Digitally enabled health education to increase health knowledge in rural Tanzania – development and implementation, user perspectives and knowledge retention

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Abbreviations

AIDS: Acquired Immunodeficiency Syndrome

ART: Anti-retroviral therapy

CHW: Community health workers

CI: Confidence interval

DigI: Non-discriminating Access for Digital Inclusion

GDPR: The EU General Data Protection Regulation

Part 1: Health education intervention part I, exposure to three health animations

Part 2: Health education intervention part II, access to InfoSpots with digitally enabled health education

ICT: Information and communications technology

IT: Information Technology

NIMR: National Institute for Medical Research, Tanzania

NSD: Norwegian Centre for Research Data

SDG: Sustainable Development Goals

SUA: Sokoine University of Agriculture, Tanzania

TB: Tuberculosis

TSCT: *Taenia Solium* Cysticercosis/Taeniasis

TSD: Services for Sensitive Data (at the University of Oslo)

UiO: University of Oslo, Norway

WHO: World Health Organization

Summary in English

Background: Improved health knowledge for both people and communities can play an important role in disease management and prevention, thus contributing to strengthening the healthcare system. Access to quality health education for rural communities in the Global South is limited, but crucial to achieve the health-related Sustainable Development Goal (SDG) 3. This not only pertains to the classical infectious diseases such HIV/AIDS and Tuberculosis (TB), but also to so far neglected tropical diseases such as *Taenia solium* cysticercosis/taeniosis (TSCT), the pork tapeworm, which can also cause a parasitic brain disease called neurocysticercosis. TSCT represents a classic One Health disease, where human, animal and environmental health needs to be integrated to create impact. All three diseases, i.e. HIV/AIDS, TB, and TSCT, were chosen as target diseases in the health education intervention described in this study, not only because of their high burden in the communities under investigation, but also because of their overall importance in achieving SDG 3.

The innovation and science project Non-Discriminating Access for Digital Inclusion (the DigI project) addressed the above described knowledge gap by digitising government approved health messages and developing a health education platform (herein referred to as the platform) and information spots (InfoSpots) with free access to digitally enabled health education, in rural communities in Iringa, Tanzania.

Objectives: The overall aim of this PhD thesis was to understand how digitised health education material for relevant target diseases needs to be designed, to investigate whether the developed health education intervention leads to an increase in health knowledge among community participants of rural Tanzania, and to explore how the intervention was received by individuals in the communities.

The primary objective of this PhD study was to assess the effect of the health education intervention on HIV/AIDS, TB and TSCT knowledge uptake and retention. The secondary objectives were 1) to provide a detailed description of the study objectives, their context, the study design, and the chosen mixed methodological approach, 2) to describe the development of the contextualised digitised health messages and the multi- and interdisciplinary process involved, and 3) to explore the perspectives and experiences of the users and non-users of the InfoSpots in Migoli and Izazi.

Methods: The digitised health messages, including three animated videos (animations) about HIV/AIDS, TB, and TSCT and the platform were developed between 2017-2019 through a multi- and interdisciplinary as well as community-participatory approach. Feedback from local stakeholders and test users was taken on board during the process of digitising the paper-based health messages provided by Tanzania's Ministry of Health. In the mixed method study that followed, two data sources were used: Qualitative semi-structured interviews and a questionnaire in a non-randomised health education intervention study.

The effect of the digitally enabled health education (provided within the health education intervention) on disease-specific health knowledge was assessed in the non-randomised intervention study. We recruited 600 participants to intervention and control group, between the ages of 15 and 45, from Iringa, Tanzania. The intervention included two parts. The first part was supervised and consisted of showing the intervention group the animations of the above mentioned three diseases after a baseline knowledge assessment. The second part consisted of giving the same group (and community) voluntary access to the InfoSpots with the same health animations, in addition to text, graphics, and quizzes related to the three diseases, six months after the baseline assessment. Altogether, the participants were followed up at three and 12 months after the baseline assessment with the same disease-specific questions. The effect of the intervention was calculated from the difference in disease-

specific knowledge between the intervention and control group 12 months after baseline. Perspectives and experiences among the users and non-users of the InfoSpots were explored in 35 semi-structured interviews, before content analyses were used to analyse the data.

Results: The multi- and interdisciplinary as well as participatory process of designing the digitized health messages resulted in a functional health education platform with quality health messages for HIV/AIDS, TB, and TSCT for people in both English and Swahili.

The non-randomised intervention study demonstrated that the intervention group (n=298) had a 10.2% higher mean proportion of correct answers related to HIV/AIDS (95% CI 5.0, 15.4), 12.0% higher mean proportion of correct answers related to TB (95% CI 7.7, 16.2) and 31.5% higher mean proportion of correct answers related to TSCT (95% CI 26.8, 36.2) 12 months after the baseline assessment, compared to the control group (n=300). The results were adjusted for potential confounders, and the significance of the primary results was maintained in the sensitivity analysis ('worst case scenario'). The participants in the intervention group who reported having used the InfoSpots for digitally enabled health education after the first part of the intervention, were able to increase their health knowledge even further. Compared to those in the intervention group who reported not having used the InfoSpots, the users had a 6.8% higher mean proportion of correct answers related to HIV/AIDS, a 7.5% higher mean proportion of correct answers related to TB, and a 13.9% higher mean proportion of correct answers related to TSCT.

In the qualitative part, 25 participants were classified as InfoSpot-users, while 10 participants were classified as non-users. The non-users reported that they would have used the InfoSpot if they had been aware of its existence. Most users utilized the InfoSpot for health education only, while some utilized the InfoSpots in different ways – for their own health education, educating others, internet surfing and practicing English. The less formally educated users reported a need for guidance to access the health platform, while the majority of the users found it easy to navigate the platform on their own. All participants in the qualitative component reported having a positive view of the digitally enabled health education, and animations as a knowledge transfer tool were emphasized as useful.

Conclusion: The multi- and interdisciplinary approach of the DigI project ensured that the digitized health messages were clear, of high quality, culturally appropriate, and aligned with the government's own promotion goals. The intervention study showed a profound increase of health knowledge among those who had seen the animations and used the InfoSpot for health education. The effect was most pronounced for TSCT, followed by TB and HIV/AIDS. However, our results also show that the InfoSpots could have been promoted more extensively by the DigI project, which may have led to better use of the platform in the community. On-site user tests in the InfoSpots with a human-centered approach could have revealed that many potential users had difficulties accessing the platform due to target users' lower digital literacy.

Based on the study results, it seems that digitally enabled health education in the rural communities of Tanzania may have the potential to strengthen disease management and prevention, and could thereby support a rather weak healthcare system. Further research is needed to determine the impact of digitally enabled health education on health outcomes and health behaviour change.

Summary in Norwegian

Bakgrunn: Forbedret helsekunnskap for både individ og samfunn kan spille en viktig rolle i sykdomshåndtering og forebygging, og på den måte bidra til å styrke helsesystemet. Tilgang til helseinformasjon av høy kvalitet for rurale samfunn i det globale sør er begrenset, men avgjørende for å oppnå FNs bærekraftsmål nummer 3 (SDG 3), som handler om god helse og livskvalitet. Dette gjelder ikke bare klassiske infeksjonssykdommer som f.eks HIV/AIDS og Tuberkulose (TB), men også så langt neglisjerte tropiske sykdommer som *Taenia solium* cysticercosis/taeniosis (TSCT), svinebendelorm, som kan forårsake parasittisk hjernesykdom, kalt nevrocysticercose. TSCT representerer en klassisk én-helse (one-health) sykdom, hvor helse for mennesker, dyr og miljø må sees i sammenheng for å skape innvirkning. De tre sykdommene HIV/AIDS, TB og TSCT, ble valgt som tema-sykdommer i dette prosjektet, ikke bare på grunn av den høye forekomsten i studieområdet, men også på grunn av deres generelle betydning for å oppnå SDG 3.

Innovasjons- og forskningsprosjektet Non-Discriminating Access for Digital Inclusion (DigI prosjektet) adresserte kunnskapsgapet beskrevet ovenfor ved å digitalisere helseinformasjon godkjent av Tanzanianske myndigheter, utvikle en helseinformasjonsplattform (heretter kalt plattform) og informasjonskiosker (heretter kalt InfoSpotene) med kostnadsfri tilgang til digitalisert helseinformasjon for alle i småsamfunn på bygda i Tanzania.

Mål: Det overordnede målet var å forstå mer om hvordan digitalisert helseinformasjon kunne utvikles, implementeres og vurderes med tanke på helsekunnskap i en rural Tanzaniansk setting. Hovedmålet var å evaluere effekten av intervensjonen på helsekunnskap, både kortsiktig og langsiktig, om HIV/AIDS, tuberkulose og TSCT på bygda i Tanzania. De sekundære målene var 1) å gi en detaljert beskrivelse av studiens mål, kontekst, design og kombinerte metodologiske tilnærming, 2) å beskrive utviklingen av den kontekstualiserte digitalisert helseinformasjon og den tverrfaglige prosessen involvert, og 3) å utforske perspektiver og erfaringer hos brukerne og ikke-brukerne av InfoSpots i Migoli og Izazi.

Metode: Den digitaliserte helseinformasjonen, inkludert tre animerte videoer (heretter kalt animasjoner) om HIV/AIDS, TB og TSCT og plattformen ble utviklet i prosjektet mellom 2017-2019 med en multi- og interdisiplinær, samt en deltakende tilnærming. Tilbakemeldinger fra lokale interessenter ble vektlagt i prosessen med å digitalisere den papirbaserte helseinformasjonen levert av helsemyndighetene i Tanzania. I den påfølgende studien med kombinerte metoder (mixed methods) ble to datakilder benyttet: kvalitative semi-strukturerte intervjuer og en spørreundersøkelse i en ikke-randomisert intervensjonsstudie.

Effekten av den digitaliserte helseinformasjonen, formidlet i intervensjonen, ble vurdert i den ikke-randomiserte intervensjonsstudien med 600 deltakere i alderen 15 til 45, rekruttert fra Iringa, Tanzania. Intervensjonen bestod av to deler. Den første delen skjedde under oppsyn og innebar å vise intervensjonsgruppen animasjonene etter en første vurdering av helsekunnskap. Den andre delen handlet om å gi den samme gruppen frivillig tilgang til InfoSpoter med de samme animasjonene, i tillegg til tekst, bilder og quizzer relatert til de tre sykdommene, fra seks måneder etter første vurdering av helsekunnskap. Alle deltakerne ble fulgt opp tre og 12 måneder etter den første vurderingen av helsekunnskap, med de samme sykdomsspesifikke spørsmålene. Effekten av den digitaliserte helseinformasjonen ble kalkulert av differansen i sykdomsspesifikk helsekunnskap mellom intervensjon- og kontrollgruppen 12 måneder etter den første vurderingen av helsekunnskap. Perspektiver og erfaringer blant brukere og ikke-brukere av InfoSpotene ble utforsket i 35 semi-strukturerte intervjuer, før innholdsanalyse ble benyttet for å analysere dataene.

Resultater: Den multi- og interdisiplinære, så vel som den deltakende tilnærmingen til utviklingen av den digitaliserte helseinformasjonen, resulterte i en funksjonell plattform med helseinformasjon av høy kvalitet relatert til HIV/AIDS, TB og TSCT, både på Engelsk og Swahili.

Den ikke-randomiserte intervensjonsstudien viste at intervensjonsgruppen (n=298) hadde 10.2% høyere HIV/AIDS kunnskap (95% CI 5.0 til 15.4), 12.0% høyere TB kunnskap (95% CI 7.7 til 16.2) og 31.5% høyere TSCT kunnskap (95% CI 26.8 til 36.2) 12 måneder etter den innledende vurderingen av helsekunnskap, sammenlignet med kontrollgruppen (n=300). Resultatene ble justert for potensielle bakenforliggende faktorer (konfundere), og signifikansen i primærfunnene ble opprettholdt i sensitivitetsanalysen, i ett konstruert "worst case scenario". Deltakerne i intervensjonsgruppen som rapporterte å igjen ha sett den digitaliserte helseinformasjonen i en av InfoSpotene etter første del av intervensjonen, økte helsekunnskapen sin ytterligere. Sammenliknet med de i intervensjonsgruppen som ikke hadde brukt InfoSpotene for helseinformasjon, hadde brukerne 6.8% høyere gjennomsnitt av korrekte svar relatert til HIV/AIDS, 7.5% høyere gjennomsnitt av korrekte svar relatert til TB og 13.9% høyere gjennomsnitt av korrekte svar relatert til TSCT.

I den kvalitative delen ble 25 deltakere klassifisert som InfoSpot-brukere, mens 10 deltakere ble klassifisert som ikke-brukere. Ikke-brukerne rapporterte at de ville ha benyttet seg av InfoSpotene hvis de hadde visst at disse eksisterte. De fleste brukerne benyttet plattformen bare for helseinformasjon, mens noen brukere benyttet plattformen på variert vis - for egen helseutdanning, for andres helseutdanning, internettsurfing og for å lære Engelsk. Brukere med mindre formell utdanning rapporterte et behov for veiledning for å få tilgang til den digitaliserte helseinformasjonen, mens mesteparten av brukerne fant det enkelt å navigere i plattformen selv. Alle deltakerne i den kvalitative komponenten av studien fortalte at de hadde et positivt syn på digitalisert helseinformasjon, og animasjoner som en læringsmetode ble trukket fram som virkningsfull.

Konklusjon: Den multi- og interdisiplinære tilnærmingen brukt i DigI prosjektet sikret utvikling av digitalisert helseinformasjon som var klar, av høy kvalitet, kulturelt tilpasset og i tråd med myndighetenes egne helsefremmende mål. Intervensjonsstudien viste en betydelig økning i helsekunnskap blant de som hadde sett animasjonene og de som senere hadde brukt en InfoSpot for tilgang til helseinformasjon. Effekten var mest uttalt for TSCT, etterfulgt at TB og HIV/AIDS. Imidlertid viser resulatene våre også at InfoSpotene kunne blitt bedre promotert av DigI prosjektet, noe som hadde bidratt til økt bruk av plattformen i småsamfunnene. Brukertesting på stedet i InfoSpotene med en human-sentrert tilnærming kunne ha avdekket at en del potensielle brukere fant det vanskelig å få tilgang til plattformen, på grunn av lave digitale ferdigheter i målgruppen.

Basert på studiens resultater, ser det ut til at tilgang på digitalisert helseinformasjon i småsamfunn på bygda i Tanzania kan ha potensiale til å styrke sykdomshåndtering og forebygging, og videre støtte et relativt svakt helsesystem. For å fastslå effekten av digitalisert helseinformasjon direkte på helsemessige utfall og helsesøkende atferd, er ytterligere forskning nødvendig.

List of papers

This thesis is based on the following papers:

Paper 1: Holst C, Sukums F, Ngowi B, Diep LM, Kebede TA, Noll J, Winkler AS. Digital Health Intervention to Increase Health Knowledge Related to Diseases of High Public Health Concern in Iringa, Tanzania: Protocol for a Mixed Methods Study. JMIR Res Protoc. 2021;10(4):e25128.

Paper 2: Holst C, Isabwe GMN, Sukums F, Ngowi H, Kajuna F, Radovanović D, Mansour W, Mwakapeje E, Cardellichio P, Ngowi B, Noll J, Winkler AS. Development of Digital Health Messages for Rural Populations in Tanzania: Multi- and Interdisciplinary Approach. JMIR Mhealth Uhealth. 2021;9(9):e25558.

Paper 3: Holst C, Tschirhart N, Ngowi B, Noll J, Winkler AS. Utilizing community InfoSpots for health education: perspectives and experiences in Migoli and Izazi, Tanzania [published online ahead of print, 2021 Dec 13]. Health Promot Int. 2021;daab187. doi:10.1093/heapro/daab187.

Paper 4: Holst C, Stelzle D, Sukums F, Ngowi B, Diep LM, Noll J, Winkler AS. Improving Health Knowledge Through Provision of Free Digital Health Education to Rural Communities in Iringa, Tanzania: Nonrandomized Intervention Study. J Med Internet Res. 2022 Jul 28;24(7):e37666.

1 Introduction

This thesis is built upon the research emerging from the three-year innovation and science project entitled *Non-discriminating Access for Digital Inclusion* (DigI). The DigI project, aiming to provide free access to information for all, including *digitally enabled* health education, was based on technical innovations for inclusive access to the internet, where the main concepts, including a wireless community information spot ("InfoSpot"), were prototyped. The project was funded as an innovation project from the Norwegian Research Council. During the project period between 2017 and 2020, the health task force in the project team developed digitised health messages about three target diseases, HIV/AIDS, Tuberculosis (TB), and *Taenia solium* cysticercosis/taeniosis (TSCT), through animations, text, graphics and quizzes. In addition, a health education platform was created to facilitate the delivery of the digitised health messages, with the overall goal of increasing disease-specific health knowledge (hereafter referred to as health knowledge) as a first step towards health literacy and disease prevention. A mixed-method research project (=PhD thesis) evolved among the researchers in the DigI team, with the overall aim of delivering relevant disease-specific knowledge for health service users in rural communities in Tanzania. This thesis includes both qualitative and quantitative techniques, and contributions from the phases of intervention development, study design, as well as results from the mixed method study. It is not an attempt to evaluate the overarching DigI project, but rather to compile and present the health research results from the different phases undertaken in the project.

