurements in difficult-to-reach populations.

   This study answers the following research questions:

   RQ1: Does implementing a location-based game improve the measurement efficiency of CHWs more than a conventional data entry application?

   RQ2: Is the efficiency gained through the game-based intervention maintained in the long term?

[1] **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location-Based Games in India. International Conference on Information Technology for Social Good (GoodIT '24, Bremen, Germany)
https://dl.acm.org/doi/10.1145/3677525.3678685)

2. Methods

The design development of the gamified activities followed a co-design workshop, conducted with 20 pairs of CHWs. We used a six-step process: building bridges, developing user models, mapping possibilities, prototyping, feedback loops, and iterative changes. Details of the co-design process are in Section 2.5 of the publication annexed in the Annexure section 10.5.

The measurement efficiency index is a score between 1 and 100, calculated using performance factors of CHWs, like measuring accuracy, speed, and effectiveness of data collection of children's anthropometric measures by them. In this experiment, the CHWs are given a set of tasks of visiting houses in their community. The activities include anthropometric measurements of newborn children, comprising height, weight, and mid-upper arm circumference (MUAC). Along with each CHW, a local person keeps shadowing the process, rechecks measurements, compares with the readings by CHWs, and takes notes. The game mechanics emphasized sustained participation of CHWs across time and space, incentivized exploration, and story-driven progression. The game allowed CHWs to record measurements during their home visits and visualize their contribution to a growing heatmap of child health metrics like prevalence of stunting, wasting, and underweight in the community.

Sample size estimation using G*Power ((d)=0.5, power (1-β)=0.95, and level of significance (α)=0.05) suggested 88 participants per group. Accounting for attrition, we recruited around 200 CHWs across multiple Indian states following convenience sampling, and 94 participants per group completed the study. We conducted a quasi-experiment with 188 CHWs in two groups: one using the game-based app and the other using a typical non-game data entry app. There were pre- and post-intervention tests and a delayed retention test (DRT) three months after the intervention to assess long-term engagement and data collection efficiency.

We chose a quasi-experimental design (QED) due to logistical constraints in randomization. The study involved pre-tests, post-tests, and a delayed retention test (DRT) conducted three months later. While CG received equal attention, we tried to make the game inaccessible to them during the intervention phase.

Paired and independent t-tests compared improvements within and across groups. The

	Control Group (CG) (n=94) Using Regular Monitoring App		Intervention Group (IG) (n=94) Using Game-based Monitoring App	
Test phase	Mean (SD)	Median (min-max)	Mean (SD)	Median (min-max)
Baseline	51.46 (9.21)	49.85 (36-70)	49.04 (10.57)	48.8 (18-72)
Post-test	54.84 (14.96)	53.84 (29-84)	73.9 (14.28)	75.82 (46-111)
Long Post-test (After 3 months)	52.58 (13.59)	52.6 (28-79)	69.14 (16.63)	70.79 (26-108)

Table 7.1: Study 4: Test Scores

evaluation considered novelty effects, long-term retention, and potential confounders such as education and years of experience.

3. **Results**

The intervention group (geolocation game app) showed statistically significant improvements in measurement efficiency compared to the control group (regular data collection app) ($p=0.00004$; Cohen's D = 1.6). While both groups showed score reduction in the delayed post-test, the IG maintained a significantly higher performance level than the CG, supporting both RQ1 and RQ2. Mean scores for the IG improved from 49.04 at baseline to 73.9 post-test and slightly declined to 69.14 at DRT. In contrast, the CG scores moved from 51.46 to 54.84 post-test and returned to 52.58 in DRT.

The findings indicated that the game-based application significantly improved the efficiency of data measurement among CHWs compared to the traditional non-game app. The game-based model showed better engagement and retention. CHWs indicated a higher motivation level for gathering data in untapped regions. The study established that the initial motivation towards the game-based application gradually reduced, indicating the need for sustained reinforcement and support to achieve long-term engagement.

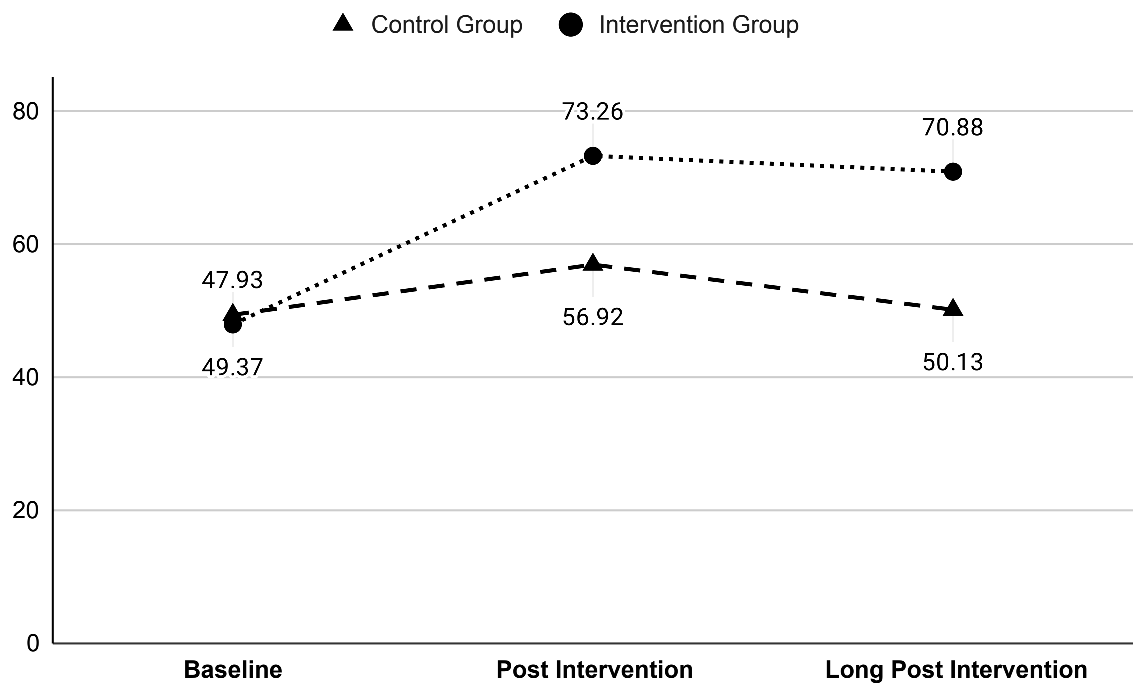

Figure 7.1: Study 4: Line chart showing trends of change of mean value in baseline, post-test, and long-post-test across the control and the intervention group

4. **Discussion**

Counterintuitive Findings in Playful Learning

Several unexpected patterns emerged in this study, highlighting interactions between gamification, spatial behavior, and CHW motivation.

(a) **CHWs prioritized actions with higher extrinsic values**

While the intervention group (IG) generally outperformed the control group, some CHWs initially avoided data collection from nearby households and instead chose distant locations in order to achieve higher game scores. This risk-seeking behavior is counterintuitive from a purely efficiency point of view. This is in line with Operant Conditioning Theory (Skinner, 1963), where participants prioritized actions with higher extrinsic reinforcement, even at the cost of immediate convenience. One ASHA remarked, "I walked to the farthest houses first because the game points were bigger there. I thought I was helping more and earning more rewards." This highlights how incentive structures in games can temporarily skew task prioritization. The game app temporarily increased home visit frequency and motivation. However, as with most gamification interventions, the novelty dipped. Long-term efficacy may require adaptive narratives, seasonal updates, and embedded real-world impact stories.

(b) **Experienced learners value Relevance and Autonomy**

CHWs who had more years of experience sometimes underperformed compared to the younger or less experienced ones. We found through qualitative feedback that experienced CHWs initially resisted game mechanics, as they thought it was more complex compared to real-world practice. This behavior can be explained by Adult Learning Theory (Andragogy) (Knowles, 1980). Adult learners usually prioritize the relevance of the learning content and autonomy while learning it. If they somehow feel that the learning tool is misaligned with their lived experience, they usually disengage with the learning activity. A CHW shared, "I have been doing measurements for years—I didn't feel I needed the game. I thought it would slow me down." We observed that she took some time but eventually adapted to the new way of learning. She realized the value of real-time feedback, spatial mapping, and peer comparison. This finding is aligned with Transformative Learning Theory (Mezirow, 2000), which explains that confusing experiences might eventually help reflective growth.

(c) **No Correlation between Formal Education and Performance**

Findings revealed no correlation between formal education and baseline performance, highlighting the significant role of on-field experience. Training programs have to, therefore, emphasize practical, scenario-based training. Field observations indicated that CHWs enjoyed the game after initial learning, forming teams, and engaging competitively. While this enhanced engagement, occasional rivalry led to demotivation among weaker performers.

(d) **Gaming the Game**

We also observed cases where the incentives of the game led to compliance rather than deeper engagement. Some CHWs were flagged by the system while they were repeatedly entering placeholder data for remote or difficult-to-reach households to maintain game scores or unlock game rewards. During the feedback session, one CHW said, "I added dummy entries for the houses I couldn't reach on time—I didn't want to lose points." This behavior can be explained by Self-Determination

Theory (SDT) (Miller et al., 1985), where the extrinsic motivators of learning can sometimes override the intrinsic motivation when the tasks are not balanced with mechanisms supporting autonomy. Through field observations, we found that if we can provide immediate contextual feedback (like showing heatmaps and marking underrepresented or hard-to-reach areas), it would help CHWs recalibrate their behavior towards meaningful data collection. A few instances of data fabrication by the participants underscore the need for real-time verification features. Anomaly detection, time-stamped entries, and location confirmation features can mitigate this risk.

(e) **Social Pressure hinders Participation**

We had a conjecture that learning in social circles would be effective. Counter-intuitively, CHWs reported that team based competition sometimes created social pressure to win which hindered introverts or less confident ones to participate, thus reducing engagement in small circles. This behavior can be explained by Social Comparison Theory (Festinger, 1954), which explains that competition can both motivate and demotivate depending on self-efficacy and social context. An ASHA from a rural area, after playing a session, said during the feedback session, "I liked the game, but when everyone saw my points, I felt shy and didn't try as hard in front of the others."

5. Conclusion

The study concludes that location-based games can significantly enhance the efficacy and productivity of CHWs in data collection. Not only was the game-based system more accurate and efficient in data collection, but it also motivated CHWs to go into underserved areas, leading to improved reach of data collection. The study suggests that incorporating game elements into data collection will enhance health data quality and reliability, eventually leading to improved healthcare planning and intervention.

Integrating co-designed location-based games into the workflows of CHWs significantly improves the collection and quality of child anthropometric data. The findings reinforce the potential of participatory digital tools in transforming public health systems. Game-based interventions not only maximize efficiency but also create purpose and agency for CHWs as well.

In subsequent studies, we need six months to one year to explore the long-term effects of adaptation. We need to explore integrating the game with national health dashboards. Scaling the app and conducting randomized trials across varied geographies would validate its broader applicability.