The thesis is structured as follows: Chapter 2 describes the background for the PhD study, chapter 3 presents the objectives of the study and the rationale, chapter 4 describes the methods used, while chapter 5 presents a summary of the four papers that forms the basis of the PhD work. Chapter 6 discusses the methodological considerations and main findings of the study, while chapter 7 presents the thesis's conclusion and implications.

2 Background

This thesis is about health education to individuals and communities provided through digital devices. In this background chapter, the following topics are defined and contextualised: health education, health knowledge and health literacy, before we move into the digital sphere and explore the area of digital health interventions and the sub-Saharan context. The overarching DigI project is presented, and the chapter ends with a presentation of the study context and the diseases of public health importance targeted in the health education intervention presented in this work.

2.1 Health education

Health education, defined in the 80s as "any combination of learning experiences designed to facilitate voluntary adaptations of behaviour conducive to health" (1), is essential to prevent diseases and

promote health (2). Nutbeam states that "health education comprises consciously constructed opportunities for learning involving some form of communication designed to improve health literacy, including improving knowledge, and developing life skills which are conducive to individual and community health" (3, p. 353). Green et al. provides a more recent and technical definition of health education as "a planned process designed to achieve health- and illness-related learning" (4, p. 343). Health education refers to the process of teaching people about health-related topics, such as disease prevention, promotion of optimal health and healthy lifestyles, early detection of illness, treatment and rehabilitation (5). The goal of health education is to provide people with information and skills to make informed decisions about their health and to encourage them to adopt healthy behaviours (6,7). Health education takes place in a variety of settings, for example schools, hospitals, churches and community settings (5), and it may involve a variety of methods, such as lectures, oral speech, workshops, and informational materials.

In health behaviour science, it is common to distinguish health-enhancing behaviours from health-impairing behaviours (8). Health-enhancing behaviours include healthy actions as, for example, physical activity, intake of fruits and vegetables and using condoms in order to prevent sexually transmittable diseases. It relates to being proactive towards one's own health – for example, going to the doctor for cervical cancer screening. Health-impairing behaviours have harmful effects on health and include, for example, risky behaviours like smoking, excessive drinking, consumption of unhealthy food, in addition to unsafe sex. Related to the intervention described in this thesis, potential harmful behaviour like having unprotected sex, sharing sharp objects or eating undercooked meat are some examples of health-impairing behaviour.

In the literature, the term "health information" is used in various contexts, including medical records as *personal or private* health information, defined as "any personal information about your health or disability" (9). Additionally, it is used in the context of consumer health information within health education. Consumer health information is defined as "information intended for potential users of medical and healthcare services", with emphasis on self-care and preventive approaches as well as information for community-wide dissemination and use (10, p. 42). In this thesis, health information is used specifically in the context of health education for consumers or clients, i.e., for health service users in rural communities in Tanzania. Knowledge transfer can be described as a concept where academic knowledge is converted into formats that can be used in non-academic settings (4).

No standard definitions exist for the term "health message", but it can be applied to "persuasive messages that are designed to change any behaviour within the realm of healthcare" (11). Health messages can be delivered through various channels, such as TV ads, websites, billboards, or social media posts, or as in this project; InfoSpots. They can target different audiences, such as individuals, families, or communities. In summary, health information forms the basis of knowledge, while health

messages are the communicative products used to impart that knowledge effectively within the context of health education. In this thesis, "health messages" refers to information based on research evidence that is designed to be effectively communicated and to promote desired health outcomes.

2.1.1 Health promotion and disease prevention

While health education is the major drive within health promotion, the latter has a wider meaning related to social and political processes, aiming to strengthen skills and capabilities of individuals to impact public and individual health (3). Health promotion involves creating supportive environments, strengthening community action, developing personal skills, reorienting health services, and building healthy public policies. The goal of health promotion is to create conditions that enable people to live healthy lives and to address the underlying determinants of health, such as social, economic, cultural, political and environmental factors. Green et al. outline that health promotion includes strategies to deal with social and environmental determinants of health by means of healthy public policy (4), and the authors sum up the scope for health promotion as:

health promotion = health education x healthy public policy

Health promotion includes disease prevention services, which are mainly concentrated within the healthcare system (4). Disease prevention entails actions that prevent disease occurrence (12) and relates to human behaviours to promote health, the understanding of risk behaviour, and how to modify these behaviours for risk reduction (13). Nutbeam and Muscat (14) refer to primary prevention as actions that reduce risk factors that can lead to the initial occurrence of a disorder, while secondary prevention relates to early detection of existing disease and strategies to prevent the disease from re-occurring or getting worse. Risk factors can be "social, economic, or biological status, behaviours, or environments which are associated with or cause increased susceptibility to a specific disease, ill health, or injury" (15, p. 338). A comprehensive healthcare system not only focuses on disease management but also includes disease prevention including early detection of risks. An important component of disease prevention is to share relevant knowledge with individuals and communities at risk and to transfer evidence into context-specific education material.

The activities derived from health promotion and disease prevention are commonly referred to as preventive medicine and are typically focused on diseases or health problems that have a significant impact in the specific society (16).

2.1.2 Health literacy and health knowledge

An updated definition of personal health literacy reads: "the degree to which individuals have the ability to find, understand, and use information and services to inform health-related decisions and actions for themselves and others" (17, p. 259). Health education is directed towards improving health literacy (14), and many would say that health literacy is the outcome of health education (18).

Improved health literacy and healthier lifestyles can again result in reduced morbidity, mortality and disability, and increased quality of life. In addition, functional independence, and equity as a result of reduced morbidity, mortality and disability are the health and social outcomes of improved health literacy, according to Nutbeam (18). Low health literacy levels represent equity challenges and are associated with risky behaviour, more hospitalisation and associated costs (19).

Health literacy includes the capacity to "communicate, assert and enact these decisions" (20, p. 12), referring to health-related decisions about a person's own health, another person's health, or community health. In short, one can say that the term "health literacy" is used to describe the abilities that are needed to engage with health information and services. Improved health literacy gained through health education, communication initiatives, policies, and other actions taken through the health system is highlighted in Sustainable Development Goal (SDG) 3; to "ensure healthy lives and promote well-being for all at all ages" (21). However, it is important to note that information (i.e., health education) is not sufficient on its own to meet the many challenges of marginalised populations within the health system (22). The access to information and the capability to act upon that information are crucial when addressing health literacy. Examples of health literacy interventions include interventions targeting health literacy according to a clinical approach, education interventions, interventions aimed at improving patient-provider interaction/communication, interventions aimed at improving access to accurate and appropriate health information, or interventions for improving the usability of a healthcare system and health services (23).

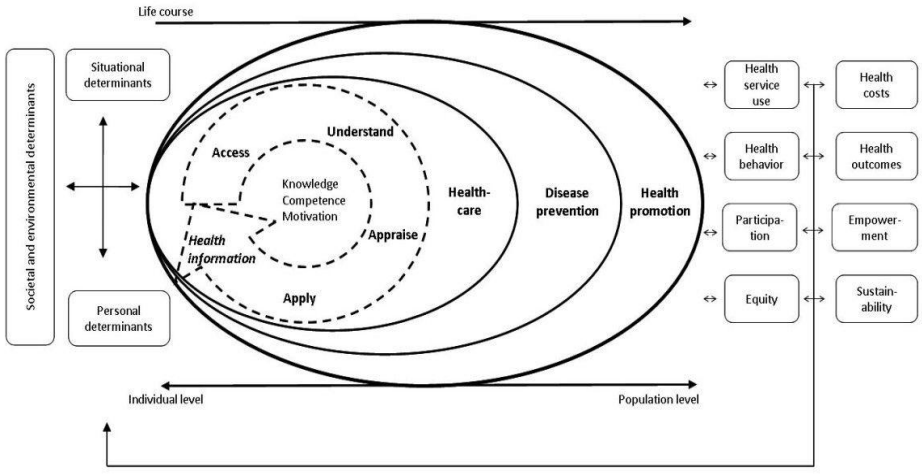

Figure 1. Sørensen et al.'s integrated model of health literacy shows how health literacy affects both the personal and population level. A health literate person would access, understand, and use the health information in a constructive way, which, on the population level, would ultimately reduce health costs and lead to more efficient health service use. The model is used with the courtesy of K. Sørensen (August 2021).

Sørensen et al. (24) have proposed a model for developing health literacy enhancing interventions as shown in Figure 1. This model includes the different dimensions of health literacy and demonstrates the link between healthcare, disease prevention, knowledge and health promotion, in addition to the

situational and personal determinants, both at the individual and population level. Interestingly, Sørensen et al. points to several researchers suggesting that health literacy results in positive outcomes, such as better self-reported health status, enhanced health knowledge, and decreased frequency of healthcare service utilization. In other words, health knowledge strengthens health literacy and vice versa.

According to Gellert and Tille (25), health knowledge is a component of health literacy that is used inconsistently across health literacy theories and definitions. A precise and consistent definition of health knowledge has yet to be provided (26, 27). Many health literacy theories include health knowledge and health literacy as related concepts or health knowledge as a consequence, antecedent, or dimension of health literacy (25). Speros found in her concept analysis of health literacy, that increased health knowledge could be a consequence of health literacy (28), which could be interpreted from the inner circle in Sørensens model above. Green et al. outline that knowledge is an enabling factor necessary to adopt a health action, but the knowledge alone is not sufficient to create behaviour change (4). Specific health knowledge is one of three fundamental components of health literacy, according to Chin et al. in the framework called the Process-Knowledge model (P-K model) (29). The other two components are processing capacity and general knowledge. Nutbeam distinguishes between three levels of health literacy: functional health literacy, interactive health literacy, and critical health literacy. The higher levels of knowledge and skills are needed to increase independence and individual empowerment in making decisions related to health. Furthermore, they involve actively interacting with a broader scope of health knowledge that spans from managing personal health to understanding the social determinants of health (2).

2.2 Digital health and digital health interventions

Digital health is an overreaching term, and an area under constant development. This thesis is grounded within medicine and health sciences, with WHO-definitions related to the field of digital health being used as a basis throughout. In 2016 the WHO defined digital health as "the use of digital, mobile and wireless technologies to support the achievement of health objectives." (30, p. 16). In 2021, the definition was updated to be "the field of knowledge and practice associated with the development and use of digital technologies to improve health" (31, p. 11).

Digital health includes mHealth, eHealth, the use of advanced computing sciences in "big data", genomics, and artificial intelligence in health (32). In other words, digital health is expanding over an immense area. It is huge, complex, context-dependent, and comprises different elements of the healthcare system.

eHealth focusses on electronic health, or the use of information and communications technology (ICT) for health (33). eHealth and digital health are often used interchangeably (7), but according to the WHO, digital health is the umbrella term that includes eHealth (30). mHealth, the use of mobile

wireless technologies for health (32, p. ix), is defined by the WHO's Global Observatory for eHealth as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices" (34, p. 6). Thus, mHealth falls under eHealth.

A digital health intervention (DHI), according to the WHO classification system from 2018 is defined "as a discrete functionality of digital technology that is applied to achieve health objectives and is implemented within digital health applications and ICT systems, including communication channels such as text messages" (35). DHIs can be delivered via digital technologies (i.e., smartphones, websites) (36) through formal or informal care (37). In the classification system the most prominent lines drawn are between the primary users of DHIs, from a) clients (now referred to as health service users); "members of the public who are potential or current users of health services, including health promotion activities" (35, p. 1), to b) healthcare providers, c) health systems and resource management, and d) data services.

In WHO's classification scheme (35), DHIs for clients are interventions aimed at the client, the patient, the end user and / or the general population, and includes targeted client communication, untargeted client communication, client-to-client communication, personal health tracking, citizen-based reporting, on-demand information services to clients, and client financial transactions (35). DHIs for clients can be interventions dealing with interactive voice responses for targeted groups (38), appointment reminder systems from healthcare providers (mail, SMS, apps) (39,40), SMSs sent to large groups during outbreaks (41), social media used to boost social distancing during pandemics (42), online groups for patients or others affected by disease (43), interventions facilitating access to personal health tracking (44), and access to hospital records and diagnostic data (45). It can be apps connected to the use of digital health devices (46,47), client feedback online surveys (48), webpages aimed at a public audience (49), health information apps (50), and mobile banking solutions to pay for patient services (51).

2.2.1 Digital health interventions targeting health literacy

The advent of digital transformations brings about a change in how we perceive health and approach health education and promotion of public health (52). Jacobs et al.'s systematic review (53) from the US showed that eHealth interventions may be effective in improving health literacy, particularly for individuals with low reading literacy. Kim and Xie's systematic review (54) concluded that both mHealth and eHealth have potential for reaching people with low reading literacy, but this group needs to be provided with appropriate technological and practical support to lower the barriers to the use of eHealth services. The utilisation of digital technology related to health promotion has potential to increase the access to health information, and it is believed that this increased access will improve people's health literacy (55). However, a direct link between digital health interventions, including

increased access to digital information, and improved health literacy is not evident given the complexity of health literacy, the influence from other channels and the time it takes to demonstrate such changes in health behaviour.

Providing the relevant health information and health messages through appropriate digital health interventions might cause a target population to change its health behaviour (56,57), and digitised health messages can therefore play an important role in helping to prevent and manage diseases (58). A systematic review of systematic reviews by Marcolino et al. showed that mHealth "is increasingly being used (1) for patient communication, monitoring, and education, (2) to reduce the burden of diseases linked with poverty, (3) to improve access to health services, clinical diagnosis, and treatment adherence, and (4) for chronic disease management" (59, p. 2). The authors of the review point out that the majority of mHealth studies were performed in high-income countries, indicating that research on mHealth is still at an early stage in lower-middle, and low-income countries. It may also be that more eHealth interventions are targeted towards urban populations than those marginalised and in the least urbanised countries, as Njoroge et al. show in their systematic review from Kenya (60).

There is no consensus definition for *digitally enabled health education* in the literature. In this thesis, it refers to health education being provided with the use of digital technology, to individuals and communities. *Digitised health messages* are health information that has been converted into a digital format, such as text, images, audio, or video, before they are provided digitally to people. These two terms cover what was developed in the DigI-project and what was provided to the intervention group described in this thesis. The use of the terms, and the "digital health" connection is further discussed in the methodological considerations in section 6.1.4.

2.3 Digital literacy

To use and benefit from any digital tools and digital health interventions, a certain level of digital literacy is needed. Digital literacy, recently labelled as a new social determinant of health (61), is understood as the necessary skills in technology use and problem solving (62) as, for example, the use of digital devices to retrieve information.

eHealth literacy, or digital health literacy, was first defined by Norman and Skinner as "the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem" (63, p. 2). A more recent definition of eHealth literacy was developed by Griebel et al. (64) and includes a contextual dimension, perspectives related to interactivity, integration of technology, dynamic evolvement of literacy, in addition to the changing information practices of individuals. The definition reads: "eHealth literacy includes a dynamic and context-specific set of individual and social factors, as well as consideration of technological constraints in the use of digital technologies to search, acquire, comprehend, appraise,

communicate, apply and create health information in all contexts of healthcare with the goal of maintaining or improving the quality of life throughout the lifespan" (64, p. 436).

Norgaard et al. have identified seven domains of digital health literacy which characterise an e-health literate patient (65). The ability to process information, engage in one's own health, engage with digital services in an active way, feel safe and in control, be motivated to engage with digital services, access digital services that work, in addition to suiting individual needs. This describes the digital health citizen in the Global North. In the Global South, we find that digital health projects have been rolled out at a smaller scale (66). For many rural communities in the Global South, digital health services do not exist, and if they exist, many will lack the device needed to access them. Thus, such a characterisation of an eHealth literate patient can be difficult to apply to a Global South context.

Providing open public health information and the devices and tools to access the information is a critical step to revitalising public health practice (67) and is an entry point for digital literacy and eHealth literacy. The SDG 4, on ensuring "inclusive and equitable quality education and promoting lifelong learning opportunities for all" (68), recommends, among other things, a significant increase in the proportion of people having technical skills (target 4.4.), which is relevant for this thesis.

2.4 The non-discriminating access for digital inclusion (DigI) project

The innovation- and science project was funded by the Ministry of Foreign Affairs/The Norwegian Agency for Development Cooperation and The Norwegian Research Council in 2016 (69), with a start date in January 2017. It was funded as part of the Vision2030, an initiative with the objective of contributing to poverty reduction in countries receiving developmental aid from Norway by developing and scaling up innovative solutions that promote achievement of the SDGs for education and health (70). The DigI project was a multi- and interdisciplinary and multinational collaboration between healthcare workers, IT workers, and scientists in the disciplines of the humanities, social sciences, formal sciences, and applied sciences. The team members had various backgrounds ranging from epidemiology, medicine and health to electronic engineering and human-computer interaction. Others team members specialised in public health, veterinary medicine, visual and creative arts with graphic and interaction design, communication, educational technology, education and information science. In addition, team members were experts in internet science and ethics.

The 11 partners in the project were from Tanzania, Rwanda, Germany, France, Spain, Serbia, United States, and Norway.

The project included an innovation part and scientific component which consisted of research by the Basic Internet Foundation and two independent PhD studies. One was located at Sokoine University of Agriculture (SUA), with the main objective of investigating the determinants for adoption and implementation of digitally enabled health information for pig farmers to determine the epidemiology

of porcine cysticercosis. The other PhD study is presented in this thesis. Researchers from National Institute for Medical Research (NIMR) in Tanzania contributed to both PhD studies.