7.2 Study-4 Reflections

The results of this study validate the hypothesis that integrating game-based mechanisms into anthropometric data collection significantly enhances the measurement efficiency of Community Healthcare Workers (CHWs). The intervention group (IG) using the game-based application demonstrated significant improvements in post-test scores compared to the control group (CG), which used a conventional data entry app. Statistical analyses revealed a substantial effect size (Cohen's D = 1.6) favoring the game-based group, affirming our first hypothesis (H1). The game platform led to better accuracy and timeliness in child measurement recording, improved spatial coverage, and greater enthusiasm among CHWs.

However, the delayed retention test (DRT) conducted after three months revealed an overall decline in performance for both groups. It confirms the second hypothesis (H2) that designing dynamic game elements, such as seasonal campaigns, evolving narratives, or rewards, is necessary to facilitate long-term engagement. Most participants reported greater confidence and interest in their work using the game, attributing this to the user-friendly interface and real-time feedback systems. Co-design facilitated the mapping of game mechanics onto the cultural context, age, and digital literacy of CHWs. The participatory method enhanced usability and created a sense of ownership and control among the participants. CHWs began to internalize the importance of spatial coverage and timely data entry, reflecting a shift towards more autonomous and proactive health surveillance practice.

By crowdsourcing geospatially tagged anthropometric data live through gameplay, this study reaffirms the potential of serious games as a platform for civic participation and community-based data sourcing. This insight opens up new opportunities for public health data collection and efficient planning of healthcare service delivery at a more granular level at scale.

Chapter 8

Connecting the Dots: Synthesizing Insights from the Four Studies

1. **Rise and Decline pattern in Knowledge**

   We found a pattern that was repeating across the studies. Participants in the intervention groups showed statistically significant and sharp improvement in scores from the pre-test phase to the immediate post-test phase (comparing just before and after the gameplay sessions). These gains were mainly due to the immersive, engaging, and novel nature of the digital gameplay experience, especially for users with limited prior exposure to such technologies. This sharp rise was followed by a gradual yet significant decline in knowledge during the long-term post-test phase, performed several weeks or months after the intervention. This raises concerns about the retention of learning outcomes achieved through short-term interventions. The findings suggest the need for continued engagement and reinforcement mechanisms in game design. This can be brought through timely content updates, narrative progression, social competition, and real-world incentives. This pattern was not only observed across three knowledge-based studies (Studies 1, 2, 3) but also in the skill-based study (Study 4).

2. **Complementary Affordances Model** Synthesizing these findings, we propose viewing the paradoxes not as contradictions, but as *complementary affordances* of playful learning modalities. AR affords rapid, embodied feedback that engages intuition and supports immediate competence acquisition, particularly benefiting less literate or less technologically experienced learners. In contrast, physical cards afford deliberative reasoning, peer negotiation, and social scaffolding, sustaining knowledge over time and amplifying relatedness. Rather than competing, these modalities occupy orthogonal cognitive and motivational spaces, suggesting a hybrid learning ecosystem in which different learner profiles and educational goals can be supported through strategic integration. Conceptually, this model frames playful interventions along two axes: *cognitive pathway* (System 1 intuition vs. System 2 deliberation) and *social pathway* (individual feedback vs. collaborative negotiation). By mapping each modality onto this space, practitioners can design learning experiences that deliberately exploit the unique strengths of both, turning apparent paradoxes into synergistic opportunities for durable, engaging, and context-sensitive knowledge acquisition.

3. **Co-Design**

   Another key conclusion across the studies is the imperative of co-design in ensuring relevance, usability, and adoption. CHWs were involved in all phases - ideating, designing, and testing the games. This shaped the interventions to reflect the ground realities and user preferences of CHWs. The co-design approach aligns with Human-Centered Design (HCD) principles and ensures that interventions are methodologically sound and socially acceptable.

4. **Difference in Control Groups across studies**

   In all these studies, the baseline knowledge or skills were not significantly different between groups, which ensures baseline equivalence among groups and methodological consistency in all four studies. This condition allowed each study to isolate the effects of the intervention itself, whether digital or physical games, classroom-based, or conventional apps, based on learning outcomes or efficiency of work. However, in some studies, the Control group was assigned to a classroom teaching. At a few locations, we faced problems with the unavailability of trainers who could physically attend and conduct regular classroom training. The trainers often had different styles of teaching and engaging with students, which made a difference even within a study group. Therefore, in some cases, it was difficult to compare the results of one control group to another.

5. **Effective Training Method**

   The studies show that interventions through games are more effective than traditional methods as they motivate, encourage participation, and provide immediate learning outcomes. Gamification and game-based research on learning support these findings. It says that direct feedback and active participation play a significant role as they help enhance cognitive processing and memory formation. Digital interventions, especially on smartphone platforms, provide rich and interactive affordances to acquire abstract information and make it relatable to CHWs.

   The physical card-based games, while less interactive, provided surprisingly equivalent long-term retention rates. This finding suggests that physical play's haptic and social learning elements entail more elaborate information encoding despite lower short-term gains. Physical gameplay supports collaborative thought and enhances repetition orally, which are the most effective methods for knowledge reinforcement, especially in collectivist cultural settings like India. These findings challenge the assumption of digital solutions and argue in favor of multimodal solutions, which include various learner preferences.

   Subsequent game versions could address this limitation by incorporating design enhancements like periodic reinforcement mechanisms, increasing difficulty levels, narrative progression, or periodic tests built into the game. These enhancements can help maintain learner motivation over the long term and mitigate the loss of knowledge retention indicated in long-term measurements.

   The multi-arm comparative study across digital and physical card game modalities provides significant insights. Although digital games consistently yielded significantly higher immediate post-test gains, long-term retention scores for digital and physical interventions were not significantly different in most studies. The results suggest that both learning modes of game-based learning can be as good after some time, provided learners are engaged enough. Both modes of game-based learning were better than classical classroom training and placebo or control conditions.

6. **Knowledge to Practice**

   Study 4 adds a new dimension by shifting the evaluation metric from knowledge to measurable work performance. The significant gains in measuring efficiency, as captured through real-time geospatial data, reflect the broader applicability of gamification beyond pedagogy to operational workflows. The design and field-testing of a location-based game for mapping malnutrition improved task accuracy and enhanced data quality for health planning. This contribution is critical, as it moves the discourse from training to implementation, bridging the gap between learning and action. Measurement effectiveness, captured by the timeliness and quality of anthropometric data collection, also experienced the same increase and decrease pattern as knowledge-based results, thus making the learning-retention curve universal for cognitive and procedural functions.

The research offers a strong case for institutionalizing game-based refresher training within national health programs. We suggest including game-based training modules for routine skill updates and reporting as a part of the existing data collection initiatives, like the Poshan Tracker app. The study also highlights that training programs should be evaluated on work productivity and long-term behavioral change, apart from knowledge acquisition.

Chapter 9

Discussion

9.1 Reflections on Experiments

The experimental design had multiple formats, like physical card games, digital games, traditional classroom sessions, and control groups, to assess the impact of gamified learning. We found the immunization cards game to be significantly effective for refresher training of CHWs, with significant knowledge gain and retention. We compared the results by repeating the experiment with similar groups. We also found that the digital card mode was significantly better in most cases than the physical card game. Different intervention arms helped compare learning outcomes across different groups. The digital card game on immunization offered immediate feedback to players. Gradual difficulty levels and interactive game elements improved engagement and motivation among CHWs. This finding is in line with Self-Determination Theory (SDT) (Miller et al., 1985; Ryan and Deci, 2000), which focuses on autonomy, competence, and relatedness, which are required for effective learning. The physical card game lacked digital interactivity, but in contrast, it improved peer collaboration and discussions among the CHWs. The findings of this study are similar to Vygotsky's social constructivist theory (Vygotsky, 1978), which says that social interactions are necessary for effective learning. The traditional classroom model was more effective in a few settings than the gamified tool. However, as it lacked the interactive and immersive elements of the gamified tool, it led to comparatively lower engagement and retention of knowledge than the gamified tool. During delayed retention tests conducted a few weeks after the intervention, the marginal reduction in post-test scores across groups shows the limitations of one-time interventions and reduced motivation to practice.

9.2 Reflections on Learning by Doing through Gameful Activities

After a few years of going to the field and experimenting with the research prototypes with CHWs, we observed that the ethos of learning by doing appears to be gradually diminishing among CHWs and getting replaced by a culture of immediacy and convenience. They expect technology to make things increasingly possible to bypass the laborious processes of exploration, iteration, and skill-building, while still achieving knowledge gains and retention that appear satisfactory on the surface. However, the adoption of such shortcuts reduces engagement and the reflective connection that is inherent in the act of free exploration. When the learning process is sacrificed for efficiency, the resulting knowledge and engagement often start to feel depersonalized and lack the knowledge that emerges through routine practice.

9.3 Effects of Ageing on Learning

In all experiments across four papers, we observed a significant trend across all experiments that with the aging of CHWs, the change in knowledge gains between pre- and post-tests was lower. In other words, it was getting harder for aged CHWs to learn new content and adopt digital tools. Some CHWs were highly motivated and enthusiastic learners, even at higher ages. Research on learning in other contexts also finds similar results in adult education. Years of formal education also have an insignificant effect on baseline test scores, as the knowledge and experience mainly gained depend on the years of experience, working in the field as a CHW, and having hands-on experience dealing with the prevalent issues. A systematic recruitment policy for new young CHWs can make the cadre more effective.

9.4 Reflections on Social Factors

Social factors like cultural norms, language diversity, socio-economic conditions, and group dynamics influenced how learners interacted with the training materials and each other, influencing participants' in-game engagement and knowledge performance. India has 22 official languages and more non-scripted ones. CHWs operate in regions with different language intersections. Standardized training materials pose challenges for the CHWs. The designed game offered content in the local language, which might have contributed to improved comprehension and engagement. The CHWs' social and economic context can have influenced their access to digital devices and the internet. Those from economically disadvantaged groups might have utilized the physical card game as a more accessible medium, especially for less digitally literate or resource-poor individuals. Peer-to-peer dynamics and group interactions also played a key role. Collaborative learning was particularly evident in the physical card game sessions, where participants often discussed answers and strategies collectively. This social learning environment likely enhanced engagement and supported deeper understanding through dialogue and peer learning.

9.5 Expanding the Content of the Card Game beyond Immunization to other Maternal and Child Health Topics

Future researchers, designers, and content creators can expand the game's content beyond the immunization module to cover other maternal and child health topics, such as adolescent care, maternal nutrition, breastfeeding practices, complementary feeding, and disease prevention. Adding hands-on skills to the game could also help CHWs develop competencies for healthcare delivery.

9.5.1 Expanding Content Coverage for Holistic Health Education

Healthcare services provided by CHWs cover various health issues concerning mothers and children. The game should include adolescent care modules, including topics such as preventing anemia, managing menstrual hygiene, knowledge of contraceptive methods, coping with mental health, etc. Maternal and child nutrition should also focus on the importance of balanced diets before and during pregnancy, exclusive breastfeeding for the first six months, and complementary nutrient-dense foods after six months.

The game's expansion should maintain the game's endogenous mechanics, which should evolve from the content. The game module on nutrition could introduce cards representing food groups and types of nutrients. In the game, players could create balanced meals without repetition for a week for varying age groups, which is also a part of the advocacy provided by the CHWs. The adolescent care module may challenge players to identify malnutrition signs or offer proper counseling for effective menstrual health management. Such mechanics help translate health concepts into concrete, familiar actions for communicating information more effectively.

9.5.2 Game Theory and Collaborative Learning

The work duties of CHWs require contact and coordination among them, e.g., organizing health camps, disease outbreaks, or community nutrition programs. Cooperative learning can teach them how to effectively work in teams to achieve common goals by replicating real-world dynamics in their job.

Group players can develop a comprehensive care plan for a malnourished child in collaborative modules. Each player would have different information (imperfect information gameplay), like dietary habits, clinical signs, or family history. They must contribute their insights to arrive at an accurate diagnosis and treatment plan. This collaborative mechanic would reinforce the importance of information sharing, communication, and teamwork in mother and child and community healthcare.

Competitive game elements like leaderboards can also improve engagement without compromising the cooperative nature of providing healthcare in the game. It can motivate CHWs to improve their performance while supporting competition and providing consistent learning.

9.5.3 Implementation Challenges on adding new content

Expanding the game's content and mechanics brings new challenges, hindering its effectiveness. One of the challenges is about balancing complexity and accessibility. Realistic scenarios and advanced skill-building tasks demand more proficiency from players. The game must remain accessible to CHWs with varying technical and smartphone literacy levels and technical proficiency. Simplified instructions, visual cues, and intuitive interfaces help the game experience to be inclusive and user-friendly.

Health knowledge, beliefs, and medical practices vary geographically and between communities. In order to make the game culturally sensitive and appropriate, designers must consider India's cultural and contextual context when developing card games for refresher training for front-line healthcare workers. The heterogeneity of India, traditional games, and social fabric are crucial to making such educational materials effective.

Involving CHWs in developing the content will help tailor it to make it compatible with the local traditions and norms as part of the attempts to ensure that the game is culturally appropriate and suitable for the intended target group. Incorporating elements of significant games like Badam Satti and Rummy was helpful. Satti or Badam Satti, a cultural game from India, is identified by its strategic approach, skill requirement, and across-the-board appeal to varied age groups and classes. Taking on the familiar form and principle from the game assisted in making the training game more appropriate for healthcare providers. Playing cards evolved from recreations to symbolic objectification of status and custom in India. This historical background can be applied by developing card games in such a manner that they educate and serve as a social activity for bonding among healthcare professionals, fostering teamwork and communication.

9.6 Methodology of Play

This game translates the content of the immunization schedule into interactive and tangible mechanics through cards (game elements) representing age-specific vaccine milestones and resource management challenges (game mechanics). The game simulated challenges like shortages of vaccines and disease outbreaks. The players need to make quick, informed choices throughout the game. The game provided experiential learning through hands-on activities like card stacking in the proper sequence of vaccine administration and transformed abstract concepts into concrete actions. These interactions reinforced memory pathways, enabling CHWs to internalize and apply what they have learned in daily practical settings. Repeated exposure to these concepts through gameplay scenarios and constant processes of learning, application, and reinforcement helps in long-term knowledge retention.

9.6.1 Game Mechanics: Promoting Emotionally Engaging Learning

The game mechanics, adequate challenges, and constructive feedback invoked curiosity, anticipation, and a sense of achievement. It helped to sustain motivation in the game. The game mechanics were endogenous or derived directly from the content. In the game, players stacked cards representing vaccines in the correct chronological order based on a child's age. This game mechanic was similar to the decision-making process that CHWs went through in scheduling and administering vaccines. The real-world tasks of CHWs are aligned with the gameplay mechanics. They were more likely to comprehend and internalize the sequencing rules, increasing learning and retention. Opposition mechanics, such as artificial vaccine shortages or outbreaks, added complexity and realism. These dynamic, challenging opposition mechanics caused players to change strategies, further improving their critical thinking and problem-solving skills. The unpredictability of opposition mechanics kept players engaged. Overcoming these challenges became a memorable experience for the CHWs, reinforcing the knowledge gained during gameplay. The rewards and feedback elements induce emotional engagement. Overcoming in-game challenges generated a sense of achievement, which drove continued participation. The emotional satisfaction derived from mastering complex tasks (in-game mastery) deepened the player's connection to the content.

9.6.2 Rules of Play: Structuring Learning Through Interaction

The game's rules were designed to structure learning in incremental, interactive, and engaging ways. The sequence of the game was structured with an incremental difficulty scale. Initially, there were simple stacking game mechanics to help CHWs onboard with the experience. The game later revealed advanced topics such as resource constraints and age-specific critical immunization as players progressed. This technique is known as 'scaffolding' in educational theory. The basic concepts are taught and tested first before teaching more advanced concepts. By ensuring a smooth and steady increase in the complexity of content type, CHWs remained motivated while they mastered more advanced topics.

Collaboration played an important role in the game's rule structure. The game allowed players to work together or compete to complete vaccine sequences. The collaborative and competitive nature of Social dynamics enhanced engagement by promoting peer interaction between CHWs or groups of CHWs. Through collaborative play, CHWs experienced peer learning, as they often shared strategies and explanations, reinforcing their understanding of the content and the process. Social experiences between CHWs made the game more memorable, contributing to better knowledge retention.

CHWs receive feedback for their actions in the game through bonus points for correct moves or penalties for wrong moves. A real-time feedback loop enables players to identify and correct misconceptions, leading to a practical learning experience. Positive reinforcement also supports retention since correct actions are associated with accomplishment.

9.6.3 Translating Content into Multiple Channels of Learning

The game's design translated content into multichannel learning to cater to different cognitive processes and learning styles. We created the integrated learning experience through game elements that are audio-visual, action-based, informational, and decision-making. Visual elements made a substantial impact on knowledge recall improvement. Color-coded cards and disease-specific information allowed players to identify vaccines and matching age groups at a glance. These visual cues create mental associations that allow for recall in the long term. Action elements in the game sped up learning by leveraging procedural memory. Card stacking or vaccine sequencing activities use physical actions that enable the steps of the immunization schedule to be committed to memory. Repeated physical interactions and recall help in the retention of information. The cards' content provided factual information, such as detailed explanations of the purpose and timing of each vaccine. Re-reviewing and re-reading these facts repeatedly reinforced verbal memory so the players could remember key information. Decision-making elements incorporated higher-order thinking into the learning process. Strategic decisions, such as which vaccines to hold on to to win the game, support the synthesis and application of the knowledge. This type of learning goes beyond recall to strengthen critical thinking and problem-solving skills.

9.7 Implications for Policy and Practice

1. **Integrating Gamified Learning into Curricula**

   The studies show the effectiveness of digital and physical card games as a refresher training tool, which can be integrated into regular training programs for CHWs. Such tools can be implemented in healthcare training curricula at the state and national levels by adopting hybrid learning models. Traditional classroom instruction can be supplemented with gamified applications as a refresher to improve engagement and retention of knowledge by CHWs. CHWs with high smartphone proficiency can use digital apps as supplementary refresher tools during coursework, while the others can benefit from physical card games in low-resource areas where digital access is a challenge.

2. **Addressing Digital and Resource Barriers**

   In rural and tribal areas in India, ownership of smartphones, access to the internet, and smartphone proficiency among CHWs may still hinder the adoption of smartphone-based digital games. Policy advocacy for improving digital infrastructure is crucial to ensure access to digital gamified refresher tools among CHWs. The mobile application for CHWs should prioritize working offline to accommodate users with low or no internet access. The availability of physical versions of the training games as an alternative can cater to CHWs in resource-constrained settings and ensure that they are not left behind.

3. **Language and Cultural Adaptations**

   Training materials should be made accessible in multiple regional languages across India to address linguistic diversity and cultural differences. Policymakers and educational institutions should engage CHWs, their supervisors, and master trainers in co-designing training materials and translating them into local dialects for better acceptance and effectiveness.

4. **Policy-Level Support for Continuous Training and Reinforcement**

   The reduction of knowledge over time observed in all study arms highlights the need for continuous reinforcement learning. Policymakers should advocate for periodic refresher training for CHWs to ensure sustained knowledge retention. Gamified digital refresher sessions, conducted periodically, can provide cost-effective solutions.

5. **Data-Driven Policy and Decision-Making**

   Digital gamified applications enable close monitoring of learner performance through in-app analytics. Training institutions identify knowledge gaps and customize learning pathways for future training improvements, and policymakers can make data-driven decisions by leveraging the collected longitudinal data. Such data can also help assess the long-term impact of gamified interventions on healthcare service delivery and community health outcomes.

Chapter 10

Limitations, Future Research, Summary and Conclusion

10.1 Limitations of the study

- **Hierarchical Settings:** The experiment was conducted in a formal institutional environment of a healthcare centre. The job profiles of the CHW, the participants, or players of this experimental research are voluntary field functionaries or street-level bureaucracies. ASHAs and AWWs are cadres of CHWs of the state, under which they are obliged to act or function within the framework of the top-down bureaucracy.
- **Sample Size and Diversity:** The studies were conducted with relatively small sample sizes, limiting the generalizability of the findings. Future research should include larger, more diverse samples to validate the results across different regions and healthcare settings. Ensuring diversity in terms of geographical location, language, age, and educational background can help identify context-specific challenges and solutions.
- **Technological Literacy:** Some CHWs faced challenges with the use of digital and AR-

based games due to varying levels of technological literacy. Future interventions should include comprehensive training on the use of digital tools to ensure equitable access and participation. Additionally, user interfaces should be designed to be intuitive, culturally sensitive, and accessible to low-literacy users.

- **Retention Period:** While the studies assessed knowledge retention over a few months, longer follow-up periods are needed to evaluate the sustained impact of game-based interventions on CHWs' knowledge and performance. Longitudinal studies can provide deeper insights into how game-based learning influences long-term behavior changes and healthcare practices.

- **Cultural and Contextual Factors:** The studies were conducted in specific cultural and geographical contexts, which may influence the applicability of the findings to other settings. Future research should explore the adaptation of game-based interventions to different cultural and linguistic contexts. This will ensure that the interventions are relevant, engaging, and effective for diverse populations.

10.2 Future Research Avenues

Building on the findings and limitations of this dissertation, several avenues for future research open up:

- **Comparative Studies:** Future research should conduct large-scale comparative studies to evaluate the effectiveness of different game modalities across diverse populations and healthcare settings. Comparative research can help identify the specific conditions under which each game modality is most effective, guiding the development of targeted training programs.

- **Integration with Health Systems:** Research should explore the integration of game-based interventions with existing health information systems to enhance data collection, monitoring, and decision-making processes. For example, location-based games could be linked to national health databases to provide real-time updates on vaccination coverage and malnutrition rates.

- **Personalization and Adaptation:** Future interventions should focus on developing personalized learning pathways that adapt to the individual needs, preferences, and learning styles of CHWs. Adaptive learning technologies can use data analytics to offer customized content and feedback, ensuring that each learner progresses at their own pace.
- **Gamification of Additional Topics:** While this dissertation focused on immunization and data collection, future research should explore the gamification of other healthcare topics, such as maternal care, chronic disease management, and mental health. Expanding the scope of gamified learning can further enhance CHWs' competencies and improve the overall quality of healthcare services.
- **Behavioral and Motivational Factors:** Further research is needed to understand the behavioral and motivational factors that influence CHWs' engagement with game-based interventions. This will inform the design of more effective and user-centered learning experiences. Understanding intrinsic and extrinsic motivators can help create more meaningful and sustained engagement with learning activities.