The specific aim of the DigI project was to provide free access to information for everybody ("Internet Lite for All") as a basis for digital inclusion, job creation, and lifelong learning, by establishing information spots ("InfoSpots") in Tanzania. The actual innovation in the DigI project was two-fold. 1) Providing access to internet and locally stored information through the InfoSpots in areas with low- or without internet connection, and 2) introducing the 'freemium' model as the business model for access and revenue, meant free access to information and premium access to broadband services. The idea was that revenue could be created for local people by selling access to the full internet (i.e., streaming services), while providing free access to information on the Internet (*Internet Lite)* and additional information on a local server. The InfoSpots were developed for areas with weak mobile coverage – as typically found in many places in rural sub-Saharan Africa – and consisted of affordable technical equipment creating Wi-Fi for surrounding users (see Figure 2).

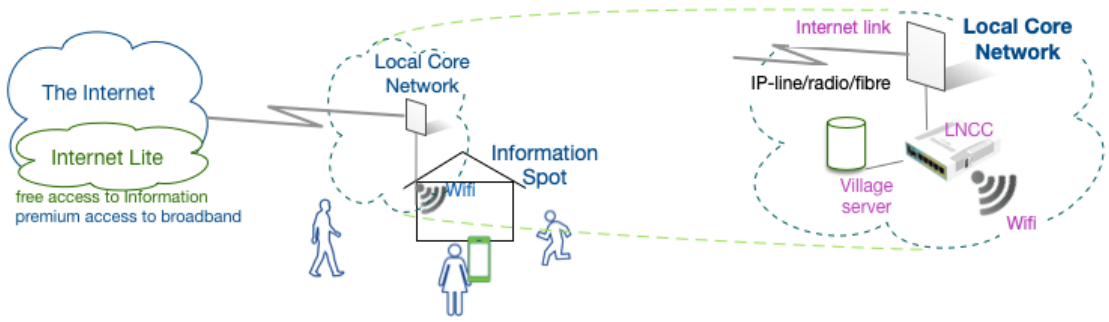

Figure 2. Basic Internet Infrastructure for optimised information provision. Source: Basic Internet Foundation.

During 2017 and 2018, the work within the DigI project revolved around the equipment needed and the development of the content to be provided on the health education platform, herein referred to as "the platform". The goal of the platform and the technical infrastructure was to provide digitised health messages to the local communities through an Internet portal stored on a local InfoSpot in the community. The technical team focused on equipment and software, while the health team and researchers developed the digitised health messages, the health education intervention, and the studies. A pilot installation of an InfoSpot was built in Kjeller at UiO's Department of Technology Systems in 2017. The technical focus was on creating affordable equipment (see Figure 3 for an overview) for the InfoSpot to support a sustainable business model for the operation of the InfoSpots in the rural areas of Tanzania.

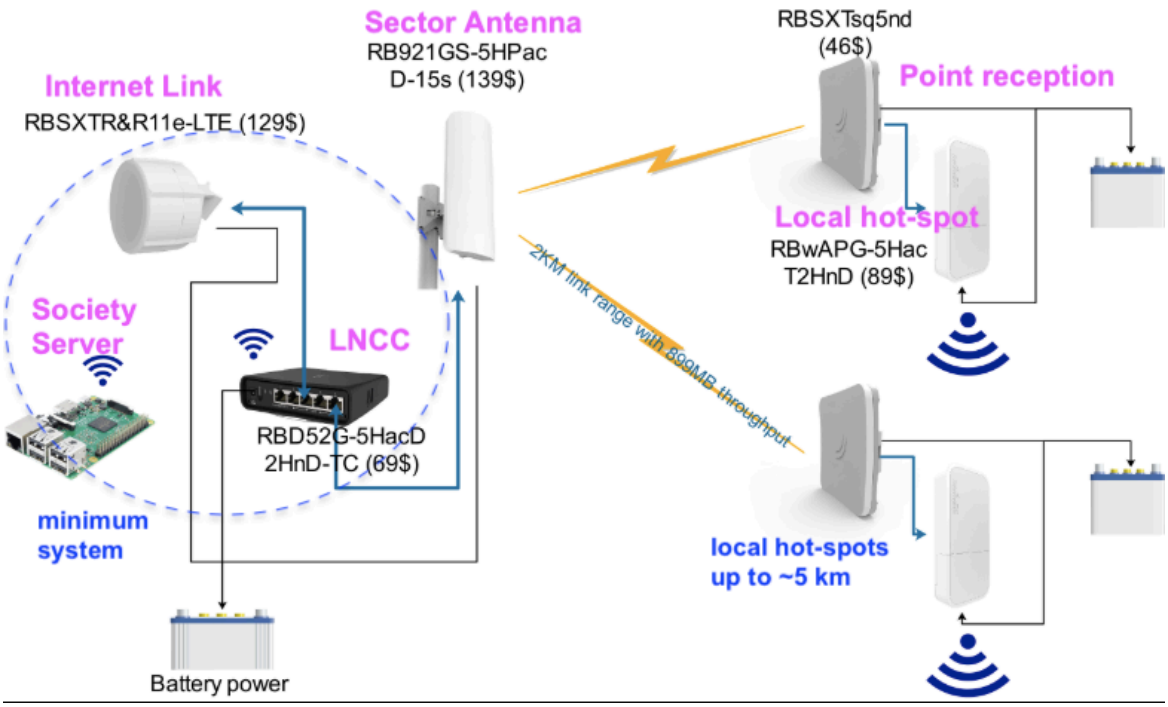

Figure 3. An overview of the technical components in the InfoSpots. The sector antenna uses the mobile signals to provide users with access to a village platform (society server) as well as the Internet. Source: Basic Internet Foundation.

Configuration of the InfoSpots was performed in Norway, followed by shipment of the InfoSpots to Tanzania and installation ('roll-out') in rural areas starting in spring 2019. One village InfoSpot was established in each project village (71), with additional deployment of Wi-Fi access points at other locations. Each InfoSpot was accompanied by one or two tablet devices (7-inch Huawei) for public use in order to enable access to information on the platform and Internet for those who did not have an internet-enabled device.

Within the WHO's digital health intervention classification system (35), outlined in section 2.2, the DigI project itself would belong in the main category "Digital health intervention for clients". The intervention is described in detail in the Methods chapter, with a brief outline here. The first part of the intervention that consisted of showing three health animations on the tablet device to randomly selected study participants (described as Part 1 in Methods) belongs in the "1.2 Untargeted client communication" bracket, while the second part of the intervention (described as Part 2 in Methods) – the voluntary use of the InfoSpots for the digitally enabled health education – belongs under the "1.6 On demand information for clients", as illustrated in Figure 4. To what degree the intervention classifies as a digital health intervention is explored in the discussion in section 6.

Figure 4. Illustration from the WHO's classification of digital health interventions for clients (35). The red rings indicate the sub-groups most important for this thesis.

2.5 The United Republic of Tanzania – study context

Tanzania is the largest country in East Africa with a population of nearly 61.7 million in 2022 (72). The country has a decentralised health system divided into three functional levels (73):

- Primary level, which consists of council health management teams overseeing hospitals at the district level, health centres, dispensaries, clinics, community post, and communities.
- Secondary level with regional health management teams overseeing regional hospitals and regional referral hospitals.
- Tertiary level, which is zonal hospitals, national and specialised hospitals.

An estimated 64% of the country's population lived in rural areas in 2021 (74), and the public and private dispensaries and health centres are the main providers of primary healthcare services. However, many of the dispensaries are hard to reach for a grand proportion for the population, leaving communities with little accessible health education. In rural Tanzania, community health workers (CHWs) and healthcare workers in health facilities, in addition to non-governmental organisations (NGOs), schools and prayer groups have traditionally been the main providers of health education to individuals, neighbourhoods, and communities (75). The formats most frequently used are personal communication or printed materials – for example, leaflets, pamphlets, billboards, banners, and posters. Community health education have traditionally been focused in and around health facilities, often with varying opening hours and a severe shortage of healthcare workers (76). Doctors and nurses may not always be available to give advice, thus less health-educated individuals, e.g.,

admission clerks working at the health facility, may become the main providers of the information intended manage and prevent diseases, both at the individual and the community level.

2.5.1 Digital health in sub-Saharan Africa and Tanzania

Sub-Saharan Africa is currently undergoing a transformation in the digital health arena and is booming with different digital health interventions (77). Adaptation of smartphones and tablets for health education in low-resource settings is seen as promising (78). Kruse et al.'s systematic review (79) demonstrated that mHealth interventions can improve health outcomes in low-income countries, especially related to infectious diseases and maternal health. The review reports poor infrastructure, lack of equipment, and the technology gap as the top three barriers for the use of such interventions.

There are many examples on how digital health interventions can strengthen the healthcare system in sub-Saharan Africa with regards to health education and disease prevention. SMS has been the main channel for information to clients since the onset of mHealth interventions in the region. Studies have shown improved adherence to antiretroviral treatment after exposure to relevant health messages in SMS format in Kenya (57) and Zimbabwe (80). In Rwanda, a national mobile and internet-based human immunodeficiency virus (HIV) / acquired immune deficiency syndrome (AIDS) informatics system was implemented in 2010. The system resulted in an improved time to anti-retroviral therapy (ART) initiation among HIV-infected infants, as the health facility received polymerase chain reaction results via SMS or the web (81). In Nigeria, scores on self-care capacity, psychological adjustment, and engagement in one's own health increased after voice calls, SMS, multimedia messages (MMS), and WhatsApp counselling among youths living with HIV (82). In another study from the same country, mothers received health education through mobile phones, and they perceived the mobile phones as useful because the distance challenges in accessing healthcare workers were reduced (83). There are growing levels of acceptability of digital health interventions for community health education among sub-Saharan healthcare and CHWs (84,85,86).

In Tanzania, the digital health landscape has undergone tremendous changes alongside the significant economic growth in the country (87). By the end of 2022, the Tanzania Communications Regulatory Authority estimated the country to have 31.2 internet users and 60.2 million mobile phone subscribers (88). It is further estimated that 66% of the population will have smartphone by 2025 (89). Telecentres, i.e., a public place where people can use computers with the Internet and other digital services, are widely used as an access point to the Internet (90) for those who face barriers accessing online information. Digital health is persistently high on Tanzania's agenda (91), and a few years ago the Digital Health Strategy 2019–2024 was launched by the government. Through its vision "Better health outcomes through a digitally enabled health system" (92, p. xvi) and the focus on increasing use of digital platforms for health information, education, and communication, the government outlined the potential for digital technologies to provide quality healthcare to all households and

contribute to achieving universal health coverage. In the current strategy, one of the strategic priorities reads as follows: “Promote healthy behaviour through access to relevant health information, education, and communication” (92, p. xviii). It is thus of upmost relevance for this thesis.

In Tanzania, mHealth interventions, including SMS, have been widespread for at least a decade already and have, for example, been associated with increased skilled delivery attendance in Zanzibar (93,94) and with being recommended for health education related to family planning (95). The acceptability of digital health interventions among healthcare workers in Tanzania is also increasing, whether it relates to the management of childhood diseases (85) or skilled birth attendants using technology to assist births (96). In the initial phases of the COVID-19 pandemic, requests for teleconsultations increased in Tanzania (97).

2.5.2 Animations for health education in sub-Saharan Africa

A recent systematic review undertaken by Moe-Byrne et al. suggests that video animations are a promising patient information tool, particularly for effects on knowledge (98). The review, although focussing on western countries, consisted of 38 studies, with great variation in size, and effect in knowledge was assessed in 30 of the included studies.

Animation has been used in sub-Saharan health education context before. For instance, UNICEF came up with the Sara Communication Initiative in 1996 to educate teenage girls and their families about the importance of staying in school, HIV/AIDS, and early marriage, among other things, via animations (99). In the context of more recent global health activities, we find several programmes rooted in Global North academia that produce animations in collaboration with sub-Saharan stakeholders (100,101,102).

Only a few studies in sub-Saharan Africa deal with clients in general as the main target for health animations. Bello-Bravo et al. found in their study (103) from Benin that health-animated videos are very useful in transferring agricultural and health knowledge to low-literate learners, i.e., farmers. Other research focused on CHW as the target viewers of the health animations. Coetzee et al. (104) published a study from a township in South Africa where videos – provided on a tablet device – were found to be an effective means of health education on HIV, alcohol, nutrition, and breastfeeding, which could assist CHW while conducting visits at home. In Burkina Faso, Hébert et al. (105) found that healthcare workers significantly increased their knowledge of the dengue virus after exposure to three training videos: one journalistic, one dramatic, and one animated. The study further highlights that the videos should use a narrative form, a good communicator, visuals that reinforce the health messages, and be adapted to the local context. Isler et al. report in their study (106) an mHealth video intervention on maternal nutrition that was transferred from South Africa to Burkina Faso. The authors concluded that the adaptation to the new context must be customized to meet the target audience,

healthcare workers and the environment in Burkina Faso, demonstrating yet again that digital health interventions need to be contextualized to be impactful.

2.5.3 Diseases of public health importance targeted in the intervention: HIV/AIDS, Tuberculosis, and *Taenia solium* cysticercosis/taeniosis

Within the DigI project, the health education intervention was designed to fill the basic information gaps for individuals and communities in rural areas related to HIV/AIDS, Tuberculosis (TB), and *Taenia solium* cysticercosis/taeniosis (TSCT), the pork tapeworm, our so-called target diseases.

Tanzania is one of the countries that has been hardest hit by the HIV/AIDS epidemic, with an estimated 1.7 million people living with HIV, 29,000 AIDS-related deaths, and 54,000 new infections in 2021 (107). In the recent Health Strategic Plan, the government has focused on ensuring that 95% of people living with HIV are aware of their HIV status, 95% of people diagnosed with an HIV infection receive ART, and that all pregnant women eligible for prevention of mother-to-child transmission receive treatment (108).

Due to drug resistance TB is one of the leading killers of individuals living with HIV. Tanzania is highly burdened by TB but reached the 2020 milestone (20% reduction) for diminishing both the incidence (by 20%) and mortality (by 35%) (109). The Tanzanian Health Sector Strategic Plan emphasises that improvement is needed in prevention efforts, even though the disease control programmes of HIV/AIDS and TB have been a success in terms of early detection and treatment (75).

According to the WHO, TSCT, a parasitic zoonotic disease, is one of the most neglected tropical diseases globally and represents a classical One Health disease complex (110). One Health is defined as “an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent.” (111, p. 2) Humans contract the parasite mainly by consuming undercooked and contaminated pork containing the larval cysts. Larvae develop to adult worms in the human intestine, shedding eggs into the environment. If eggs are taken up by scavenging pigs and accidently (lack of hygiene) humans, larval cysts can develop in organs such as muscles and the brain (112); the latter can be responsible for up to 30% of epilepsy in TSCT endemic areas (113) This increases the significance of preventative strategies to reduce the disease burden, especially epilepsy, in Tanzania (114).

All target diseases included in the health education intervention described in this study are endemic to the Iringa region. The region has a high prevalence of HIV (115), the second highest TB incidence in the country (116), and TSCT has been reported to be highly endemic in the southern highlands of Tanzania (117) . Efforts aiming at reducing the prevalence/incidence of HIV/AIDS, TB and neglected tropical diseases can directly affect SDG 3, target 3.3, with the number of new HIV infections, TB

incidences, and the number requiring interventions against neglected tropical diseases as stated in indicators 3.3.1, 3.3.2, and 3.3.5 (118).

2.6 Summary of Chapter 2

Main messages from this thesis's first part:

- Health education can create health knowledge, which again can foster health literacy and healthy behaviours.
- Increased health literacy and healthy behaviours can contribute to disease prevention, less morbidity, mortality, and disability, and increase quality of life.
- Digital health interventions for clients can play an important role in health education, as long as people know how to access and use the content.
- More research is needed to evaluate what works related to digital health interventions in the Global South.
- Sub-Saharan Africa in general, and Tanzania specifically, have increased their focus on digital health, rooted in government strategies and in the number of projects and interventions being implemented.
- Although disease control programs have shown to be successful in fighting HIV / AIDS and TB, prevention strategies have to be further scaled up and focus on specific, so far neglected areas, as mentioned in the above paragraph; also, the One Health disease complex of TSCT has not been part of major control programs up to now.
- The innovation- and science-focused DigI project was introduced as the overarching arena for this PhD thesis.

3 Study objectives

New technologies to increase disease specific health knowledge are increasingly used to strengthen the healthcare system. Digital technologies can be impactful, especially in resource-poor settings where access to quality health education for health service users can be limited and where shortages of healthcare workers is critical. The DigI project digitised approved public health education materials, developed and showed health animations to participants in our study, assessed their knowledge uptake and retention, and installed InfoSpots with free access to information on the Internet and to a health education platform in rural communities in Iringa, Tanzania. The intervention study, consisting of showing health animations (part 1) and later providing access to InfoSpots with digitally enabled health education (part 2), is important due to the ongoing public health challenges posed by HIV/AIDS, TB, and TSCT in the region. The choice of the target diseases for the intervention aligns with the prevalent health concerns in the region (see section 2.5.3 for an elaboration). These diseases have significant public health implications, and improving knowledge about them is fundamental for prevention, early detection, and proper management. The study's multi- and interdisciplinary approach ensures a comprehensive understanding of the intervention's contextual relevance.