10.3 Summary

This research compared the efficacy of gamified refresher training of CHWs in improving knowledge acquisition and retention by comparing the performance of CHWs, as well as nursing students, across physical and digital game formats, traditional classroom training, and control groups, in three phases, pre (before intervention), post (after intervention) and long-post (weeks after intervention). The study shows the significant effectiveness of game-based learning in different socio-cultural. Digital and physical card game interventions show significant improvements in knowledge acquisition and retention of CHWs, compared to the classroom training and control group (didn't receive training during the experiment, but later compensated), showing the effectiveness of gamified training tools across different CHW groups.

In this research, self-determination theory (SDT), flow theory, constructivist learning theory, and other gamification theories, helped in framing the relationship between game mechanics, learner engagement, and knowledge outcomes in CHWs. The findings of this research closely resembles, previous game-based researches that focus on autonomy, competence, relatedness, and immersion in creating meaningful and effective learning experiences. By combining theoretical reflections with empirical evidence, this research contributes to the growing body of literature on the role of games and gamification in education, particularly in resource-constrained environments.

In some cases, the absence of significant differences between physical and digital based card game formats indicates that the medium is less important than the quality of the learning experience. The acquired knowledge depreciates over time signifying the importance of continuous learning and periodic refresher training as reinforcement to ensure sustained knowledge retention.

10.4 Conclusions

This study contributes to the academic discourse on game-based learning through theoretical and practical insights by demonstratrating that gamified interventions can be customized to diverse learner needs, educational levels, and social contexts to enhance motivation, engagement, and learning outcomes. These findings suggests that game-based tools can provide a scalable, cost-effective alternative to traditional training pedagogy. The study also contributes to theoretical discussions on the applicability of gamification in real-world learning scenarios, particularly in low-resource settings.

Future game based research should explore the intersection of game design, motivation, and learning outcomes in community healthcare and across domains such as environmental education, financial literacy, and public health campaigns. Emerging technologies such as augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) might help enhance the personalization and interactivity of learning experiences of CHWs.

Future research should also explore the long-term impact of gamified learning on behavioral outcomes, service delivery, and societal change driven by CHWs. Game-based analytics should be used to create personalized learning pathways. Co-designing games with CHWs, their supervisors, and their trainers would bring more cultural relevance and inclusivity.

This research shows the transformative potential of game-based learning as a tool for empowerment and lifelong learning. By building on the foundations laid by this study, educators, policymakers, and researchers can harness gamification to create engaging, inclusive, and impactful learning environments for CHWs.

10.5 Personal Reflections

As a researcher with a Masters in Design (M.Des.) background, venturing into the domain of maternal and child healthcare, has been both challenging and rewarding at the same time. This interdisciplinary journey has led me to navigate through uncharted territories, from understanding the complexities of public healthcare content and systems to designing, developing, testing, and evaluating gamified training solutions for Community Health Workers. Despite the challenges, the experience has been deeply satisfying, offering valuable insights into the potential of gamification in the training of Community Health Workers. While this work is still evolving, I believe that it has contributed meaningfully to the broader effort to improve maternal and child health outcomes in India.

In spite of the selfless efforts put in by the CHWs, they were rarely appreciated by the state and sometimes by the community. Recently, the WHO Director-General announced ASHAs of India as one of the six awardees of the Global Health Leaders Awards for their crucial role in linking the community with the health system and ensuring those living in rural poverty can access primary health care services during the crucial times of the COVID-19 pandemic. The intention here is not to romanticize and idealize the lives and struggles of the ASHAs, but to highlight the immense amount of dedication they show towards their job in spite of often having physical fatigue and sometimes carrying emotional breakdowns as a woman and often as a mother.

Appendix A

Designing the Refresher Training Activity

A.1 Content for designing Refresher Training Activity

Conducting a Focused Group Discussion (FGD) among a group of AWWs and ASHAs, it was found that most CHWs lacked complete knowledge of the immunization schedule, growth monitoring chart, and other aspects of the Mother and Child Protection card (MCP card). The findings of other researchers from different parts of India were also similar to our (Bag and Datta, 2017). A study found that the issuing of MCP cards to pregnant mothers was strongly associated with partial immunization in children (Kizhatil et al., 2019). The child immunization table from the MCP card was chosen as content for the game. This schedule also follows the Indian Academy of Paediatrics (IAP) guidelines (Kasi and et.al., 2021). A reference to the immunization schedule is in Table A.1 in the Appendix.

Vaccine Name	Birth	$1\frac{1}{2} months$	$2\frac{1}{2} months$	$3\frac{1}{2} months$	9 months	$1\frac{1}{2} - 2 years$
BCG	✓					
Hepatitis B	✓					
OPV	✓	✓	✓	✓		✓
IPV		✓		✓		
Penta		✓	✓	✓		
PCV		✓		✓	✓	
Rota		✓	✓	✓		
MR					✓	✓
JE					✓	✓
DPT						✓

Table A.1: Child Immunization schedule

A.2 General and Specific Learning Objectives

Trainers usually or subconsciously have in mind the knowledge, skills, and attitudes they want their learners to achieve through the training course. Learning Objectives are the specifications of the sought outcomes of the training. They break the content into smaller modules with measurable or observable specific desired outcomes. The General Learning Objectives (GLOs) and the Specific Learning Objectives (SLOs) were brainstormed in a closed group and decided on. It was found that the contents mostly correspond to the cognitive domain (new knowledge creation) of learning objectives. Hence, affective (developing feelings and emotions) and psychomotor (improving physical and manual abilities) domains are not relevant here. But supportive layering of learning objectives could help students step into these domains.

The GLOs of the game are as follows:

Audience : Community Healthcare Workers

- The learner remembers the factual information like immunization schedule and medical supplementation for mother and child
- The learner becomes more aware of the consequences of their actions

The SLOs of the game are as follows:

Condition : They should be able to make the right decision in the gameplay scenario.

Degree : Depending on the number of right decisions taken (the more, the better)

Behavior :

- Memorize the sequence and dosage of immunizations and supplements required by a child from birth to adolescence.

- Memorize the sequence of medicines, immunizations, and checkups required for a pregnant mother.

A.3 Physical Card Play as a Learning Tool

Initial thoughts of game design were that the information about vaccines is displayed to players through blocks of information. Then the player has to make a decision based on the information and the current scenario. Out of many physical tokens and objects of play, card gameplay was chosen as the game artifact. The possibilities of playing through card games were explored. Physical card games are ubiquitous. The primary reasons for this are its cost-effectiveness and handling ease. A deck of cards can be played in numerous different ways just by altering the rules. Different groups of cards can be added to the existing deck to enable new ways of playing with it. Multiplayer card game researchers (Bochennek et al., 2007) have shown significant learning advantages through engagement and collaboration. However, published research papers on using card games for training community healthcare workers were sparse.

The core learning objective of the game is that the community health workers memorize the sequence and dosage of immunizations and supplements required by the child and mother. Initially, there were thoughts of modding the classic physical card games like Rummy, Solitaire, Bridge, Teen Patti, etc. It was easier to think along the lines of combining the rules and mechanics of a popular card game with educational content. However, in several instances of design iterations, the associated traditional rules of play restricted the fulfillment of our learning objectives. As a result, cherry-picking rules and mechanics were performed from several popular card games, which would address and fulfill the learning objectives of the ASHAs.

A.4 Designing the cards

The content can be categorized into 4 silos depending on the time of delivering the care to the stakeholders. 4 silos of cards were made each symbolizing an immunization, medicine supplement or a care activity or event. They are categorized as follows: Children below 1yr (n=22), Children above 1yr (n=15), ANC (n=14) and PNC (n=9) combined to form a deck of 60 cards. The deck of card design is displayed through Figures : C.1, C.2, C.3, C.4 and C.5 in the Appendix section.

These playing cards are made the size of a standard playing card or credit card (5.5 X 8.5 cm), made of card paper (200 GSM), and have printed information and graphics on them.

A.5 Combination of cards

These 60 playing cards can be equally divided between 2, 3, 4, 5, or 6 players, creating multiplayer team combinations. The most common of them is a 4-player match. Theoretically, all the 60 cards could be arranged in a total of 60! ways. But for each of those arrangements, there are many duplicate arrangements in which cards 1 to 15 are the same, but in a different order. Similarly for cards 16 to 30, and so on. For each group of 15, there are 15! ways to rearrange them and not change the cards in each player's hands. That's why four factors of 15! would be in the denominator, considering a 4-player round. The mathematical expression of the number of permutations possible for each player's hand, considering a 4-player round, is as follows: 60! / (15! X 15! X 15! X 15!) or simplified $\frac{60!}{(15!)^4}$. Google Sheet Expression =FACT(60)/POW(FACT(15),4) which calculates to an astronomical value of 2,845,616,726,065,970,000,000,000,000,000,000

A.6 Designing Challenges, Mechanics and Rules of Play

In the process of game design, after brainstorming the basic game idea of stacking cards as per the schedule, we focused on methods to translate content elements of immunization into game elements. We can call this as translation phase. This helped towards achieving endogenousness in design, where game mechanics and resources emerged directly from the immunization content itself.

We started with reimagining content elements as game elements. In the designed game, the immunization content was represented by the vaccines, which act as resources in the game. Each vaccine (such as polio, measles, or tetanus) becomes a game resource that players must acquire and administer at the correct time, simulating the real-world immunization schedule.

The designed game involved players stacking "vaccine cards" in chronological order based on when each vaccine needs to be administered according to a child's age. Players would have to strategically decide which vaccines to prioritize, mirroring real-world challenges faced by CHWs in ensuring timely immunizations. These vaccine cards were color-coded or labeled to correspond to specific diseases, time of intervention (in months), and players received points or rewards for correctly stacking the cards in line with a virtual child's immunization needs.

Our strategy of choosing Game Mechanics, firstly involved identifying player actions that can be performed with the game's resources, while the other strategy mapped established mechanics onto content elements. By linking well-known mechanics with content-derived resources on immunization, we tried to develop a system that feels more naturally connected to immunization or the game's subject matter.

We also focused on opposition mechanics, obstructions, or opposing forces within the context of immunization. In the moderately advanced level of the game, the mechanics were included in the form of unforeseen challenges like a vaccine shortage, requiring players to trade or manage limited resources, or a simulated disease outbreak that necessitates quick decision-making to administer booster shots. This created dynamic decision-making and action elements that reflect the content of immunization, transforming real-world health information into an engaging and educational game format. Challenges often arise when opposition mechanics are not apparent in the content, leading to exogenous mechanics. However, these challenges can also inspire creative solutions and novel opposition mechanics.

Endogenous design arises when resources or mechanics are organically derived from the content. However, when we were unable to synthesize mechanics or resources directly from content, we resorted to exogenous mechanics, using designs like races or other standard systems. These choices might lead to a more disjointed relationship between content and gameplay.

Once a core or opposition mechanic (blocking cards to restrict completing the sequence) has been identified, we followed the Mechanics-Dynamics-Aesthetics (MDA) framework by (Fabricatore Carlo, 2007). The translation of content to game elements, particularly through mechanics and resources, steered whether the design remains endogenous or shifts towards exogenous approaches.

In game-based learning, effective translation of content into game elements enables the delivery of learning through a variety of channels. These include visual elements (4 foundation layouts demonstrating 4 silos of mother and child care, mainly focusing on immunization), action elements (game mechanics like stacking of cards and ordering), information elements (Card details like name of immunization and time of intervention), and decision elements (player choices during the gameplay). Each of these elements contributes to how players interact with the game, allowing learning to emerge organically from engagement with the game system.

However, knowledge acquisition through game-based learning presents significant challenges, especially when introducing novel concepts. Research, including our previous studies (Majhi et al., 2021, 2022, 2024c,a,b), shows that activating prior knowledge is meaningful and sometimes easier than facilitating the acquisition of new knowledge. Designing games for novel knowledge is particularly difficult in complex subjects like immunization concepts.

Thus, while games can be highly effective for knowledge reinforcement and application, they are less frequently successful in facilitating the acquisition of entirely new knowledge, particularly in cases where the content is abstract or requires sensory engagement for full comprehension. However, in our designed game, we restricted our content to only factual information, and learning through simple game mechanics was an appropriate choice.

A.7 Rules of Play (Based on the rules of Badam Satti)

- The game starts by shuffling the deck of 60 cards, and distributing it equally to 4 players, 15 cards each (2 players 30 each or 3 players 20 each).

- Each color belongs to one silo or foundation. There are 4 foundations. Children below 1 year, above 1 year, antenatal care, and postnatal care. Make 4 spaces for 4 foundations (similar to solitaire)

- Then, at each player's turn, they need to put a card of one type onto the foundation of the same silo on the board.

- Let's say they put the cards of 2 years (eg. $2^1/_5$). This means there are 5 cards or immunizations in year 2. This might also be shown in 5 white rectangles in the new version to avoid confusion. They have to complete the 5 cards of 2 years in their turns. After completing the 2 years, they can either move up or down $1^1/_2$

- The cards are numbered in order of the months and year. If there are multiple immunizations/cards in an age group, they are numbered $2^1/_5$, $2^2/_5$, $2^3/_5$ and so on. This acts as a cue for the players to know how many more cards are left to complete the current sequence so that they don't miss a card and jump to the next month or sequence.

- If a player successfully places a card in the placeholder silo, the player gets 2 more chances or play rounds as a bonus.

- If there is no possibility of cards being placed or 2 bonus rounds are complete, then the turn goes to the next/following player.

- After one age group is completed, the following players, in their turn, can place cards in one age group above the upper set or below the lower set on the board.

- The rounds of play continue until all cards are exhausted from a player's hand. The first player to exhaust the holding cards wins the round and is awarded the first rank, followed by the next players until all cards are exhausted by all players.

A.8 Limitations of playing with physical cards

- The rules of the play need to be followed in order to achieve the intended learning. However, players need to constantly monitor the activities in order to catch deviations from the rules. This problem can be solved digitally through rules written in the form of algorithms. Every wrong move would be announced through voice cues.
- In India, there are 22 official languages. Different groups have different number literacy levels. Some are comfortable with the script of Devnagri numbers or regional ones, while some are with English numbers. Making customized decks cater to each group won't be scalable.
- The content or the knowledge to be delivered changes with new findings in medical science, which needs to be implemented over the state or country. This translates to adding new cards or scraping off the distributed cards, printing and resupplying new decks to all ASHAs, which is not a scalable solution.
- Mundane chores of play, like shuffling cards, equally distributing cards between the number of players, and packing them up, take up a lot of time for players to do manually. These can be done digitally in almost no time. It can also be done in an animated sequence to mimic the physical action sequence of shuffling, distributing, and packing up, which are very satisfying to watch in an interface.

A.9 Designing an app-based interface of the same activity

In the digital app, there are 4 foundations on the top which represent 4 silos. The players click on the desired card to pick it and click on the empty foundation to drop it. If there are multiple cards to that sequence (like $2^1/_5$, $2^2/_5$, $2^3/_5\ldots$), The cards keep stacking over. As soon as the sequence is complete, they collapse into the foundation. It opens up the possibility to stack cards over or under, the bigger and smaller cards in sequence, respectively. A reference to the app's User Interface is shown in Figure D.1 in the Appendix section.

A.10 Multiplayer Playing Variation

During previous field studies, it was observed that more than half of the ASHAs had access to smartphones but did not own them. Usually, their husbands own it and share it with their wives, the ASHA. The resource constraints of owning a phone individually could be potentially solved if one smartphone could be used by 4 players, turn by turn, while 4 players can physically arrange themselves sitting in a circle. A pass button in the User Interface to skip the turn to the next player was introduced. After each player plays her move in her turn and ends successfully stacking a card, the next player gets the turn. But if there are no moves possible, then the player can click on the Pass button to pass the turn to the next player. The player, after completing her turn, orients the phone by turning it towards the next player for her turn to play. Also, an assistive voice would be played announcing the current player's name, to reduce the confusion of which player's turn it is currently.

During previous field studies, it was also observed that the Community Healthcare Workers are comparatively busy during their daytime serving the community, going door to door. It becomes hard for them to manage time to physically get together, sit in a circle, and play the game either digitally or physically. A multiplayer remotely connected play would potentially solve this problem. In this case, one of the players creates a server generally called a "Room" having a meaningful name representing the team. The rest of the players connect to that room and the creator of the room starts the game. Similar mechanics are followed. The players get an opportunity to put cards in their turn. When the turn is passed, the moves get frozen until the turn comes around again, completing all the other players.

During trials, with remotely connected players, we observed that there were a lot of misunderstandings due to the lack of communication between players. They felt frustrated if they couldn't perform a task due to the restrictions enforced by the rules of play, for example, when the turn was missed or they couldn't place a card in their turn, etc. So we introduced audio communication similar to a radio which broadcasts audio of one player to all other players connected in the room or with the other player forming a group with the player. We observed peer learning happening through the discussions between the players while explaining the rules to one another and in general team conversations.

Following the same game mechanics, rules, and deck of cards, two variations of the Android game app were developed. The gameplay analytics of each player were saved offline and asynchronously stored in an online database whenever the internet was available, for further analysis. ASHAs having an active data connection would update the scores instantly. It was observed that a number of ASHAs didn't have an active data pack in their smartphone. For them, there would be asynchronous syncing multiple times within a week, whenever she would come to the state institution for reporting and would connect her smartphone to the Wi-Fi network of the institution (which is usually available).

Appendix B

Survey Questionnaire

मैं अपनी हस्ताक्षर के माध्यम से स्वीकार करती हूं कि इस शोध अध्ययन में मेरी भागीदारी स्वैच्छिक है। मैं इस तथ्य से अवगत हूं कि एकत्र की गई व्यक्तिगत जानकारी का उपयोग केवल शैक्षिक उपयोग के लिए किया जाएगा।

___________ ____ / ___ / २०२२

हस्ताक्षर तिथि

नीचे दी हुई जगह पर अपना पूरा नाम लिखिए :

____

अपनी उम्र लिखिए : __________ साल

आपकी स्कूली शिक्षा कौनसी श्रेणी तक हुई है :

☐ ८ वि ☐ ९ वि ☐ १० वि ☐ ११वी

☐ १२ वि ☐ ग्रेजुएट ☐ पोस्ट-ग्रेजुएट

आप कितने वर्षों से आशा कार्यकर्ता हैं :

_________________ साल

कृपया निम्नलिखित प्रश्नों के उत्तर खाली बक्सों में ☑ निशान लगाकर दीजिये। प्रत्येक प्रश्न का केवल एक ही सही उत्तर है।

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१. ओ पी वी - बूस्टर शिशु को किस आयु मै दिया जता है?

☐ ९ महीने ☐ १ १/२ साल

☐ २ साल ☐ ३ १/२ साल

२. पेंटावैलेंट - १ टीका शिशु को किस आयु मै दिया जता है?

☐ १ १/२ महीने ☐ २ १/२ महीने

☐ ३ १/२ महीने ☐ ९ महीने

३. एम आर - १ (खसरे का पहला टीका) शिशु को किस आयु मै दिया जता है?

☐ ९ महीने ☐ १ १/२ साल

☐ २ साल ☐ ३ १/२ साल

४. पहला डीपीटी बूस्टर शिशु को किस आयु मै दिया जता है?

☐ ९ महीने ☐ १ १/२ साल

☐ २ साल ☐ ३ १/२ साल

५. दूसरा डीपीटी बूस्टर शिशु को किस आयु मै दिया जता है?

☐ ९ महीने ☐ १ १/२ साल

☐ ५-६ साल ☐ ३ १/२ साल

६. टी टी / टी डी (टेटनेस / डिफ्थोरिया) का पहला टीका शिशु को कौनसी आयु मे दिया जाता है?

☐ १० साल ☐ १६ साल

☐ ६ साल ☐ ५ साल

७. टी टी / टी डी (टेटनेस / डिफ्थोरिया) का दूसरा टीका शिशु को कौनसी आयु मे दिया जाता है?

☐ १० साल ☐ १६ साल

☐ ६ साल ☐ ५ साल

८. पेंटावैलेंट - २ टीका शिशु को किस आयु मै दिया जता है?

☐ १ १/२ महीने ☐ २ १/२ महीने

☐ ३ १/२ महीने ☐ ९ महीने

Figure B.1: Questionnaire Page-1

९. विटामिन ए सबसे पहले बच्चों को कब दिया जाता है?

- ९ महीने
- १ १/२ साल
- २ साल
- ३ १/२ साल

१०. विटामिन ए दूसरी बार बच्चों को कब दिया जाता है?

- ९ महीने
- १ १/२ साल
- २ साल
- ३ १/२ साल

११. दूसरी बार के बाद विटामिन ए बच्चों को किस अंतराल में दिया जाता है?

- ३ महीने
- ४ महीने
- ५ महीने
- ६ महीने

१२. एम आर - २ (खसरे का दूसरा टीका) शिशु को कब दिया जता है?

- ९ महीने
- १ १/२ साल
- २ साल
- ३ १/२ साल

१३. जे ई - १ (जापानीज इन्सेफेलाइटिस) का पहला टीका शिशु को कब दिया जाता है?

- ९ महीने
- १ १/२ साल
- २ साल
- ३ १/२ साल

१४. जे ई - २ (जापानीज इन्सेफेलाइटिस) का दूसरा टीका शिशु को कब दिया जाता है?

- ९ महीने
- १ १/२ साल
- २ साल
- ३ १/२ साल

१५. पी सी वी - १ (न्यूमोकोकल कंजुगेट) का पहला टीका शिशु को कब दिया जाता है?

- १ १/२ महीने
- २ १/२ महीने
- ३ १/२ महीने
- ९ महीने

१६. पी सी वी - २ (न्यूमोकोकल कंजुगेट) का दूसरा टीका शिशु को कब दिया जाता है?

- १ १/२ महीने
- २ १/२ महीने
- ३ १/२ महीने
- ९ महीने

१७. पी सी वी - बूस्टर शिशु को कब दिया जता है?

- १ १/२ महीने
- २ १/२ महीने
- ३ १/२ महीने
- ९ महीने

१८. पेंटावैलेंट - ३ टीका शिशु को किस आयु मै दिया जता है?