The overall aim of this PhD thesis is to understand how digitised health education material for relevant target diseases needs to be designed, to investigate whether the developed health education intervention leads to an increase in health knowledge among community participants of rural Tanzania, and to explore how the intervention is received by individuals in the communities. Based on the different phases of planning, developing, implementing, and assessing the effect of the health education intervention (described in detail in 4.3.1), the objectives of this thesis are as follows:

The primary objective is to assess the effect of the health education intervention, part 1 and part 2, on HIV/AIDS, TB and TSCT knowledge uptake and retention in a rural Tanzanian population (Paper 4). The main hypothesis is that the proportion of correct answers in the intervention group will differ from the proportion of correct answers in the control group at three and 12 months.

Secondary objectives:

- To provide a detailed description of the study objectives, their context, the study design, and the chosen mixed methodological approach (Paper 1).
- To describe the development of contextualised digitised health messages for a rural population in Tanzania and the multi- and interdisciplinary process involved (Paper 2).
- To explore the perspectives and experiences of the users and non-users of the InfoSpots in Migoli and Izazi (Paper 3).

Amendments to the original project description, approved by the Faculty of Medicine, UiO, were submitted to the faculty twice, in June 2018 and in December 2020. See appendix 1 for details.

4 Methods and materials

The digitised health messages, the platform, the health education intervention, and the study evolved from 2017 to 2020. Figure 5 presents the timeline outlining the most important milestones, both in the DigI project and the PhD study.

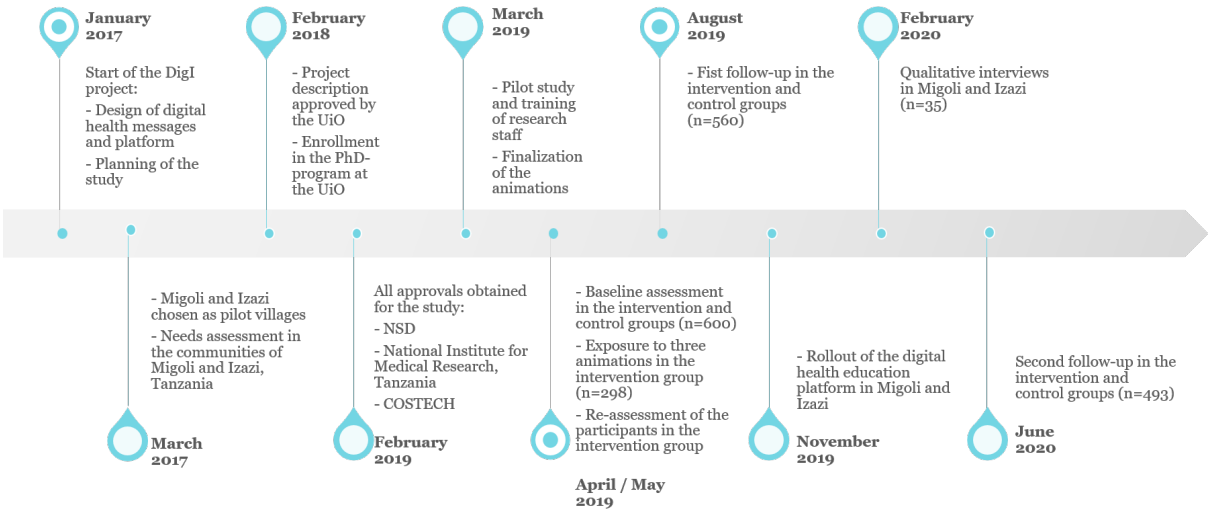

Figure 5. Timeline of project milestones and data collection.

The methods applied for the study described in this thesis are set out in detail in paper 1. However, certain elements need elaboration, thus the following section on methods is divided into eight parts. First, the use of mixed methods in research is described before a description of the study setting follows, which is relevant for all techniques used in this thesis. There then follows a research method section for all papers included in this thesis: The study protocol and the health education intervention (Paper 1), the development and design of the digitised health messages (Paper 2), the qualitative data collection; semi-structured interviews (Paper 3), and the quantitative data collection; a non-randomised intervention study (Paper 4). The data management and the ethical considerations refer to all papers of this thesis and are thus included at the end of this chapter.

4.1 Overall design – mixed methods

To adequately meet the objectives set out in the previous chapter, mixed methods were applied as an overarching methodology. The primary data were obtained through the quantitative and the qualitative components of the study. By using a mixed method approach, the qualitative and quantitative data collection and analysis strive to fulfil the objectives in the most appropriate and comprehensive way (119). To develop a complete understanding with multiple perspectives of the design, use, and effect of a health education intervention in sub-Saharan Africa, the use of only one approach would be inadequate. Mixed method research "focuses on collecting, analysing, and mixing both quantitative

and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches, in combination, provides a better understanding of research problems than either approach alone" (120, p. 5).

When designing the mixed-model study, emphasis was put on the quantitative part of the study. The qualitative component was included to complement the quantitative findings. Such qualitative data is often referred to as "embedding data" (121). The three main papers included in this thesis are presented in Table 1, as the first paper was the protocol and did not include data collection or analysis.

Table 1. Paper 2–4 details related to data collection and participants. Paper 1 is the peer-reviewed published protocol.

Paper	Design	Objective	Data collection method	Participants
2	Co-design / participatory approach	To illustrate how a multi- and interdisciplinary approach can be applied in the design process of digitised health messages for use in the Global South.	Local needs survey, participatory discussions, document analysis, and user- testing	Local stakeholders, (village leaders, healthcare workers, and community members), the DigI team and test participants.
3	Qualitative interviews	To explore the perspectives and experiences of InfoSpot users and non-users in these communities.	Semi-structured interviews	Users and non-users of the InfoSpots (farmers, fishermen, petty traders, village leaders, students, teachers, nurses, and doctors) (n = 35).
4	Quantitative – non-randomised intervention study	To assess the effect of the health education intervention on HIV/AIDS, TB and TSCT knowledge uptake and retention in a rural Tanzanian population.	Study questionnaire	Randomly selected inhabitants of Migoli, Izazi, Idodi, and Kimande (n = 600).

4.2 Study setting

The primary data for this research was collected in Iringa, in the southern highlands of mainland Tanzania. The Iringa region, surrounded by Dodoma in the north, Morogoro to the east, Mbeya to the west and Njombe towards the south, covers an area of 58,936 km^2 (122). The region includes eight districts: Iringa rural (also called Iringa district), Mufindi, Njombe, Ludewa, Kilolo, Njombe town, Makete, and Iringa (Iringa urban / Iringa town). The region's altitude spans 475 metres above sea level to high peaks of 2,981 metres. The biggest ethnic group is the Hehe (Wahehe) people, and the main economic activities are agriculture and livestock keeping. It is estimated that over 80% of Iringa region's residents have agriculture as a source of income (123). Our data was collected in the northern part of the Iringa region, in the Iringa district. This area covers six divisions, including 25 wards with 123 villages and 718 hamlets or sub-villages. In this area the total literacy rate was 76% according to a report published in 2019 (124).

During the early phases of the DigI project, it was decided to include Iringa as pilot area for the InfoSpots because the region is endemic for HIV/AIDS, TB, and TSCT, and the rural districts include many villages that were unconnected to 3G coverage, thus there was no internet access for the communities. Migoli and Izazi in Iringa, both rural villages located along the highway between Mbeya and Dodoma, were chosen to be two of the first pilot villages for the DigI project. The two villages were selected to receive the health education intervention consisting of the two parts – described in detail in 4.3.1 – for several reasons. First, logistic reasons were emphasised, as the research and IT team could reach the villages easily. The villages were also located close to each other, convenient for shipping the equipment. Second, they were appropriate in geographical size, not too large, not too small. Third, one of the villages (Izazi) was totally unconnected to the Internet and needed a line to access information. This was initially a major reason for installing an InfoSpot in the village – to connect Izazi to the Internet. The Tanzanian researchers in the DigI team had extensive experience of working with HIV/AIDS, TB, and TSCT in nearby areas. Kimande and Idodi, also in the Iringa district, were chosen as control villages because they were comparable to the intervention villages with about the same demographic, geographic (see Figure 6), and socio-economic profile. The closest control village, Kimande, was located 32 km away from Izazi, but the road between the two villages was 124 km long, suggesting that contamination in terms of knowledge transfer between them would be unlikely. It was decided that the control villages would receive the InfoSpots with the same platform with health education after the data collection in the intervention villages were finalised. After launching the platform in November 2019, one village InfoSpot was operational in Migoli and one in Izazi, and three additional Wi-Fi access points were established in other places in the community. The InfoSpots and Wi-Fi access points were installed in the local dispensaries in both villages, at the village offices and in addition at the local high school in Migoli. After the data collection period, in August 2020 village InfoSpots were also deployed in the control villages.

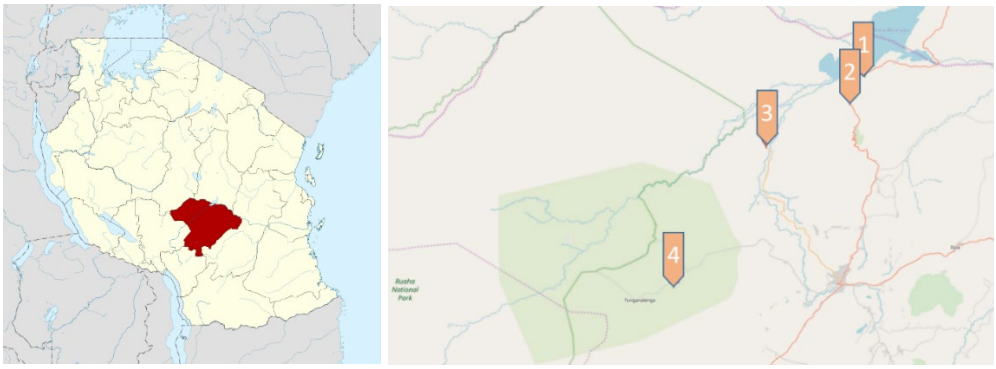

Figure 6. Location of the Iringa region and Iringa district with the four project villages. 1 = Migoli, 2 = Izazi, 3 = Kimande, and 4 = Idodi. Source: © Sémhur / Wikimedia Commons (125) to the left and Google maps on the right.

4.2.1 The intervention villages, Migoli and Izazi

Migoli village is located close to Mtera Dam, with fishing being a major source of work for people in the area. The population in Migoli ward was 15,139 in 2022 (126); however, the area is characterised by migration according to seasons of rainfall. When data collection started in April 2019, the village executive officers pointed out that only about 6,200 people lived in Migoli village. Migoli consists of the following sub-villages: Migoli Centre, Mbuyuni, Nyerere, and Nyegele. Migoli Centre and Mbuyuni are the central areas with petty traders, many small shops, various services, restaurants, bars, and places to spend the night. Migoli Dispensary is located in the centre and was host to the second InfoSpot connected in August 2019, while the third was connected at the same time in a small shop close to the highway. A high school is located in Nyerere, outside the city centre, with about 1,000 students. The first and main InfoSpot in Migoli was rolled out here in April 2019, only with access to the Internet, not to the platform. The last sub-village Nyegele is located about four kilometres to the south and is a Masaai pastoralist community with cattle farming as the main activity. Migoli is covered with 3G signals, meaning that people with smartphones can access the Internet.

Figure 7. To the left, a hippo in Mtera dam in Iringa District. To the right, installation of an InfoSpot in Nyerere high school in Migoli. (Photos: Christine Holst)

Izazi is located about 10 kilometres south of Migoli and is a smaller village with fewer activities. The population of Izazi ward was reported to be 8,764 in 2022 (126), but the village executive officer argued that only a little over 1,800 people lived in Izazi village in April 2019. Izazi village consists of five sub-villages: Ihanyi, Chekechea, Sokoni, Madukani, Kiwanjani, and Barabarani.
Barabarani and Chekechea are the central areas, and the main InfoSpot for the village was set up in the village office in Barabarani in August 2019. The dispensary is located about 12 kilometres towards Mtera Dam in the Sokoni (‘marketplace’ in Swahili) area. The second InfoSpot in Izazi village was also connected in August 2020. Izazi had no mobile broadband coverage when the InfoSpots were installed in 2019, as the village is hidden behind a mountain ridge. Thus, it was not possible to get online information in Izazi prior to the rollout of the InfoSpots.

Figure 8. Izazi village office to the left and Izazi dispensary to the right. The equipment on the pole at the village office receives and sends out signals to the additional InfoSpot in the dispensary, five kilometres away. (Photos: Felix Sukums)

4.2.2 The control villages, Kimande and Idodi

Kimande lies in Itunundu ward and has a population of 14,420 people according to the 2002 census (126), but only about 3,600 people in spring 2019 according to the village executive officer. Kimande consists of the following sub-villages: Kikuluwe, Kimande centre, Mjimwema, Igundambwanyi, and Mwatenga. Kimande centre and Kikuluwe are the central areas with mixed communities of people, infrastructure, schools, and a health centre. This area has 3G signals and access to the Internet. The main activity is crop farming. Mjimwema and Mwatenga are less central areas, and Igundamwanyi is a more isolated sub-village on the outskirts of Kimande. The ethnic groups of the Wasukuma people and Maasai dominate the area, with activities relating more to livestock farming communities and local customs. The sub-village has limited infrastructure and no 3G signals.

Idodi village, in Idodi ward (population 10,202, but only 3,600 according to the village executive officer) (126), is located close to the southern part of the huge Ruaha National Park. Idodi village consists of the following sub-villages: Mbuyuni A, Mbuyuni B, Mjimwema A, Mjimwema B, Msimbi, and Ilamba. Mjimwema A and Mjimwema B are the most central and populated sub-villages with a mixed population, relative high interaction and infrastructures in place, in addition to 3G access. The other sub-villages have unstable 3G access. Agriculture is the main activity in the area.

4.3 The study protocol (Paper 1)

Planning of the study encompassed a substantial time of the PhD period. The study protocol was developed in the first year of the DigI project in order to obtain approvals and registration of the study. Important reasons for registering a study are to be transparent and to reduce publication bias (127) and selective reporting (128). According to the Helsinki Declaration on Ethical Principles for Medical Research Involving Human Subjects, “Every research study involving human subjects must be

registered in a publicly accessible database before recruitment of the first subject" (129). Despite the research presented in this thesis not being *medical* research, the ethical obligations when researching people's health knowledge in rural Tanzania was emphasised, and thus the protocol was registered in "clinicaltrials" in 2018 (see 4.8 Ethical considerations).

Protocols are developed to provide clear research questions, the research context in form of a literature review, the research design including the research setting and the methodology including the envisaged data analysis. Further, the protocol should include ethical considerations, assurance that the research approach matches the research questions, and critical discussion on requirements and limitations in order to obtain the research objectives (130). When developing the protocol for this study, relevant items from both Consolidated Standards of Reporting Trials (CONSORT) (131) and the SPIRIT guidelines for clinical trial protocols were included, even though these guidelines are made for randomised trials. The protocol was not submitted as an article until after data collection. Therefore, it can be seen as a retrospective protocol article. The aim of such articles is to have a transparent research process and to provide a detailed description of how data collection was planned and conducted in the field.

4.3.1 Description of the health education intervention

The main aim of the health education intervention was increased health knowledge of the target diseases. The health education intervention developed in the DigI project consisted of two parts:

1. Intervention part 1 (Part 1): Exposure to three animated health videos (hereafter referred to as animations). The animations can be found online (132) in both English and Swahili.

2. Intervention part 2 (Part 2): Free community access to InfoSpots, with Wi-Fi providing the health education platform with access to digitally enabled health education consisting of text, pictures, quizzes, and animation formats.

The animations that were provided to the participants under supervision in the first part are the same animations available on the platform. However, that platform contains additional educational materials, and the use of the platform was unsupervised. Below follows a detailed description of each part, and a completed GREET checklist (133) reporting the evidence based practice in the intervention, is to be found in appendix 2. Both parts of the intervention were assessed in the non-randomised study.

Part 1): The participants recruited in the intervention group received the first part of the health education intervention immediately after they answered the baseline health knowledge questions, in April and May 2019. In a face-to-face interview with enumerators, the participants were given a 7-inch tablet and headphones to watch three health animations while the enumerator sat silently beside them. These animations on 1) HIV/AIDS, 2) TB, and 3) TSCT were in the local language (Tanzanian

Swahili). The animations were between three and seven minutes long. The health messages in the animations described aspects related to disease prevalence, causes and transmission, signs and symptoms, treatment and prevention. The reason for selecting and prioritizing these areas of content in the health education intervention, are due to the areas being building blocks in medicine, and each building block contains important evidence based messages for disease prevention and intended behaviour.

The story in the animation had a personal character and was narrated by a storyteller. The story showed and told how a person becomes infected, how one can recognise signs/symptoms, what kind of treatment is effective and where to get it, and how the disease can be prevented in the local communities.

Figure 9. Screenshot from the HIV/AIDS animation, showing Mona in conversation with the healthcare worker.

The scripts of the animations were developed by the DigI team between 2017 and 2018. The HIV/AIDS animation tells the story of Mona (see Figure 9), a young woman recently married to John. She discovers that she is infected with the virus after they got married and had sexual intercourse without condoms. This illustrates a story that occurs in the everyday life of rural people in sub-Saharan Africa. The story also shows how you can live close to a normal life with the right medical treatment. Such health messages can be important to reduce stigma of people living with HIV.

In the TB animation we meet Martin, a farmer who gets diagnosed with TB. The animation clearly shows the signs/symptoms, and it further emphasises disease prevention efforts at the individual, family, and community level. The story ends with the patient being cured of TB after adherence to a medical treatment plan provided by the health facility nearby. This also reflects the everyday lives of many people in sub-Saharan Africa.

The third animation tells the story of a grandfather who gets sick after consuming undercooked pork. The health messages in this animation concerns hygiene, hygienic animal handling, and medical treatment if TSCT signs/symptoms occur. A One Health perspective was followed in the video showing how humans, animals, and the environment interact in terms of the TSCT disease complex.

After the participants were shown the animations, the health knowledge questions from the baseline questionnaire (appendix 3) were repeated. Part 1 of the intervention ended with this activity.

Part 2): Free access to the InfoSpot with the health education platform.

The second part of the intervention concerned free access to an extended digitally enabled health education package, including the same animations as in Part 1. The educational package was provided through Wi-Fi in and outside the building hosting the InfoSpot. Part 2 was thus unsupervised. The platform was rolled out in the communities of Migoli and Izazi in November 2019. The platform could be accessed either with the clients' own smart devices or laptops, or by available tablets (7-inch Huawei) located at each of the five InfoSpots in the villages. When the clients opened their browser, they would see a Wi-Fi called BasicInternet. When they accessed this Wi-Fi, they would be redirected to the platform, and they could choose from several diseases on a dashboard. If the clients entered the HIV/AIDS section, for example, they could choose from viewing an animation or reading key messages about prevalence, causes and transmission, signs and symptoms, treatment, and prevention. Illustrations from the animations accompanied the text. Further, the client could take a quiz, where answers are presented at the end. The platform was always available and not dependent on Internet access, as it was stored on a local server. However, the InfoSpot equipment and the local server required electricity, either provided by grid or solar panel.

Figure 10. A woman using the tablet for digital health education at one of the InfoSpots. (Own photo)

4.4 Development of the digitised health messages and the platform (Paper 2)

The second substantial part of this PhD project was devoted to the development of both the digitised health messages (animations and text) and the platform, in parallel with planning of the study. The methodology for the development and design of the digitised health messages is described in detail in Paper 2. The digitised health messages provide the foundation of the health education intervention implemented in this study. Development and design of the content for the health education intervention took place between 2017 and 2019. It was a multi- and interdisciplinary process, where the team members in the DigI project came from several scientific backgrounds but united in pursuit of a common goal, integrated their tools, perspectives, and techniques, and together developed integrated knowledge (134). A human-centred design approach was chosen, and a group of village stakeholders, such as community members, healthcare workers, and village leaders, were included as partners to identify the knowledge gaps, to take part in the co-design of the digitised health messages and the design of the platform, and to engage the communities. Related to this process, we actively

used a participatory research approach by partnering with clients in the rural villages to use local knowledge and perspectives as the basis for research and planning (135).

4.5 The qualitative component of the study – semi-structured interviews (Paper 3)

A qualitative component was part of the study plans from the very beginning, adding a new dimension to the overall insights and allowing a better understanding of the use and non-use of the platform. The qualitative component provides a deeper understanding of how the health education intervention was received in general and explores experiences and perspectives of the InfoSpot among users and non-users in Migoli and Izazi. To understand how the intervention was received, a qualitative design was preferred, as it contributes to the understanding of behaviours, attitudes, and perceptions (136). Early on we formulated the research question: "What are the experiences and perspectives of users and non-users in Migoli and Izazi?" and decided that the method that would provide us with the richest data would be qualitative (137). The value-add of including a qualitative component consist of mainly two reasons. First, we wanted to hear the users' in-depth opinions and feelings about the InfoSpots and the content on the platform, i.e., the animations. Second, we wanted to explore reasons for non-use, as this could be important information for forthcoming similar projects. A semi-structured interview guide (appendix 4) was developed to steer the conversation and make sure all topics were addressed as part of the interviews.

4.5.1 Data collection and study participants

Data for the qualitative part of the study were collected in and around the five InfoSpots in the intervention villages in February 2020; at Nyerere High School, at the village office in Migoli, at Migoli dispensary, at the village office in Izazi, at Izazi dispensary, and at a café in Migoli centre. Semi-structured interviews are particularly useful for examining the participants' points of view related to the social context, and further provide insights into the phenomenon under investigation, as well as into the cultural framework of the participants (138). All participants had interacted with the DigI project, either somehow with an InfoSpot or with an enumerator as a participant in the quantitative component of the study. The participants were sampled from two groups. Group 1 (n = 11) was participants sampled from the enrolment list in the non-randomised trial. All had viewed the animations, but only three had visited the InfoSpot after roll-out. Group 2 (n = 24) consisted mainly of InfoSpot users, however there were two participants that had never accessed the platform in the InfoSpot, thus were classified as non-users. Both group 1 and group 2 therefore consisted of both InfoSpot *users and non-users.* Across the two groups, the study participants comprised 25 users (3 from group 1 and 22 from group 2) or 10 non-users (8 from group 1 and 2 from group 2) of the InfoSpots, a number which was sufficient to gain data saturation for both users and non-users (139).

The interviews were conducted directly with the participants and held indoors in a private setting. We strived to strike up a conversation in each interview (136). Thirty of the interviews were conducted in

Swahili, three with mixed language, both English and Swahili, while two were conducted in English. The interviews were between 25 and 40 minutes long. The team leader from the field research team in the quantitative data collection was recruited as a research assistant and simultaneous translator for the interviews. The research assistant had comprehensive knowledge about the DigI project and the villages. The qualitative research team spent a day preparing and training for the interviews prior to undertaking them. The research assistant and the PhD student were present at all interviews. Immediately after each interview, a debriefing session lasting approximately 15 minutes was conducted, noting important aspects arising from the interview in a debrief field note document. The interviews were recorded using an app from UiO Services for Sensitive Data (TSD) and a backup Dictaphone. No names or other personal data were recorded. The audio files were transferred to NIMR for transcription and translation by a trained sociologist and verified and approved by the Tanzanian partners in the DigI project. The audio files were deleted from the Dictaphone after transcription and from TSD after project ending date, as stated in the consent form.

4.5.2 Qualitative data analysis

A qualitative content analysis was applied. "Content analysis is a research method that provides a systematic and objective means to make valid inferences from verbal, visual, or written data in order to describe and quantify specific phenomena" (140, p. 314). Content analysis can be performed in several ways. In this study, we applied a four-stage process including de-contextualisation, re-contextualisation, categorisation, and compilation (141). The transcribed text was read by the PhD student and one other DigI team member in order to 're-familiarise' us with the data. When summarising the interviews, a table was developed with excerpts from the most important findings of the qualitative research, alongside quotes from the interviews, and this table was also frequently used in the analysis process. After this, meaning units were derived and labelled with a code in the software NVivo. The coding frame was developed, and the codes were merged into categories. Themes of interest from the interview guide, as well as new themes found in the data, were analysed to contextualise the participants' perspectives and experiences. A qualitative researcher, unconnected to, and independent from, the DigI project, was brought into the analysis process to assist and contribute in a meaningful, unbiased way.

4.6 The quantitative component of the study – a non-randomised intervention study (Paper 4)

In order to assess an effect of an intervention, it is essential to conduct a comparison between individuals exposed to the intervention and those who are not, incorporating a baseline assessment (32). A randomised design is preferred, but non-randomised/quasi-experimental designs can be applied when randomisation is not feasible. Such research can create good confidence evidence (30) and is therefore an important value add in this study.

4.6.1 Design

The quantitative component of this mixed method study was a longitudinal, non-randomised intervention study of people aged 15-45, living in Migoli, Izazi, Kimande, and Idodi, in the Iringa rural district. A non-randomised design can be used when a random allocation of participants to either the intervention or the control group is not possible, as quasi-experimental techniques do not require such random assignment (142). Migoli and Izazi were included as pilot villages in the DigI project, and allocating participants either to the intervention or the control group in these villages would include a high risk of knowledge contamination between participants, as the second part of the health education intervention was open and available to all people in the community. Thus, Migoli and Izazi became the intervention villages, and Kimande and Idodi, which would receive the InfoSpots as the last pilot villages in the project, functioned as control villages. Despite the design being non-randomised, due to the reason above, a random selection of participants from each village, at the sub-village level and at the household level, was included in the study.

4.6.2 Development of research tools and outcome measures

The employed questionnaire was based on earlier questionnaires used in previous studies by the DigI researchers, in addition to a few newly constructed questions. The majority of the HIV/AIDS and TB questions were reused and adapted from multiple choice questions applied in previous research projects undertaken by the Tanzanian researchers (143,144), and the majority of the TSCT questions were reused from a 2015 study from Northern Tanzania (145). The new questions were derived from the paper based health information materials provided by the Tanzanian government, and forward and backward translated by trained sociologists at NIMR. Together with NIMR and SUA, a pilot study in Morogoro was carried out in March 2019 to pre-test our questionnaire on a group of people (n = 50) living in a nearby rural area. The reason for undertaking the pilot in Morogoro was that SUA, located in Morogoro, facilitated the piloting and recruited participants from the area. In addition to this, the area had sufficient distance from the research area in Iringa. After the pilot, a workshop was held where the Tanzanian researchers and enumerators critically evaluated and discussed each question with their respective answers in detail. Potential misunderstandings were further assessed, and seven of the questions were edited in Swahili to be clearer. The English version of the question was back translated in the same workshop. The health knowledge answers were collected from four domains: causes and transmission (referred to as “transmission” in the analysis), signs and symptoms (referred to as “symptoms” in the analysis), treatment and prevention. See Table 2 for an overview of questions and correct answers related to each domain. In addition to the domains presented above, questions like “Have you ever heard about the pork tapeworm?” were included, simply to gauge whether the participants were aware of the different target diseases, and the prevalence of these. In total, 13 HIV/AIDS questions, 10 TB questions, and 17 TSCT questions were prepared. All questions were decided to be presented as open-ended questions to the participants, except for one TB question. We

decided to phrase that one question as a multiple choice question, where the enumerators would read out loud the options to the participant: “QT3: Do you think TB can also spread through the following ways? (List options) (Check all boxes that apply)”. This item was later removed from analysis for two reasons. The first was that we missed about 30 responses to that single item, due to an update to the enumerators’ tablet that went wrong on the first days of data collection. The error was fixed, and we had no missing items after that. Nevertheless, the main reason for removing this item from analysis is that we were told by the enumerators that the participants did not understand how to respond to this different type of question, as all other questions were presented open-ended, and that gave us the belief that this question confused the participants. This is further discussed in 6.1.1.

Table 2. Overview of questions and correct answers to the questions in the questionnaire. The number of questions and correct answers are not alike, as one question could have several correct answers.

Domain / Disease	**HIV/AIDS**	**TB**	**TSCT**
Prevalence	1 question	1 question	4 questions
Transmission	4 questions 8 correct answers	1 question 6 correct answers	4 questions 6 correct answers
Symptoms	2 questions 2 correct answers	2 questions 12 correct answers	4 questions 9 correct answers
Treatment	3 questions 3 correct answers	3 questions 3 correct answers	1 question 1 correct response
Prevention	3 questions 10 correct answers	2 questions 9 correct answers	4 questions 6 correct answers
Total included for health knowledge analysis	12 questions 23 correct answers	8 questions 30 correct answers	13 questions 22 correct answers

All questions presented to the participants could either have one or several correct answers (see Table 2). This implies that even if the question was posed as an open-ended one, the form utilized by the enumerators included one or more correct answers to be checked after participant’s response. On the tablet that the enumerators used for data collection, the most common responses, i.e., the correct answer(s), as well as common incorrect answer(s) along with 'I don’t know' when reporting participants’ responses to the questions. In the three month assessment, the research team asked five additional questions to the participants in the intervention group related to their view of the animations. In the 12 month assessment, the participants in the intervention group were asked if they had access to a smartphone, in addition to eight questions related to the health education intervention, the platform, and the InfoSpots. The additional questions from both assessments can be found in appendix 5.

4.6.3 The fieldwork research team

The data for this study was collected between April 2019 and June 2020, and all activities related to the fieldwork were undertaken in close collaboration with the Tanzanian researchers. The field research team consisted of the PhD student and six enumerators recruited and trained by NIMR. The Tanzanian principal investigator and other researchers in the DigI project frequently visited the research team in the field for supervision and for overseeing the progress of the data collection. The enumerators came from Dar es Salaam and Arusha, and all had research experience from several other health-related scientific projects. The enumerators interviewed between four and eight participants daily. One enumerator was assigned team leader responsibility and corresponded directly with the PhD student and the Tanzanian principal investigator, and provided daily reports from the field when the PhD student was not able to be part of the data collection team in the field.

4.6.4 Participants and recruitment

When planning the study, we obtained population sizes of the sub-villages from executive village leaders. These figures were used to calculate the probability proportional to size (PPS) (146) in order to give each individual an equal chance of being selected to participate in the study. Before recruitment, executive village leaders were contacted to provide the research team with an updated list of households in their communities. These lists can be hard to maintain with up-to-date information, as the season and rainfall results in households shifting around for work opportunities, as described in 4.2. When collecting data, we discovered that many of the randomly selected households had moved to other places, and new households had settled in the villages. In order to reach the desired sample size and to include all eligible households, newcomers as well, we had to obtain new updated sub-village lists with resident households. This time we collaborated with the sub-village leaders who were more knowledgeable about the frequent shifting of households in their communities than the leaders at the village level.

For selecting a random sample of the households from the sub-village lists, we used the following technique: Each household received a number, and a random number generator randomly selected the desired numbers of households from the sub-village list. Then the list of the randomly selected households was presented to the sub-village leaders who escorted the enumerators to each household. The sub-village leaders approached the household in person, introduced the research project to the head of the household, before leaving for the next household with another enumerator. The PhD student was introduced to most of the households and observed the enumerators in hundreds of interviews. When the enumerator was introduced to the head of the household, they would sit together to list all members of the household eligible for taking part in the study (see appendix 6 for the form used). When all household members were listed on the “list and selection” form with name, sex, and age, the enumerator recorded all household members in the following order: All men from oldest to youngest, all women from oldest to youngest. The unique KISH sticker on the bottom of the form was

thereafter used to randomly select one participant per household by using the Kish grid (147), which is a sampling method using a pre-assigned table of random numbers when selecting the participants. When the randomly selected eligible household member was chosen, they were informed about their rights and given thorough information related to the study, their data, and their voluntary participation in the study.

Inclusion criteria were being between 15 and 45 years of age, permanent residence in the area, and not planning to leave the village for more than three weeks within the next eight months. In addition to this the participants had to be able to sign their name or provide a thumb print if illiterate. We used broad inclusion criteria to ensure recruitment of an adequate sample, but we also conjectured that those over 45 might have significantly lower digital skills than the younger generation, which may have rendered meaningful comparison during analysis difficult. Hence, they were excluded (142).

The essence of the information letter and the consent forms is described in 4.8.1. After the participants consented to take part in the study by signing the consent form, they were registered with their name on a paper form and were assigned a digital objective identifier (DOI). The DOI consisted of two letters, indicating the village and a unique number for each participant. The paper form with the identification code was carried by the enumerator only on the day of the interview.

The enumerator further created a new digital submission form in KoboCollect (explained in 4.7) on their Huawei tablet, entering the DOI and the sociodemographic variables (village, sub-village, age, sex, education, occupation) before the first health knowledge question was posed to the participant. The enumerator would read the question out loud to the participant and wait for their immediate response. Thereafter, the enumerator would check the participant's answer(s) from a list of alternatives on their tablet, based on the multiple-choice origin of the questions (see 4.6.2). They would check correct or incorrect responses that the participant gave, or a response labelled "I don't know" (see appendix 3). The enumerators did not have the chance to note down what the participants answered, in case they provided incorrect answers that were not listed among the alternatives. If the participant gave an incorrect answer which was not in the pre-made list, "I don't know" was checked. The correct answer to the target disease questions was not given to the participants after their response, as an important point of the study was to assess whether the participant would increase their health knowledge through the use of the InfoSpots. Rather, the enumerator proceeded to the next question in KoboCollect, until all questions had been answered.

When the interview was over, the enumerator would finalise and save the digital submission form. The form would then no longer be accessible to the enumerator but stored in the app. When the enumerators were online with the tablets, i.e., with Wi-Fi either in the place the research team stayed during data collection, in the InfoSpots, or via their own mobile phones, the submission forms from each participant were uploaded to the KoboToolbox platform.

4.6.5 Statistical analysis

The data were exported as Excel files from KoboToolbox prepared in IBM® SPSS® Statistics and analysed in Stata 16.1. The sociodemographic variables (sex, education, and occupation) were categorical, and age was continuous. To minimise the risk of bias in non-randomised studies, identifying and accurately measuring potential confounders is essential (142), and in our case, we considered the mentioned sociodemographic variables as such. Frequency and percentage distribution were calculated with the categorical variables, while mean and standard deviation were applied to the continuous variables. Descriptive statistics were also applied to determine the degree of comparability between the groups (142). Frequency tables with all correct answers (single items) for each group at all time-points were created in Excel. The number of participants with correct answers was thereafter converted to percentages. A Pearson chi-squared test was used to test the difference in proportions between the intervention and control group at baseline for each correct response in the domain. The total number of correct answers in each of the four domains, in each disease, and for each disease overall was calculated for each participant and divided by the maximum number of correct answers.