- १ १/२ महीने
- २ १/२ महीने
- ३ १/२ महीने
- ९ महीने

१९. हेपेटाईटिस बी टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२०. रोटा - १ (रोटावायरस) का पहला टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२१. बी सी जी का टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२२. रोटा - २ (रोटावायरस) का दूसरा टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२३. ओ पी वी - 0 (ओरल पोलियो वैक्सीन) का पहला टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२४. रोटा - ३ (रोटावायरस) का तीसरा टीका शिशु को कब दिया जता है?

- जन्म
- १ १/२ महीने
- २ महीने
- ३ १/२ महीने

२५. जन्म के तुरंत बाद शिशु को क्या दिया जाना चाहिए?

- कोलोस्ट्रम
- ओ पी वी - 0
- हेपेटाईटिस बी
- बी सी जी का टीका

Figure B.2: Questionnaire Page-2

२६. ओ पी वी - १ (ओरल पोलियो वैक्सीन) का दूसरा टीका शिशु को कब दिया जता है?

- [ ] जन्म
- [ ] १ १/२ महीने
- [ ] २ महीने
- [ ] ३ १/२ महीने

२७. आई पी वी - १ (इनएक्टिवेटेड पोलियो वैक्सीन) का पहला टीका शिशु को कब दिया जता है?

- [ ] जन्म
- [ ] १ १/२ महीने
- [ ] २ महीने
- [ ] ३ १/२ महीने

२८. ओ पी वी - २ (ओरल पोलियो वैक्सीन) का दूसरा टीका शिशु को कब दिया जता है?

- [ ] जन्म
- [ ] १ १/२ महीने
- [ ] २ महीने
- [ ] ३ १/२ महीने

२९. पेंटावैलेंट - २ टीका शिशु को किस आयु मै दिया जता है?

- [ ] ९ महीने
- [ ] १ १/२ साल
- [ ] २ साल
- [ ] ३ १/२ साल

३०. ओ पी वी - ३ (ओरल पोलियो वैक्सीन) का दूसरा टीका शिशु को कब दिया जता है?

- [ ] जन्म
- [ ] १ १/२ महीने
- [ ] २ महीने
- [ ] ३ १/२ महीने

३१. आई पी वी - २ (इनएक्टिवेटेड पोलियो वैक्सीन) का पहला टीका शिशु को कब दिया जता है?

- [ ] जन्म
- [ ] १ १/२ महीने
- [ ] २ महीने
- [ ] ३ १/२ महीने

३२. एक गर्भवती माँ को अपनी पूरी गर्भावस्था में कितने न्यूनतम प्रसवपूर्व देखभाल सत्रों की आवश्यकता होती है ?

- [ ] १
- [ ] २
- [ ] ३
- [ ] ४

३३. किस प्रसवपूर्व देखभाल पर गर्भवती माँ को टी टी - १ (टिटनेस टॉक्साइड) का पहला इंजेक्शन दिया जाता है ?

- [ ] पहला
- [ ] दूसरा
- [ ] तीसरा
- [ ] चौथा

३४. किस प्रसवपूर्व देखभाल पर गर्भवती माँ को टी टी - २ (टिटनेस टॉक्साइड) का दूसरा इंजेक्शन दिया जाता है ?

- [ ] पहला
- [ ] दूसरा
- [ ] तीसरा
- [ ] चौथा

३५. टीटी बूस्टर उन गर्भवती माताओ को दी जाती है जिन्होने पिछले कितनी सालो में टीटी के २ टीके लगवा चुकी है ?

- [ ] १
- [ ] २
- [ ] ३
- [ ] ४

३६. किस प्रसवपूर्व देखभाल पर गर्भवती माँ को आयरन फोलिक एसिड (आई एफ ए) की गोलियां सेवन चालू करनी चाहिए ?

- [ ] पहला
- [ ] दूसरा
- [ ] तीसरा
- [ ] चौथा

३७. गर्भवती महिलाओं को कौन सी कृमिनाशक गोली दी जाती है ?

- [ ] कैल्शियम
- [ ] एल्बेंडाजोल
- [ ] आई एफ ए
- [ ] विटामिन डी

३८. आई एफ ए गोलि के साथ किस गोलि का सेवन नहीं करना चाहिए ?

- [ ] कैल्शियम
- [ ] एल्बेंडाजोल
- [ ] आई एफ ए
- [ ] विटामिन डी

३९. सिफलिस टेस्ट और एचआईवी टेस्ट किस प्रसवपूर्व देखभाल पर गर्भवती माँ को करवाना चाहिए ?

- [ ] पहला
- [ ] दूसरा
- [ ] तीसरा
- [ ] चौथा

४०. पहला प्रसव पश्चात देखभाल कितने घंटों के भीतर करना चाहिए?

- [ ] ४
- [ ] ६
- [ ] १२
- [ ] २४

Figure B.3: Questionnaire Page-3

	A	B	D	E	F	G
1	Sl	English	IndiaTyping	Google	Corrected Human	Reverse Translated
2	1	I felt content	मला समाधान वाटले	मला सामग्री वाटली	मला समाधान वाटलं	I was satisfied
3	2	I felt skillful	मला कुशल वाटले	मला कुशल वाटले	मला खेळामुळे खूप कुशल वाटलं	I felt very skilled because of the game
4	3	I was interested in the game's story	मला खेळाच्या कथेत रस होता	मला खेळाच्या कथेत रस होता	या खेळामधील गोष्टी साठी मी उत्सुक होते	I was looking forward to the things in this game
5	4	I thought it was fun	मला वाटलं गंमत आहे	मला वाटले की ते मजेदार आहे	मला हा खेळ गम्मत वाटली	I had this game of fun
6	5	I was fully occupied with the game	मी खेळात पूर्णपणे गुंतले होते	मी खेळाने पूर्णपणे ताब्यात घेत होतो	मी खेळामध्ये पूर्ण दंग झालेले	I was full of timber in the game
7	6	I felt happy	मला आनंद वाटला	मला आनंद झाला	मला आनंद वाटला	I was happy
8	7	It gave me a bad mood	मला वाईट मूड दिला	यामुळे मला एक वाईट मूड दिला	याच्यामुळे मला वाईट अनुभव आला	I had a bad experience because of this
9	8	I thought about other things	मी इतर गोष्टींचा विचार केला	मी इतर गोष्टींबद्दल विचार केला	मी खेळताना दुसऱ्या गोष्टींचा विचार करता होते	I was thinking of other things while playing
10	9	I found it tiresome	मला ते कंटाळवाणे वाटले	मला ते कंटाळवाणे वाटले	मला हा खेळ थकवणारा वाटला	I found this game tiring
11	10	I felt competent	मला सक्षम वाटले	मला सक्षम वाटले	मला सक्षम असल्यासारख वाटलं	I felt like I was able to
12	11	I thought it was hard	मला वाटले ते कठीण आहे	मला वाटले ते कठीण आहे	मला वाटले ते कठीण आहे	I thought it was hard
13	12	It was aesthetically pleasing	ते सौंदर्याने सुखावणारे होते	हे सौंदर्यात्मकदृष्ट्या आनंददायक होते	खेळ दिसायला सुंदर आणि आकर्षक होता	The game was pretty and attractive to see
14	13	I forgot everything around me	मी माझ्या आजूबाजूचे सर्व काही विसरलो	मी माझ्या सभोवतालचे सर्व काही विसरलो	मी सगळं विसरून खेळात आकंठ बुडाले	I forgot all about the game
15	14	I felt good	मला बरं वाटलं	मला बरे वाटले	मला छान वाटल	I would like to feel nice
16	15	I was good at it	मी त्यात चांगला होतो	मी त्यात चांगला होतो	मला खेळात गती होती	I had a speed in the game
17	16	I felt bored	मला कंटाळा आला	मला कंटाळा आला	मला कंटाळा आला	I got bored
18	17	I felt successful	मला यशस्वी वाटले	मला यशस्वी वाटले	मला यशस्वी वाटलं	I felt successful
19	18	I felt imaginative	मला कल्पनारम्य वाटले	मला काल्पनिक वाटले	मझ्या कल्पनाशक्ती ला चालना मिळाली	My imagination got a walk
20	19	I felt that I could explore things	मला वाटले की मी गोष्टी शोधू शकतो	मला वाटले की मी गोष्टी शोधू शकतो	मला असा वाटलं कि मी पण गोष्टी शिकू शकते	I think I can learn things but
21	20	I enjoyed it	मला मजा आली	मी त्याचा आनंद घेतला	मी इंजॉय केला	I did the engoy
22	21	I was fast at reaching the game's targets	मी खेळाचे लक्ष्य गाठण्यात जलद होते	मी खेळाच्या लक्ष्यात पोहोचण्यात वेगवान होतो	मी खूप वेगाने एक की टप्पा पार करत होते	I was crossing a key phase very fast
23	22	I felt annoyed	मला चीड वाटली	मला राग आला	मला खूप त्रासदायक वाटलं	I feel very annoying
24	23	I felt pressured	मला दडपण जाणवले	मला दबाव वाटला	मला दबाव जाणवला	I felt the pressure
25	24	I felt irritable	मला चिडचिड वाटली	मला चिडचिडे वाटले	खेळताना माझी चिडचिड झाली	I got irritated while playing
26	25	I lost track of time	मी वेळेचा मागोवा गमावला	मी वेळेचा मागोवा गमावला	मी खेळताना वेळेचा भान विसरले	I forgot about the idea of time while playing
27	26	I felt challenged	मला आव्हान वाटले	मला आव्हान वाटले	मला खेळ आव्हानात्मक वाटला	I found the game challenging
28	27	I found it impressive	मला ते प्रभावी वाटले	मला ते प्रभावी वाटले	मला खेळ आकर्षक वाटला	I found the game attractive
29	28	I was deeply concentrated in the game	मी खेळात मनापासून एकाग्र होतो	मी गेममध्ये खोलवर लक्ष केंद्रित केले होते	मी खेळ खेळताना खूप एकाग्र झालेले	I
30	29	I felt frustrated	मला निराश वाटले	मी निराश झालो	मला खूप निराश वाटले	I felt very frustrated
31	30	It felt like a rich experience	एक समृद्ध अनुभव वाटला	हा एक समृद्ध अनुभव वाटला	हा खूप आल्हाददायक अनुभव होता	It was a very pleasant experience
32	31	I lost connection with the outside world	माझा बाहेरच्या जगाशी संपर्क तुटला	मी बाह्य जगाशी संबंध गमावला	मी बाकीच्या जगाचा भान विसरले	I forgot about the rest of the world
33	32	I felt time pressure	मला वेळेचा दबाव जाणवला	मला वेळ दबाव वाटला	मला वेळेत पूर्ण करण्याचा दबाव जाणवला	I felt the pressure to complete in time
34	33	I had to put a lot of effort into it	त्यासाठी मला खूप मेहनत घ्यावी लागली	मला त्यात बरेच प्रयत्न करावे लागले	मला खूप मेहनत घ्यावी लागली	I had to work a lot of hard work
35						
36	34	not at all	अजिबात नाही	अजिबात नाही	अजिबात नाही	Not at all
37	35	slightly	किंचित	किंचित	किंचित प्रमाणात	Quantitatively
38	36	moderately	माफक प्रमाणात	माफक प्रमाणात	मध्यम प्रमाणात	To a moderate amount
39	37	fairly	प्रामाणिकपणे	प्रामाणिकपणे	चांगल्या प्रमाणात	Well
40	38	extremely	अत्यंत	अत्यंत	खूप जास्त	Too much