We used linear mixed-effect regression models to calculate the mean percentage difference between the groups at all time points. As several tests were run, we used a significance level of < 0.001. Mean percentage correct answers in both groups were calculated on the domain level and disease level with a 95% confidence interval. For the dropouts in the three month and 12 month assessment, a sensitivity analysis was conducted. A worst-case scenario was created, assuming that all participants who dropped out either at three months or at 12 months, both in the intervention and in the control group, received 0 as the imputed value in all responses after dropout.

In the mixed model, the time variable was specified as the random slope variable, sub-village and household as random variables, and group (intervention / control) as a fixed variable. These advanced calculations were performed by the statisticians from the Oslo Centre for Biostatistics & Epidemiology, while the PhD student conducted the initial rough calculations, i.e., the summary of how many participants with correct answers to each response (the single items), the calculation of the sociodemographic variables, the sensitivity analysis, and the initial linear regression calculations. A statistician from the Centre for Global Health at the Technical University of Munich performed a descriptive statistical analysis of the users in the intervention group who reported having accessed the InfoSpot after rollout.

4.6.6 Sample size

As stated in chapter 3, we hypothesised that the proportion of correct answers in the intervention group would differ from the proportion of correct answers in the control group at three and 12 months.

In order to detect this difference between the groups with and without the intervention, assuming that the proportion of correct responses was 50% in the group without intervention, a two-sided significance level of $p < 0.016$ using Bonferroni correction, to compensate for three planned time points (148), was set together with 80% power. A calculated sample size of approximately 460 participants was required, but to increase the precision of the key estimates and to take dropouts into account, it was decided to include 600 participants.

4.7 Data management

A data transfer agreement between UiO and NIMR was signed, ensuring the availability of the research data at both institutions. A data processor agreement is needed between UiO (the data controller) and an external data supplier when personal data is processed by the external supplier (149). Repeated attempts to get in contact with KoboToolbox to review and sign the UiO data processor agreement form were not successful. Based on a discussion with the co-supervisor of the study and project leader of the DigI project, who has co-developed medical applications and is a well-recognised security and privacy expert in mobile and wireless systems, we decided to perform a thorough risk and vulnerability analysis of KoboToolbox prior to use. KoboToolbox was developed by the Harvard Humanitarian Initiative (and is widely used for collecting data in challenging environments. The greatest advantage of using this tool is the ability to collect data digitally without being online, essential in our fieldwork. The UiO-provided solution for digital data collection would be Nettskjema, but then again, this would require an online connection, which was impossible for our research field team who were collecting data in the rural areas of Iringa, without any coverage. KoboToolbox was assessed, and it was decided that the security and privacy of our research data were appropriately taken care of, given that only pseudonymised data was collected digitally. The participants' names were registered and kept directly in TSD using Nettskjema, when the enumerators could get online. The de-identification code, the sheet with the DOI, and the participants' name, was guarded either by the PhD student or the research team leader when in the field.

The data set that landed in KoboToolbox consisted of each participant DOI, age, sex, village, sub-village, education, occupation, in addition to the questionnaire responses. The data transferred to KoboToolbox from the tablets used in the field for data collection, was always pseudonymised, and the de-identification code was kept separately from the data files. The data would be classified as restricted (yellow) (150) according to UiO's categorisation. The data was classified as yellow, and not red, as it would not be harmful to the participants if the information were exposed to third parties. The data set contained no information about the participants' own health or other sensitive information.

In KoboToolbox, the pseudonymised data was only accessible to the PhD student, with username and password. The server is hosted by Harvard Humanitarian Initiative (151) and KoboToolbox's policy to never access users' data unless explicit access is provided, is in line with the General Data

Protection Regulation (GDPR) (152). Initially, it was planned that all the data was going to be stored and analysed in TSD. However, as the pseudonymised data did not contain any sensitive information to be analysed, only the de-identification code was kept in TSD. Instead, the data files were transferred from KoboToolbox to a shared project server for the multinational research group. The server was GDPR compliant in Germany, with an end-to-end-encryption (153). Only the Tanzanian and Norwegian principal investigators – in addition to the PhD student – had access to the data on the shared server, by username and password. During the analysis process, the data was stored on the PhD student's encrypted laptop maintained by UiO and the pseudonymised data files were transferred to the biostatisticians who assisted in the analysing process by the UiO email. The data files have been confirmed as deleted both from email and from the biostatisticians' ownership. The pseudonymised data was fully anonymised after analysis phase. The following steps were undertaken to anonymise the data: The de-identification code linking the names and DOIs, only kept in TSD, was erased. Age was converted to age-groups with a range of five years. The variable "sub-village" was deleted. The anonymous data is now stored on an encrypted memory stick, kept by the PhD student. The recording of the semi-structured interviews was undertaken with an app from TSD. The anonymised transcriptions and the coding frame were kept on the shared project server for the DigI project, while the recorded files were deleted, as described in 4.5.1.

4.8 Ethical considerations

Global health research and addressing inequities in health and human development can play a crucial role in global progress, but the research must be based on sound scientific and ethical principles (154). Our research was conducted in accordance with the Declaration of Helsinki (129), and the GDPR (155). We followed the Guidelines for Health Research in Tanzania (156). It was also intended that our research would have a bottom-up approach through including our study participants as contributors to the overall aim of improving the health knowledge level through health education.

The project protocol was assessed by the Norwegian Centre for Research Data (NSD), reference number 59643. Ethical approval from The Tanzanian National Health Research Ethics Sub-Committee (NatHREC) in Tanzania was granted with the reference number NIMR/HQ/R.8a/Vol IX/2947, both at the beginning of the study and at a later stage. The study is registered in ClinicalTrials.gov with ID: NCT03808597 (157). Additionally, the PhD student was given a research permit from the Tanzanian Commission for Science and Technology (COSTECH).

4.8.1 Informed consent

The Declaration of Helsinki states that informed consent should be obtained for all participants in all research with human subjects (129). A notification form was submitted to NSD when planning the study, and both information sheets and consent forms were developed with guidance from NSD. Several versions of the forms were finalised, as we needed unique versions for the quantitative part

(one for the intervention group, one for the control group, another one for minors in both groups) and the qualitative part of the study (adults and minors) (see English examples in appendices 7–8).

The GDPR was implemented in the EU and in Norway in 2018, requiring that the information sheets and consent forms were edited to meet the new regulation. Information regarding the rights of the participants, the length of storing of the participants' personal information, where it would be stored and who would have access to it, was important information to include for the participants.

All participants received full oral and written information, in own language (Swahili), prior to both the qualitative and the quantitative interviews. After the oral brief, the participants were able to ask questions of the enumerators (in the quantitative component of the study) or the research assistant (in the qualitative component of the study). An information letter (see appendix 9 for the English version) was provided to the participants. All information sheets contained information related to the following:

- A presentation of the project with the responsible entities, both local (NIMR) and international (UiO).
- A description of where the data would be kept, for how long, and who would have access to the participants' data.
- Possible benefits of taking part in the study.
- That the participation was voluntary and that the participants could withdraw at any time if they wished or access their own data at any time.

Before participants were given the information letter, they had to express their agreement to contribute to the health education intervention study with their signature on a consent form, including the information stated in the information letter. The enumerator co-signed the agreement, both to document their presence and to emphasise that participation was voluntary.

4.9 Summary of Chapter 4

In this chapter the mixed methods used in this thesis have been described. Most important to note is the following:

- This PhD study uses a mixed methods approach to fulfil the objectives in an appropriate and meaningful way.
- The study was conducted in the rural villages Migoli, Izazi, Kimande, and Idodi, in Iringa, Tanzania.
- The study protocol and the health messages were developed in a multi- and interdisciplinary way with participation of the communities.
- The qualitative component of the study involved 35 semi-structured interviews with users and non-users of the InfoSpots, and content analysis was used for data analysis.

- Altogether, 600 participants were recruited in the non-randomised intervention study, with a baseline, three month, and 12 month assessment in the intervention and control groups.

5 Summary of the results

In this chapter a summary of the results for each paper is provided.

5.1 Paper 1

Holst C, Sukums F, Ngowi B, Diep LM, Kebede TA, Noll J, Winkler AS. Digital Health Intervention to Increase Health knowledge Related to Diseases of High Public Health Concern in Iringa, Tanzania: Protocol for a Mixed Methods Study. JMIR Res Protoc. 2021;10(4):e25128.

In this paper a careful description of the mixed methods used in this thesis is presented. The paper presents the rationale for the study and the tailored two-folded health education intervention. The stated objective is to measure the effect of the health education intervention on health knowledge uptake and retention over time in the rural communities. It further presents the recruitment process and how many participants we enrolled in both the quantitative (n = 600) and the qualitative (n = 35) areas of the study. An outline of the analysis methods is provided together with a brief description of the limitations of the study.

5.2 Paper 2

Holst C, Isabwe GMN, Sukums F, Ngowi H, Kajuna F, Radovanović D, Mansour W, Mwakapeje E, Cardellichio P, Ngowi B, Noll J, Winkler AS. Development of Digital Health Messages for Rural Populations in Tanzania: Multi- and Interdisciplinary Approach. JMIR Mhealth Uhealth. 2021;9(9):e25558.

The objective of the paper was to illustrate how a multi- and interdisciplinary approach can be applied in design process of digitised health messages for use in the Global South. As we developed the digitised health messages that form the basis of the health education intervention during the time of the DigI project, a detailed description of the development process – together with the multi- and interdisciplinary approach used – is elaborated upon in this tutorial paper. In addition to using the diverse DigI partners' strengths, we partnered with local stakeholders early in the process to co-design the health education content with a human centred design approach. Local stakeholders gave important feedback with regards to the health education needs and the preferred health education format. The health messages, consisting of text, pictures, animations, and quizzes, resulted from a multi- and interdisciplinary collaboration in the DigI team. Emphasis was put on the animations being short, clear, with recognisable characters and environment, and in the target populations' own language. The platform hosting the digitised health messages was developed with a mobile-first design approach, with an interface easy to navigate for the target group. The unique combination of multi- and interdisciplinary and multinational collaborations, in addition to the involvement of the local stakeholders, inspired us to write up the methods of the digitised health messages and platform development in order to share them with others in the same field. Emphasis was put on a thorough

description of the process, in addition to general take-home messages from the development and design processes.

Main findings of Paper 2:

- The use of a multi- and interdisciplinary approach was needed and beneficial when developing the digitised health messages and the platform.
- The partnering and co-designing with local stakeholders was essential for the uptake of digitally enabled health education.
- We strived to make the animations short, clear, in Swahili, and with a recognisable environment, in line with feedback from the local stakeholders. Key messages were repeated and illustrated to enhance knowledge improvement.
- The platform was created with the intention to develop health and digital literacy skills among the users of the InfoSpots.

5.3 Paper 3

Holst C, Tschirhart N, Ngowi B, Noll J, Winkler AS. Utilizing community InfoSpots for health education: perspectives and experiences in Migoli and Izazi, Tanzania. Health Promot Int. 2021 Dec 13:daab187.

The objective of this paper was to explore the perspectives and experiences of InfoSpot users and non-users in the communities. Participants were randomly sampled from the quantitative study (Group 1) and convenience sampled from around the InfoSpots (Group 2), and both groups consisted of InfoSpot users and non-users. We interviewed 25 users and 10 non-users of the InfoSpots. Most users reported navigating the platform on their own without problems, while about 30% of the user's needed guidance in order to access the platform and the digitised health messages. Content analysis demonstrated acceptability, diversity, variations, and creativity in use patterns among InfoSpot users, but different uses of the platform across education groups. The higher the education, the more advanced the use of the InfoSpot and platform. The animations were also used by some students to practice English, and by the healthcare workers and the CHWs not only to educate others, but also to refresh their own memories. All non-users reported that they would have used the InfoSpot if they had known it existed, indicating that better promotion of the InfoSpots could have led to more adoption in the communities. All participants expressed a positive view on animations as a health knowledge transfer tool. Eight out of 10 non-users had viewed the aminations in the first part of the health education intervention. During the qualitative interviews, 30 out of 35 explained that they had shared key messages from the animations with friends, family, colleagues, fellow students, patients, and people in the neighbourhood.

Main findings of Paper 3:

- InfoSpot users reported variations in use patterns, and non-users reported they would have used the platform if they had been aware of its existence.
- Most users found the platform easy to use. However, users with less formal education reported needing guidance to access and navigate the platform.
- All participants reported a positive view of digitally enabled health education, especially animations.
- Unintentional use of the platform and digitised health messages was reported:
    - Some high school students used the animations to practice English
    - Healthcare workers and CHWs used animations to refresh memory and educate others

5.4 Paper 4

Holst C, Stelzle D, Diep LM, Sukums F, Ngowi B, Noll J, Winkler AS. Improving Health Knowledge Through Provision of Free Digital Health Education to Rural Communities in Iringa, Tanzania: Non-randomised Intervention Study. J Med Internet Res. 2022 Jul 28;24(7):e37666.

The objective of this paper was to assess the effect of the health education intervention on health knowledge uptake and retention related to HIV/AIDS, TB, and TSCT among rural communities in Iringa, Tanzania. The main hypothesis was that the proportion of correct answers in the intervention group would differ from the proportion of correct answers in the control group at 3 and 12 months, while the secondary hypothesis was that there would be differences among the groups' proportion of correct answers per domain.

A non-randomised intervention study with 600 females and males between the ages of 15 and 45 was conducted from April 2019 to June 2020. An open-ended questionnaire, with binary (correct / incorrect answers) was used to gather the data at baseline, three months, and 12 months. The intervention groups (n = 298) were shown three health animations and about four months later given free and voluntary community access to the InfoSpots with the same animations and more digitally enabled health education. The control group (n = 302) received no intervention.

Overall, the adjusted difference in baseline HIV/AIDS knowledge between the intervention and control groups was small, amounting to 0.3% (95% CI 4.7 to 5.4). The intervention group had an adjusted higher mean in correct answers to the HIV/AIDS questions of 8.3% (95% CI 3.2 to 13.4) in the three month assessment. Further, we saw that the adjusted mean between the groups increased to 10.2% (95% CI 5.0 to 15.4) in the 12 month assessment, both with significant differences. Increased effect was observed in the 12 month assessment, over the three month assessment for all domains. Altogether for the TB section, we found a 2.0% (95% CI -2.1 to 6.1) adjusted difference between the

groups at baseline, a 15.8% (95% CI 11.7 to 20.0) and a 12.0% (95% CI 7.7 to 16.2) higher mean in the intervention group at three months and 12 months, respectively, demonstrating that the animations were effective in transferring important key messages across the domains. The maximum effects were observed for all TB domains in the three month assessment. Knowledge of neglected tropical diseases, or zoonoses, was lower than the publicly more common and hence better-known diseases like TB and HIV/AIDS. This was reflected in the low baseline knowledge in the TSCT section, where the mean proportion of correct answers was 9.7% (SD 14.9) in the intervention group and 7.6% (SD 12.1) in the control group. The adjusted differences between the groups for the overall disease were 2.6% (95% CI -1.6 to 6.8) during baseline, then 31.2% (95% CI 26.9 to 35.6) in the three month assessment and 31.5% (95% CI 26.8 to 36.2) in the 12 month assessment, indicating a large overall knowledge improvement. As for TB, the maximum effect was also reached in the three month assessment, however, not in the symptom domain, where increased effect was observed at the 12 month assessment. The intervention effect was adjusted for the confounders, age, sex, education and occupation, with similar results. See Table 3 for crude and adjusted differences between the groups at all time points.

Table 3. Main findings related to baseline knowledge, knowledge after three and 12 months, in addition to the crude and adjusted differences between the intervention and control group.

	Time point	**Correct answers**		**Crude difference**	**Adjusted difference**	**P-value (adjusted model)**
		Intervention	**Control**			
		Mean (SD)	**Mean (SD)**	**Mean (95% CI)**	**Mean (95% CI)**	
Overall HIV/AIDS	Baseline	47.6 (17.4)	48.3 (15.6)	−0.1 (−6.5, 6.3)	0.3 (−4.7, 5.4)	
	3 months	54.7 (17.0)	47.1 (16.6)	8.0 (1.6, 14.4)	8.3 (3.2, 13.4)	< 0.001
	12 months	59.8 (11.9)	50.2 (21.1)	9.9 (3.4, 16.3)	10.2 (5.0, 15.4)	
Overall TB	Baseline	18.9 (16.2)	18.3 (14.7)	1.3 (−3.6, 6.1)	2.0 (−2.1, 6.1)	
	3 months	34.4 (15.4)	19.8 (15.0)	15.2 (10.3, 20.0)	15.8 (11.7, 20.0)	< 0.001
	12 months	35.8 (11.5)	25.1 (18.5)	11.3 (6.3, 16.2)	12.0 (7.7, 16.2)	
Overall TSCT	Baseline	9.7 (14.9)	7.6 (12.1)	2.4 (−1.7, 6.4)	2.6 (−1.6, 6.8)	
	3 months	41.0 (20.2)	10.1 (15.1)	31.1 (26.9, 35.3)	31.2 (26.9, 35.6)	< 0.001
	12 months	42.1 (22.0)	11.0 (20.0)	31.4 (26.8, 35.9)	31.5 (26.8, 36.2)	

Six months after baseline, the InfoSpots were rolled out in the intervention villages, providing free access to the platform with the digitally enabled health education, including the animations. We were able to see that the 73 participants in the intervention group who reported having used the InfoSpot

increased their knowledge markedly with a 6.3% (TB), 8.5% (HIV) and 12.1% (TSCT) higher mean in correct answers compared to the participants who said they had not used the InfoSpots after rollout.

The maximum effect for the HIV/AIDS knowledge was after 12 months, and for TB it was observed after three months. The effect was close to unchanged from the three- to 12 month assessment for TSCT. The trends in the analysis showed that the health education intervention was effective in both knowledge (short-term) uptake and (long-term) retention.

There are important limitations related to the study. The design did not provide a random allocation of the participants to intervention and control group, which may impact the estimate of the true effect of the intervention. In addition, the intervention and the control groups differed to some extent in terms of their demographic data, which could also have influenced the effect of the intervention. We were unable to assess and explain why participants in the control group also improved their health knowledge. Further, it needs to be pointed out that increased health knowledge does not guarantee a change in health behaviour.

Main findings of Paper 4:

- The health knowledge increased significantly in the intervention group after the health education intervention.
- The results show that the knowledge was retained in the 12 month assessment, demonstrating a possible sustainable effect of the intervention, despite a non-randomised design and groups that demonstrate demographic differences, although adjusted for this in the analysis.
- There was an improvement in the health knowledge of participants who reported having additionally used the InfoSpots after rollout, however we do not know whether the participants accessed other knowledge sources over the course of the study.
- The study was not designed for assessing a change in health behaviour subsequent to the seemingly sustainable knowledge increase in the context of our three target diseases.

6 Discussion

This chapter is based on findings and reflections from the four papers which constitute this thesis, and the candidates' experiences from being part of the team planning, developing, implementing and assessing the effect of the health education intervention aimed at increasing disease specific health knowledge for clients in rural communities of Iringa, Tanzania. The overall aim was to understand how digitised health education material for relevant target diseases needs to be designed, to investigate whether the developed health education intervention leads to an increase in health knowledge among community participants of rural Tanzania, and to explore how the intervention was received by individuals in the communities.

For transparency reasons and for providing a thorough description of the study design, the protocol for the study was published as a retrospective protocol article (Paper 1). The content for the health education intervention was developed with a multi- and interdisciplinary approach (Paper 2), and further co-created with stakeholders from our study areas. The study components presented in this thesis showed that the animations were seen as acceptable and appropriate as a knowledge transfer tool for the rural Tanzanian participants, although almost one third of the users had low digital literacy skills and found it difficult to access the InfoSpot to explore the digitally enabled health education without guidance from more experienced users (Paper 3). A significant increased effect in disease specific knowledge was shown among the participants in the intervention group after implementation of the health education intervention part 1 and part 2, although the study had important limitations (Paper 4).

These discussions are divided into two parts. The methodological considerations include sections on the strengths and weaknesses of the quantitative and qualitative methods applied in this thesis, critical self-reflection and a section addressing the terms and definitions used in the papers and clarification of these. Secondly, a discussion of the main findings follows.

6.1 Methodological considerations

Mixed methods involve more than just gathering quantitative and qualitative data for separate analysis. The intention is to gather both and then to apply their combined strengths to answer a research question (121). In this thesis, data from the qualitative interviews were embedded (120) in a larger primary design: the non-randomised intervention study. As the primary objective was to assess the effect of the health education intervention on HIV/AIDS, TB and TSCT knowledge uptake and knowledge retention in a rural Tanzanian population, the quantitative component of the study received priority. In retrospect, it became clear that the interviews with the users and non-users provided unique and important information, perspectives that we would not have been able to capture with the quantitative approach. The most important strength of qualitative research is the possibility to go into detail and learn from the participants; in our study the users or non-users of the InfoSpots. This

exploration of experiences, perspectives, meanings and points of view is not possible with a structured questionnaire used in quantitative studies, thus is an important value add in the mixed method study.

6.1.1 Validity and reliability

In quantitative research validity and reliability are measured to achieve methodological rigour and to evaluate the quality of the research. That is, how the researcher operated to enhance the quality in the study during the phases of planning, data collection, analysis, and reporting. Reliability and validity are used to indicate how appropriate methods and techniques are applied to measure what we are looking for. While reliability says something about the consistency of a measure, validity deals with the accuracy of a measure, i.e. how precisely the findings accurately reflect the data. We distinguish between measurement or construct (measurement), internal and external validity (158).

The strengths of our study questionnaire were the inclusion of previously used questions, the piloting and the subsequent revision of the questionnaire, together with the validation of the questionnaire. Cronbach's alpha was calculated to assess the homogeneity (internal consistency) of the measurement instrument (the questionnaire). The homogeneity assessment was done to ensure that we measured what we intended to measure (159). We validated the questionnaire with questions and answers for each disease and found that the alpha score ranged between 0.78 and 0.87, indicating an acceptable reliability score (160).

A challenge with the questionnaire emerged from the workshop in Morogoro, where it was decided that during the interviews with the participants the questions should be left open-ended. As most of the questions were reused from other studies, they were originally formatted as self-administrated multiple-choice questions. Due to a general low level of reading skills in the study population, it was decided early to read the questions out loud to the participants. The initial plan was that the enumerators would present alternatives, the multiple choices, for the participants after asking each question aloud. During the pilot and subsequent workshop it was decided that the questions should be left open-ended instead i.e. the participant would give a 'free answer' without being guided by pre-defined answers after the enumerator presented them with the question, meaning that the participants were not given any alternatives to choose from. The reason for choosing the open-ended question approach was to capture the immediate knowledge of the participants and avoid leading the participants to guess the correct option when hearing it or seeing it on the tablet device. By choosing the open-ended format, we did not have to correct for random guessing and the reliability of the findings increase (161). However, this decision created many challenges. The PhD student acknowledges that more time should probably have been spent on streamlining the questionnaire into an open-ended format, as some of the questions were more suited to be multiple choice than open-ended. This may have weakened the validity of the measurement. For example in the TB section one question reads: "QT4: What are the symptoms of TB?" The participants would then give their

answers, and the enumerator would check the responses, i.e. “Coughing that lasts two or more weeks”, “Coughing up blood”, “Chest pain”, “Fever”, “Night sweating” etc. In the TSCT section, a question related to symptoms reads: “QC9: What are the signs of tapeworm infection in a human?” Here, we used only two options for the enumerator to check as correct / incorrect: 1) “Expulsion of tapeworm segment(s) in faeces” and 2) “Stomachache, urge to vomit, weight loss, going to the toilet less often than usual and anaemia”. The latter correct response could have been divided into several smaller items, i.e. 2) “Stomachache”, 3) “urge to vomit”, 4) “weight loss”, 5) “going to the toilet less often than usual” and 6) “anaemia”. It is difficult to know whether the participant would have given all five correct answers, or only some parts of this long and detailed answer as the answer was ticked as correct by the enumerator regardless of whether one or all symptoms were mentioned by the participant.

It is fair to believe that the repetition of the key messages in the TB-animation had an impact on the knowledge transfer. However, as the questions to the participants were open-ended, it was difficult to remember the 10 different symptoms related to TB. The participants were not told how many correct answers there were for each question. Though, from an overall perspective, it makes sense that the participants only mentioned the most important or impactful ones – for example prolonged coughing, fever and coughing up blood. We saw, for example, that only a few participants remembered chills and loss of appetite, even if this was both illustrated and explained in the animation.

The shortcomings of the questionnaire described above can result in response bias, which happens when conditions or factors that take place during the process of responding affect the way responses are provided, leading to an overestimation or an underestimation of the true parameter / effect (146, 162). In retrospect, it would have been easier to compare the effect of the health education intervention if all target diseases had similar questions and the same number of questions and answers.

“Thoughtful study design, careful data collection, and appropriate statistical analysis are at the core of any study’s internal validity” (163, p. 1886). Non-randomised trials are sometimes, but not always, biased (162), and *randomised* studies are often seen as the gold standard in health research, and the only study design able to estimate a true effect. Groups or individuals were not randomised to the intervention or control group in our study, because it was not feasible from a logistical perspective. Assessing the effect of an intervention in a non-randomised trial, leaves us with uncertainty of the results. However, the large effect size reported in paper 4, is describing the magnitude of the difference between groups, and is more important than significance, p-values (164), including rejecting the hypothesis. The InfoSpots were rolled out in the pilot villages with open access for all individuals and this was the main reason for the DigI team to operate at the village level and include other villages as control units. Even though we were not able to randomise the participants to either

intervention and control group, we selected a random sample from each sub-village and we assessed confounding variables. This strengthens the internal validity.

An important weakness with non-randomised design is that unmeasured (unknown) confounders can influence the results of the study (142). For example, systematic errors create biases, but in designs like ours where the difference between the intervention and the control group is the essential outcome, and systematic errors occur in both groups, it is less problematic to interpret the results (165). Some research papers suggest the intervention effect should be corrected for the baseline values in order to make the estimate of the intervention effect more precise (166). However, the baseline values will never be exactly the same between the two groups even in a randomised controlled trial. Non-randomised studies like ours, will have greater differences in the baseline differences than in randomised studies. By adjusting for the baseline values, we could have avoided the problem of regression to the mean. We assumed that our control group was equivalent to the intervention group, as the control villages included were from the same district and had about the same size as the intervention villages. We further assumed that the remaining and unknown characteristics would not bias the results (167). We did see that both occupation and education in general – and age and gender to a lesser extent – did differ, more than expected, between the two groups. For example, in the intervention group the participants more commonly had no education, but in addition more often had education above primary school. They were more frequently petty traders (45%), while farming was reported to be the mean occupation in the control group (85%). To minimize potential bias that may have resulted from those differences, the knowledge uptake and retention outcomes were adjusted for these confounders.

Contamination was another important factor, which was relevant in two ways. First, the participants in the intervention group who had seen the animations could have talked to other people not yet recruited to the study about what they learned, and this may have influenced the baseline knowledge, as the baseline assessment spanned a period of two months in the intervention group (April and May 2019). This was longer than anticipated because we experienced that many of the randomly selected households from the sub-village lists were not to be found in the villages. As described in Paper 1, we needed to create updated sub-village lists in order to recruit the desired number of households. We ran analysis between the two list systems, and no significant differences in baseline knowledge were detected between those recruited in April and those recruited in May. However, this gap in time may contribute to potential weaknesses in our study.

Second, it is possible that participants from the control villages, Kimande and Idodi, visited the intervention villages Izazi and Migoli, assessed the platform or talked to people about the health messages. Such contamination between the groups could not be controlled, as the InfoSpots were available for all, and it is impossible to know about personal relations beyond geographical

boundaries. This too could have weakened the internal validity. Though the evaluation of the team for selection of the control villages was that the minimum 2 hour drive, in addition to assessing an InfoSpot that was not advertised, made contamination less likely. We could have asked participants in the control group if they had accessed and used the InfoSpot in the intervention villages. Though, such a question might have triggered the interest and could have led to contamination.

In our study we assessed the effect of digitally enabled health education on health knowledge compared to *standard care*, i.e. a control group with no intervention. Standard care for client health education in rural Tanzania involves seeking information at dispensaries, schools, village offices, or through CHW's. Often individuals receive no health education at all. This is the main reason why we did not include a third arm in the study; we wanted to compare the effect of digitally enabled health education to *business as usual* being no intervention. In hindsight, extending the study including a third arm with analogue health education, could have been a possibility. Likewise, one could have added a separation of just showing the three animations or providing InfoSpots in addition. Though, given the limited resources of the study, the comparison to *business as usual* was regarded being sufficient by the supervision team, the health researchers and authorities in Tanzania.

The current study has demonstrated the need for follow-up studies, including solely leaving the InfoSpots open and available for the communities to access the digitised health messages voluntarily and unsupervised, without showing animations to individuals recruited in the trial. Likewise, establishing a three arm study with animations in analogue and digital form as intervention, and no intervention in the control group, is another opportunity for research. The three arm study would allow to assess the effect of digitally enabled health education in contrast to analogue health education. However, there are several considerations to consider regarding the inclusion of a third arm:

1. Increased risk of contamination between groups: The intervention villages were situated in proximity geographically, making it impractical to implement distinct interventions in these two locations. Nevertheless, there was an opportunity to utilize one of the control groups as a third arm, as they were sufficiently distant from both the intervention villages and each other.
2. Reading levels (literacy): During the initial needs assessment, village executive officers, sub-village leaders, and health workers informed the research team that formal literacy levels—specifically, reading skills—in the rural communities were low. This circumstance was one of the key factors influencing our decision not to distribute text-based leaflets to the communities. Nonetheless, storyboards or oral health education could have been administered to the third intervention arm.
3. The costs associated with providing paper-based drawings or orally delivered health education would have been excessive for the project.

In quantitative research, missing data can create bias (168). Luckily, in this study, we only had few missing item non-responses, as all questions had to be answered in KoboCollect in order to proceed to the next question. This strengthens the internal validity of the study, as does the low number of participants (n=5) refusing to take part in the study during recruitment. This may be explained by the fact that we had a tight collaboration with the sub-village leaders in the villages. Prior to data collection, we had held several meetings with the sub-village leaders, and we experienced a strong leadership and a positive view of digitally enabled health education. The sub-village leaders vouched for the InfoSpots being an asset for the villages. This resulted in willingness and trust by the randomly selected participants.

Iringa district is characterised by mobility, often for agricultural reasons (169). Dropouts during the study are another challenge, specifically if parts of the population travel around for work opportunities, as described under 4.2. When we recruited participants for the study, we excluded participants who planned to shift villages within the next eight months because they would, by dropping out, represent a substantial risk to the quality of the study (142). It is reasonable to believe that we would have had more dropouts if we had not applied this exclusion criterion when recruiting. The dropouts accounted for the missing units (questionnaires) at three months and 12 months. Analysis showed that the dropouts did not differ significantly from the participants who took part in all three assessments in terms of age, gender, occupation or education. We conducted a sensitivity analysis with the intention to treat principle (170), in order to be able to analyse all observed data and to investigate the effect of dropouts. To mitigate for the dropout effect, we could have carried forward the last observation, meaning that if a participant dropped out at the 12 month assessment we would use their data from the three month assessment. This is often claimed to be conservative, but the results could be biased (170) in favour of the intervention, as the results at the three month assessment would probably have been higher in general compared to the 12 month assessment. This is the reason why we used 0 correct answers for the dropout as a worst-case scenario, in both the intervention and control group.

External validity relates to whether the results can be generalized to different settings, people, times and measures (171). The health education intervention was effective in improving health knowledge in Migoli and Izazi, but would this be the case in other settings with a different population? The animations were created with, and for, a rural Tanzanian population. Thus, the results may not be generalizable to urban areas where people have more access to health education.

Selection bias can be an important drawback in non-randomised studies (162). A strength with using quantitative random approaches is the possibility of being able to generalize due to the overall study population (120), in our case the rural population of Tanzania. In our study, we recruited 600 participants at baseline, which is a relatively large sample. Although the villages, sub-villages and

participants were not allocated to intervention or control groups at random, the selection of the households and participants within the household was random, not only due to the PPS we applied when calculating the sample size from each sub-village and the random generator we used to select households, but also because of the KISH method we applied to select a household member. In addition, we further increased our sample size (see 4.6.6) compensate for envisioned dropouts and the risk of type I error due to multiple statistical testing, which, in turn, increases the external validity. The broad inclusion criteria applied in the recruitment process to ensure a representative sample – together with the few participants who refused to take part in the study – both increase the external validity (172).

6.1.2 Trustworthiness

Concepts like credibility, dependability, transferability and confirmability (173) can be applied to judge the quality of research based on content analysis, instead of the more quantitatively research-oriented concepts mentioned above.

Credibility corresponds to validity in quantitative research, dependability to reliability and transferability to generalization, while confirmability refers to the objectivity and the neutrality of the data (141). A weakness in qualitative research arises when the researcher relies totally on the translation. However, credibility was increased by the close collaboration with the Tanzanian research assistant, who could also be referred to as an expert due to his longstanding work in the DigI project in several stages of the research process. His tasks included everything from simultaneous translating and probe questioning during the interview, to discussing each interview immediately after it finished and taking part in the analysis after data collection. The transcripts were reviewed by the Tanzanian team members before analysis and agreement on the main findings were carried out in collaboration. In addition to working closely with the Tanzanian research colleague, the inclusion of a totally independent qualitative researcher in the analysis process can increase the credibility of the findings (141).

Dependability refers to how stable the findings are and is related to how much the researcher changes her decisions during the analysing period (141). The importance of the collected field notes cannot be overemphasized (136), and this is applicable to our study. The de-brief document we used after each interview was probably the most used document in the analysis process. We spent 10-15 minutes after each interview writing down the most interesting aspects. Notes describing the setting of the interview and the participants were also taken. In this analysis, this document – together with the transcriptions – was actively used to recall each interview. This allowed the PhD candidate to be taken back in time, and even if the interviews were in Swahili with simultaneous translations, thanks to the de-brief document the English transcriptions could be separated from each other. Such documents can be used to accelerate the process of inductive reasoning characteristic of qualitative research. The concrete

examples can be used to arrive at a more general understanding (136) and can thus help to strengthen the dependability.