Figure B.4: GEQ Translation Processs

Appendix C

The designed deck of cards

1 कोलोस्ट्रम बच्चे का जन्म	1 के एम सी कंगारू मदर केयर बच्चे का जन्म	1 ओ पी वी - 0 ओरल पोलियो वैक्सीन बच्चे का जन्म	1 हेपेटाईटिस बी बच्चे का जन्म
1 बी सी जी का टीका बैसिलस कैलमेट गुएरिन बच्चे का जन्म	2 ओ पी वी - 1 ओरल पोलियो वैक्सीन 1½ महीने	2 पेंटावैलेंट - 1 टीका 1½ महीने	2 रोटा - 1 रोटावायरस का टीका 1½ महीने
2 पी सी वी - 1 न्यूमोकोकल कंजुगेट टीका 1½ महीने	2 आई पी वी - 1 इनएक्टिवेटेड पोलियो वैक्सीन 1½ महीने	3 ओ पी वी - 2 ओरल पोलियो वैक्सीन 2½ महीने	3 पेंटावैलेंट - 2 टीका 2½ महीने
3 रोटा - 2 रोटावायरस का टीका 2½ महीने	4 ओ पी वी - 3 ओरल पोलियो वैक्सीन 3½ महीने	4 पेंटावैलेंट - 3 टीका 3½ महीने	4 रोटा - 3 रोटावायरस का टीका 3½ महीने

Figure C.1: Immunization cards for children below 1 year (continued on next page)

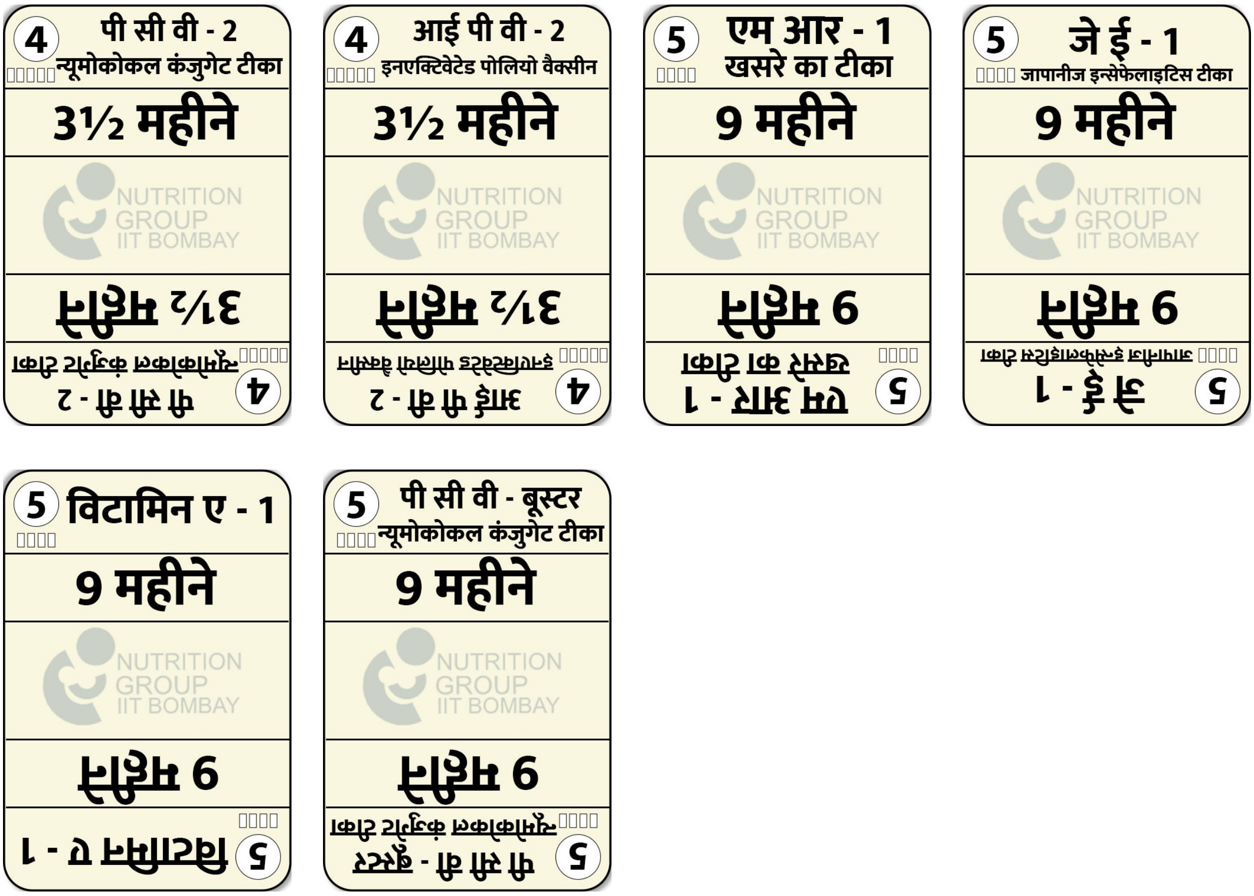

Figure C.2: Immunization cards for children below 1 year (continued from previous page)

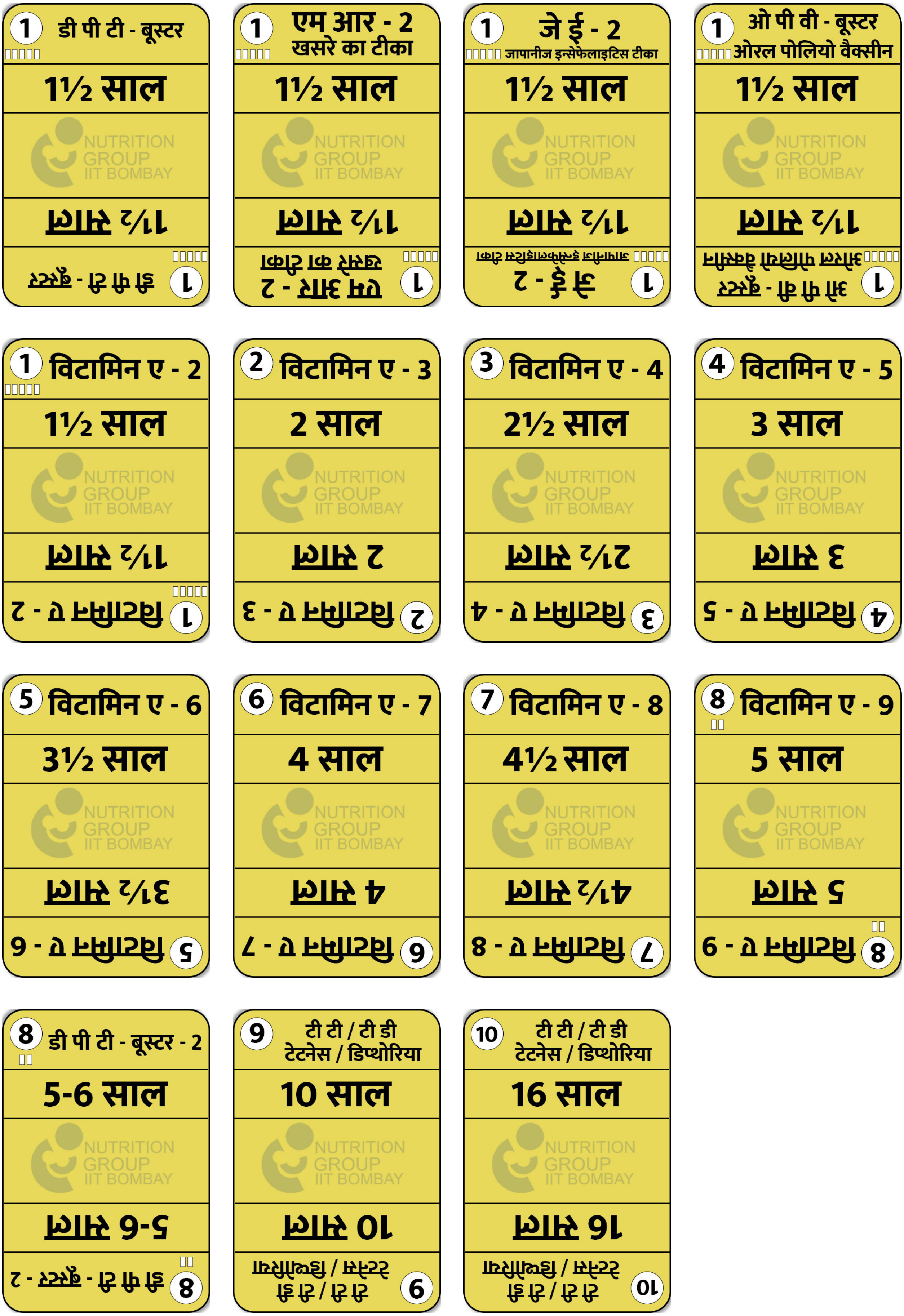

Figure C.3: Immunization cards for children above 1 year

Figure C.4: Ante-Natal-Care (ANC)

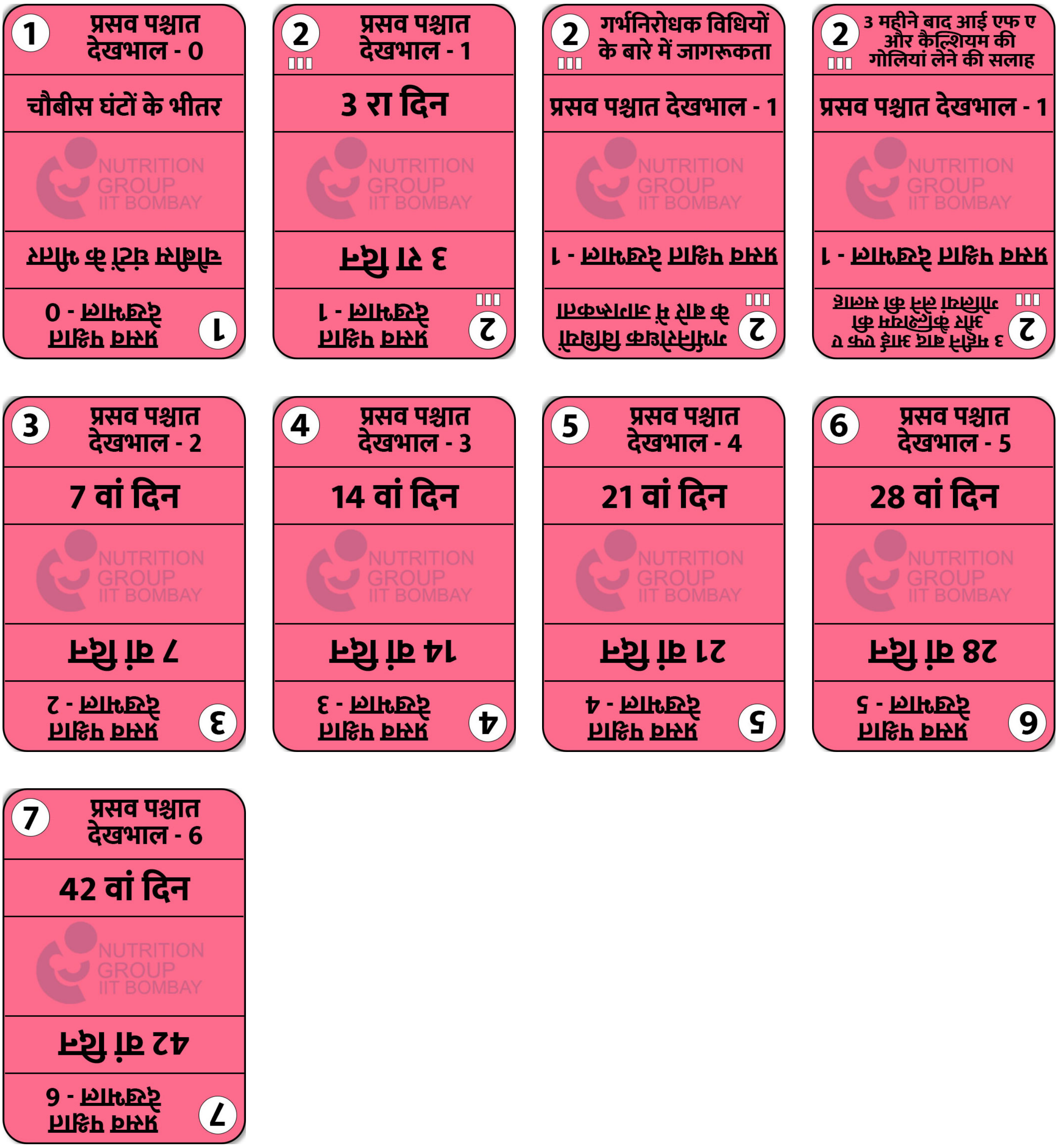

Figure C.5: Post-Natal-Care (PNC)

Appendix D

Mobile app Screenshots

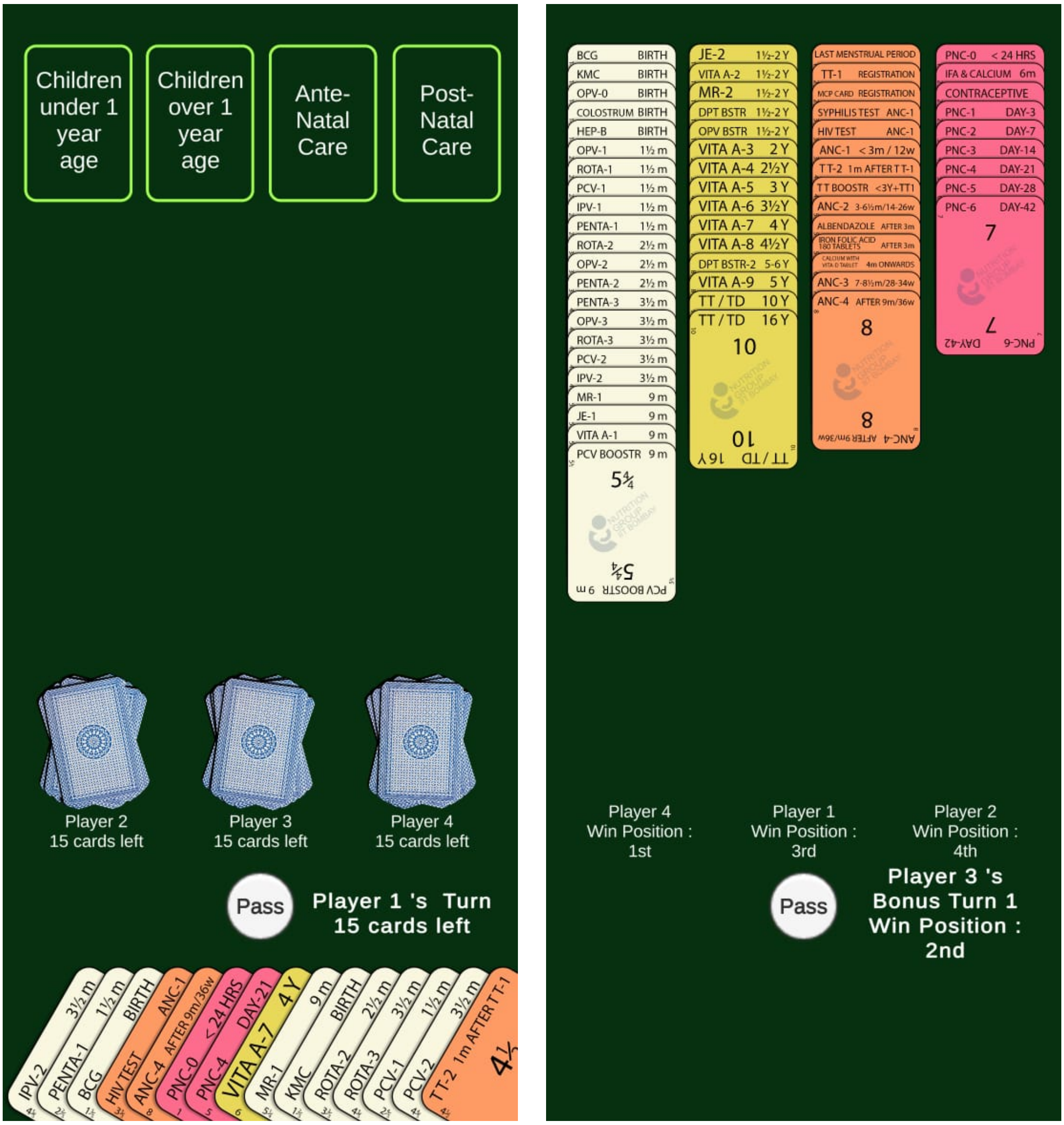

Figure D.1: Mobile app Screenshot - Play Start and End Screen (4 players playing with one phone and passing after their turn)

Appendix E

Institute Review Board Approval

IRCC, Office of the Dean R&D, IIT Bombay

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

Institutional Review Board (IRB)

January 17, 2023

To
Prof. Satish Agnihotri
CTARA
IIT Bombay

Ref: Proposal No. IITB-IRB/2022/051

Sub: Review of the above-mentioned project proposal

Dear Professor,

Thank you for submitting your proposal to the IITB Institutional Review Board (IRB) for review. The IRB has reviewed the proposal submitted by you and the following proposal is approved:

Proposal number	: **IITB-IRB/2022/051**
Title	: **Refresher Training through Games for Frontline Healthcare Workers on Maternal and Newborn care**

The IRB approval is for the ethical conduct of the study. The study is approved for the entire duration and a closure report should be submitted within 2 months of the completion of the study.

Further, it is also confirmed that neither you, nor any of the study team members have participated in the decision-making process of the committee.

In case there are any changes in the proposed work (which is not limited to scope, dates, participants and methodology etc.), please communicate to IRB within 15 days of such a change.

Thank you.
With Best wishes from IRB for your study,

D Parthasarathy
Chairperson IITB-IRB

Figure E.1: IRB Approval

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List of Publications

1. **Majhi, A.**, Mondal, A., Joshi, A., Agnihotri, S. B., 2021. Refresher Training through Quiz App for capacity building of Community Healthcare Workers or Anganwadi Workers in India. ", *CHI 2021, Yokohama, Japan : Asian CHI Symposium 2021* (Best Paper award in Long Paper category)
   https://dl.acm.org/doi/10.1145/3429360.3468186

2. **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2022. Physical and Augmented Reality based Playful Activities for Refresher Training of ASHA Workers in India ", *CHI 2022 : Asian CHI Symposium 2022* (Best Paper and Best Presentation award in Long Paper category)
   https://dl.acm.org/doi/10.1145/3516492.3558788

3. **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Replay, Revise, and Refresh: Smartphone-Based Refresher Training for Community Healthcare Workers in India ", *HCI International 2024, Washington DC, USA*
   https://link.springer.com/chapter/10.1007/978-3-031-61966-3_34

4. **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Mapping Child Malnutrition and Measuring Efficiency of Community Healthcare Workers through Location Based Games in India. International Conference on Information Technology for Social Good (GoodIT '24, Bremen, Germany)
   https://dl.acm.org/doi/10.1145/3677525.3678685

5. **Majhi, A.**, Agnihotri, S. B., Mondal, A., 2024. Refresher Training through Digital and Physical, Card-Based Game for Accredited Social Health Activists (ASHAs) and Anganwadi Workers (AWWs) in India. CHI PLAY Companion '24, October 14–17, 2024, Tampere, Finland
   https://dl.acm.org/doi/10.1145/3665463.3678819

Author’s Contributions

The following list presents the research contributions of the included publications’ authors using the Contributor Roles Taxonomy (CRediT).

1-5: The Publication Numbers
AM1: Arka Majhi
AM2: Aparajita Mondal
SBA: Satish B. Agnihotri
AJ: Anirudha Joshi

	AM1	AM2	SBA	AJ
Conceptualization	1-5		1-5	1
Data curation	1-5	1-5		
Formal analysis	1-5			
Funding acquisition	1-5		1-5	1
Investigation	1-5	1-5	1-5	1
Field Work	1-5	1-5		
Methodology	1-5		1-5	1
Project administration	1-5	1-5	1-5	1
Resources	1-5			
Software	1-5			
Supervision			1-5	1
Validation	1-5			
Visualization	1-5			
Writing – original draft	1-5			
Writing – review & editing			2-5	1

Table 10.1: Author’s Contributions

Reference of definition and details of contributor roles (https://credit.niso.org/)

1. **Conceptualization –** Ideas; formulation or evolution of overarching research goals and aims.
2. **Data curation –** Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use.
3. **Formal analysis –** Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.
4. **Funding acquisition** - Acquisition of the financial support for the project leading to this publication.
5. **Investigation –** Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.
6. **Methodology –** Development or design of methodology; creation of models.
7. **Project administration –** Management and coordination responsibility for the research activity planning and execution.
8. **Resources –** Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.
9. **Software –** Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components.
10. **Supervision –** Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team.
11. **Validation –** Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs.
12. **Visualization –** Preparation, creation and/or presentation of the published work, specifically visualization/data presentation.

13. **Writing – original draft** – Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).

14. **Writing – review & editing** – Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.

Acknowledgments

I wish to record a deep sense of gratitude to **Prof. Anand B. Rao**, my supervisor and **Prof. Satish B. Agnihotri**, my co-supervisor for their valuable guidance and constant support at all stages of my Ph.D. study and related research. I would also like to thank **Prof. Rupal Dalal**, **Prof. Uday Athavankar**, **Prof. Girish Dalvi**, **Prof. Amit Arora** and **Prof. Sarthak Gaurav** for their constant support in my research. I would also like to thank the anonymous reviewers of my submitted papers in different conference venues for their valuable feedback. Also, I would like to thank **Science & Engineering Research Board (SERB)** , **Federation of Indian Chambers of Commerce & Industry (FICCI)** and **UNICEF, New Delhi** for supporting with the research fellowship, Prime Minister's Fellowship Scheme for Doctoral Research. I would like to thank all the Community Healthcare Workers, their supervisors, and the nursing students who participated and supported this research. I would like to thank **Child In Need Institute (CINI)** for their support in my research.