Transferability is related to how applicable the results are to other groups, settings and to the number of participants. In the qualitative component of the study, we sampled participants in two ways: we randomly selected participants from the intervention group in the quantitative part of the study (referred to as group 1 in paper 3) and we employed convenience sampling and recruited on site in and around the InfoSpots (referred to as group 2 in paper 3). We were assisted by key people in the village, and sub-village leaders, teachers and healthcare workers, and we employed snowballing sampling technique to be able to talk to different users and non-users. In paper 3, it was not clear how the sampling from group 1 and group 2 was undertaken, and how we eventually reached data saturation in both categories of users and non-users. Most of the non-users were sampled from group 1. Our main impression was that they were not aware that the InfoSpot was open and accessible. In group 2 we found two non-users, and with 10 non-users all together, mainly reporting the same, we reached data saturation. This was different for the users. Many had different perspectives and experiences, however, after the 25th interview with a person that had used the InfoSpot, we were able to conclude that data saturation was reached.

A strength of the study is the inclusion of a large sample size (n=35), and the fact that we reached data saturation point (139) related to new emerging themes strengthens the qualitative rigour of the study. However, it is acknowledged that in paper 3, Table 1 should have indicated whether the participants were classified as users or non-users. This would have allowed the reader to identify the demographic characteristics of both users and non-users.

The formal educational level in the quantitative and qualitative components of the study was different. The mean educational level among the participants in the quantitative component of the study was primary school. Only four participants from the intervention group had post-secondary education, while in the qualitative part almost half of the participants had post-secondary education. We explored experiences among teachers, healthcare workers and village leaders, who all had post-secondary education. The sample in the qualitative and quantitative component of the study is therefore different, and it may be challenging to compare results from the two groups directly. It may be that more people with higher education used the InfoSpot and that their views were different from other potential users with less formal education. This indicates that the findings from the qualitative component of the study is not transferrable to a larger part of the population in rural Tanzania, although the gap in education between the participants is emphasised in the paper. At the InfoSpot in the high school in Migoli, we were presented to students who often used the InfoSpot by one of the teachers. We experienced that the female students were introduced to us, only after our inquiry. It might have been important for the teachers to present students with a higher level of digital skills, as the DigI team had provided the

equipment and access to the Internet, which raises a question about the sampling. During the revision process of Paper 3, one reviewer advised that we reframed the paper as a case study to simply reflect and share the experience from the 'ground', as the sampling bore the imprint of being opportunistic and unstructured. We redrafted the manuscript to be a case study, except from a few places (methods/ethical considerations) where we used the term “study” when describing the recruitment, as the qualitative component was not framed as a case study at that point. A qualitative case study approach is suitable for studying complex phenomena in health and social care, due to its focus on factors interacting with each other (174), which is relevant for the qualitative part of the study. In retrospect, we could have viewed the DigI project as more of a case that needed a slightly different approach. As the research was conducted in the community setting, paper 3 should have indicated the practical, policy and social implications of the findings. Considerations related to how the work performed could inform or impact practices in the field, influence policy decisions, and contribute to social understanding or change, should have been stated more clearly.

Confirmability is of special importance in this study, as the PhD student represented the donor organization, also when conducting the interviews. The role as both the implementer and the researcher in the DigI project might have influenced the responses from the participants in the semi-structured interviews. Truth value in qualitative research recognizes that multiple realities do exist, and that the methodological bias may be a result of the researchers’ personal experiences. Thus it is extremely important to present the participants’ views in an accurate way (175). It has been argued that participants may respond to the interviewer based on who the interviewer is. The participants’ life, with the underlying social categories to which we all belong – related to age, sex, class and race – may come into play and this can trigger practical, epistemological and theoretical concerns (138). The motivation of the participants to take part in the study – perhaps to be a receiver of a health education programme – as well as the researchers’ understanding of what the participant was trying to convey (176), could have biased the data. The researcher’s role and self-reflection are discussed below.

6.1.3 Critical self-reflection

Self-reflection is essential in a research process. Critical self-reflection refers to the process of questioning one's own assumption, presuppositions, and meaning perspectives (177).The researcher’s background influences the research process in several phases; what to investigate and the angle of investigation, and the choice of data collection methods (178). Researchers cannot exclude themselves from the research process, and in any study the researcher’s ‘self’ is integrated (179). Thus the researcher’s perspectives will always influence what is identified as important in the findings. My pre-understanding did influence this research. The values that I brought with me not only from my own cultural and social upbringing, through my earlier experiences and education, but also from the DigI project, the fieldwork, the talks and observations, were all part of me when collecting, analysing and presenting the data.

Evaluating an intervention that you have been part of creating can be challenging. In the DigI project, the team worked for two years with the digitised health messages before the animations were ready to be used. One of the primary difficulties encountered in the composition of this thesis revolved around the need to maintain a distinct demarcation between the research outcomes stemming from the DigI project and the evaluation of the DigI project itself.

A question that arose was whether it was feasible to make assertions regarding the impact of the health education intervention without undertaking an assessment of the DigI project as a whole. A consistent effort has been made to emphasize the research conducted within the project rather than focusing on the DigI project as a whole. Research involves systematically constructing knowledge, while evaluation entails systematically assessing the merit, worth, or value of programs, policies, activities, technologies, or similar entities (180). The primary objective in this thesis seeks to assess the effect of the intervention through a biomedical approach to the statistical effect size. In a digital health context, evaluation of an intervention requires more; it is “a systematic and objective assessment of an ongoing or completed intervention with the aim to determine the fulfilment of objectives, efficiency, effectiveness, impact and sustainability” (30). In retrospect, I acknowledge the need to see the intervention in a larger perspective, than simply the effect size. A discussion related to whether the intervention could be classified as digital health follows in the next section.

6.1.4 Definitional clarifications

Including a section on definitional clarifications is necessary within this thesis. The terms "health education," "health promotion," "health literacy," "digital health," and "digital health education" were utilized in papers 1-4 without adequate attention to their definitions and distinctions. In acknowledging the potential for a more precise portrayal of the intervention through a narrower set of terms, the distinguished terminologies "health education" are used to denote the intervention's objective and "health knowledge" as the primary outcome variable of interest. Additionally, the term "digitally enabled health education" is now used to delineate the study's framework, and "digitised health messages" refers to the materials provided to participants and the Migoli and Izazi communities. This section concludes with a discussion regarding the classification of the project and intervention as digital health.

Health education, health promotion and health literacy

Education is defined as “the process of teaching or learning, especially in a school or college, or the knowledge that you get from this” (181). Our intention did not involve incorporating the digitised health messages into a curriculum, nor did it specifically target medical students. In hindsight, alternative terms like "health communication" could have been employed to better describe the intervention's objective.

In paper 2, health promotion was employed interchangeably with health education. In that context, we used "health promotion" to depict the process and the role we envisioned our intervention fulfilling. In retrospect, it's evident that our intervention strictly centred on health education, as our objectives didn't encompass altering broader aspects such as the healthcare system, policies, or overarching strategies aimed at enhancing health.

Digital health education and digital health promotion

Throughout the DigI project and the foundational papers of this thesis, the intervention was denoted as a "digital health education intervention." Although researchers within the DigI team highlighted the "health education" aspect, they incorporated a digital prefix:

Digital health education = health education in a digital format

Other scholars in the field may prioritize the term "digital health" as the foundation of the education:

Digital health education = education about the field of digital health

The utilization of the term "digital health education" might have led to confusion among readers. The interpretation of digital health education varies based on the users and learners involved, which hinges on whether the intended audience encompasses the health workforce, researchers, developers, policymakers, or clients. Brown and Bewick refer to digital health education in UK's National Health Service (NHS) workforce as a process that "develops an understanding of the pragmatic use of digital technologies, including health apps, artificial intelligence and wearables" (182, p. 1), while Tudor et. al. use the term to describe the use of digital technology in health professions education (183). Considering *digital health* as*: "*The field of knowledge and practice associated with the development and use of digital technologies to improve health." (31), it becomes evident that a more suitable terminology in the papers would have been "digitally enabled health education," as employed in this synopsis.

Digital health promotion was also mentioned as a concept in the paper 1. According to Stark et al. digital health promotion and prevention is an emerging and heterogeneous research field (184). The authors propose that digital health promotion and prevention can be achieved via one-way communication of health information through mass media. Recent descriptions of digital health promotion encompass the utilization of digital technologies to enhance health and well-being through diverse channels like websites, mobile apps, social media, and other digital platforms. The essence of digital health promotion centres on granting access to health information and resources, encouraging healthy behaviours, and facilitating communication between patients and healthcare providers – aspects that could have been pertinent to our study. Nonetheless, given that health promotion encompasses a broader process involving social and political dimensions (3), which also encompasses

health education activities, health education remains the primary focus of the intervention outlined in this synopsis.

Digital health intervention

Throughout the project's duration, the project team - including the candidate - held the assumption that converting analogue materials into digital formats and subsequently delivering health messages through digital equipment (such as smartphones, tablet devices, or personal computers) within a study context would be classified as a digital health intervention. The candidate's perspective is that digitally enabled health education can be seen as a subset of digital health. This is because it employs digital technologies to provide health-related information and education to individuals, albeit within a narrower scope of digital health.

However, the DigI team, including the candidate, could have benefited from a more structured use of existing frameworks for designing and implementing digital interventions. The Principles for Digital Development (185) or UNICEFS guide for Designing Digital Interventions for Lasting Impact (186) was assessed at the beginning of the design phase. Elements of these frameworks were used as methodology for executing a digital health intervention. Furthermore, we could have applied WHO's key concepts for conducting digital health evaluations in a systematic way (30), and we could have used the mERA checklist (187) for improved transparency in the reporting.

We understand the concern that the intervention described is not explicit on the framework and the framework elements to be used. Though it is evident that the core principles, from a human-centered design approach as for example The Principles for Digital Development were considered during the design phase. This led to the formulation of our own methodology for creating the animations, as described in paper 2.

At the inception of the DigI project, a needs assessment was conducted in the selected villages, to understand the existing ecosystem (32). In essence, a health system challenge was recognized (34). In the rural areas, quality health messages on the targeted diseases were notably scarce, apart from those available at dispensaries – a significant challenge due to their often difficult accessibility (geographical inaccessibility). Hence, the health system challenge can be succinctly articulated as the "absence of access to quality health education for clients in rural communities" (34).

As previously mentioned, the health education content for clients was based on governmental approved guidelines and materials. Together with the Tanzanian researchers' expertise from the study areas, and the identified needs for disease prevention outlined in The Tanzanian Health Sector Strategic Plan (75) emphasis was placed on evidence-based health messages addressing various aspects including prevalence, transmission, signs and symptoms, treatment, and prevention (see 4.3.1). The content in the intervention was thus rooted in scientific evidence and built upon existing research

and best practices within the mentioned domains and targeted diseases. The rationale for selecting health messages for each domain was based on their potential to enhance health knowledge and their feasibility for implementation within the communities (4). These initial analyses were supported by input from local stakeholders during the needs assessment.

The content was crafted while considering the needs and preferences of the target users, and the co-design process in in line with how digital interventions should be designed (185). However, it's worth noting that the user testing during the content design for the intervention could have been conducted in a more systematic manner, and more feedback from target users could have informed the development of the platform to be more user-friendly. The human-centred design approach (188), which was employed during the design phase, should have similarly been implemented for community testing when the "prototype" of the health platform in InfoSpots was introduced. This likely would have unveiled challenges faced by users with limited digital skills. In fact, qualitative interviews demonstrated that the platform could have been designed in an even more user-friendly way, as the platform designers overestimated the capabilities of many potential users. Another option could also have been to rollout the InfoSpots in co-creation with groups of local users to build local capacity, which is key in digital health (31). Other work could also have been performed locally to create local capacity, for example the advanced data analysis conducted in Norway and Germany after data collection. Acceptability of the intervention was shown among healthcare workers and CHW. From what we experienced in the Digi project, both healthcare workers and CHW found the animations on the devices useful for providing health education to individuals and communities, which is important in a digital health perspective. The intervention was aligned with the national strategy for digital health in Tanzania, but not integrated into an overarching national digital health architecture (32). Besides the research presented in this work, the concept of InfoSpots to connect unconnected people and areas had a range of technology issues (189). Interoperability with other elements in the health system was neither planned nor established. Learnings from informal discussions were that an InfoSpot user within a dispensary setting might seek additional information or advice from health personnel after viewing the animation. However, no formal measures were taken to ensure this, rather than to encourage such interactions with the healthcare workers. This could have impacted the outcomes of health education, but we did not formally test for it. The absence of facilitated communication between healthcare workers and users may have affected a potential positive outcome of health education: equipping individuals with more information and skills to make informed health decisions and encouraging the adoption of healthy behaviours (6,7). Another option for enhancing the impact of the digitised health messages could be peer to peer learning post intervention (4, p. 376).

In the first part the intervention (viewing the animations), participants played a passive role as consumers, engaging only in the viewing of animations on a tablet screen. While the presentation method differed from the customary manner of receiving health education, a more interactive dynamic

exchange is typically anticipated between a client and a digital health intervention than what actually happened in this initial stage. During the subsequent phase of the intervention, all community members in the intervention villages could access the InfoSpots with the available tablets or their own devices. This encouraged self-driven exploration, enabling clients to interact with the platform's animations, texts, and quizzes.

Scalability and sustainability are key for digital interventions, however not addressed in the papers of this thesis. The DigI project including the InfoSpots was designed to be scalable, and the animations and platform could be translated to other languages. The Basic Internet Foundation reports that InfoSpots, based on the design described in 2.4, have as per today been implemented in more than 200 schools in eastern Africa (190). Representatives from the Tanzanian research group confirm that the InfoSpots are still in use in some locations in Iringa, while others are no longer in use, due to lack of use and technical problems which raise the question about sustainability for long-term maintenance, financial viability, and ongoing support (32).

6.2 Discussion of main findings

Referring to the overall results from the quantitative and qualitative components included in this thesis, we can draw the conclusion that the animations developed with a multi- and interdisciplinary approach in the DigI team were successful in improving health knowledge of HIV/AIDS, TB and TSCT. The communities had a positive view on digitally enabled health education, although 7 out of 25 InfoSpot users found it difficult to access the platform. Voluntary and unsupervised use of the InfoSpots further increased the health knowledge of our target diseases among the participants who reported having accessed the digitised health messages after rollout of the platform in the intervention villages. However, there are several shortcomings in this research that need to be addressed.

Our main findings, discussed in the following address the topics:

- Animations as digitally enabled health education
- InfoSpots as novel access points for information
- Local engagement and multi- and interdisciplinary approach
- Was heath literacy and digital literacy improved post intervention?
- Non-use, spill-over effects and unintentional purpose of use

The following sections will first compare our findings with the state of literature, and then elaborate in detail on the findings of our study.

6.2.1 Animations as digitally enabled health education

As the first part of the health education intervention consisted of showing animations to each participant in the intervention group, before measuring the health knowledge again three months later, we can confidently say that the animations increased the participants' health knowledge. The health

knowledge increase is evident, as being well-researched domain in public health. Internationally, animations as a knowledge transfer tool have proved efficient in different settings – for example in oral health self-care education for children (191), for postsurgical lung cancer patients (192) and for boosting knowledge of COVID-19 prevention (193).

Our comparison focuses on health education interventions using animations as explored and investigated in studies from sub-Saharan Africa as these are somewhat related to our work. It is important to note that it is challenging to compare our findings directly to other studies measuring health knowledge, because disease topics, questions and knowledge scores differ from one study to another, and research designs, target groups and interventions vary.

The effect of a safe delivery app with animated videos has been studied by Lund et al. (194) in Ethiopia and by Bolan et al. (195) in the Democratic Republic of the Congo. Both randomised healthcare workers to either intervention or control groups and assessed maternal- and new-born health knowledge scores at baseline and in at least one follow-up. Both found that the app with the animations significantly increased health knowledge among the healthcare workers. In Lund's study, the mean difference between the intervention and control group was 38% after a year. Bolan et al. found a 17%–19.5% increase in mean difference between the intervention and control group in their three months post-test. Adams et al. (196) found a small but significant improvement in maternal knowledge in their cluster-randomised controlled trial from South Africa which included a video-based, mobile health (mHealth) intervention. However, the increase was only present in the one month follow up, not after five months. The authors concluded that the intervention was effective as face-to-face counselling by CHWs and a feasible and practical solution when CHWs are scarce. In Hébert et al.'s study (105), the animated video with information for CHWs about dengue virus improved rates of knowledge by almost 20% compared with the comparison group. These four mentioned studies show, similarly to our study, that health animations can be effective for knowledge improvement, even though our study did not assess knowledge among healthcare workers or CHWs, and deals with another type of health education, i.e., infectious diseases.

When critically assessing the animations, the single questions and corresponding correct answers from the questionnaire, it became clear that two techniques were especially important for knowledge improvement. These techniques are *(i)* the repetition of key messages and *(ii)* the simultaneous presentation of key messages by the narrator together with illustrating scenes in the stories. Mayer (197) specifies the "the multimedia effect", of using words and images together and "the temporal continuity effect", of presenting animation while narrating, as important in the cognitive theory of multimedia learning. Our results strongly support that these techniques should be applied when developing animations for learning. Both techniques enhanced the knowledge uptake and retention, as demonstrated in the high increase of correct answers. Repeated key messages for example never to

share sharp objects and avoiding unsafe blood transfusions in the HIV-animation, were well captured by participants in the intervention group. “Cough” or “coughing” was mentioned 12 times during the TB-animation, resulting in a large increase in the proportion of correct answers in the intervention group. The importance of cooking meat well before consuming was a key message clearly taken up by the participants in the intervention group, repeated several times in the TSCT-animation. By contrast, we found that key messages that were not repeated several times in the animations had less impact on the single questions and corresponding correct answers. For example, the key messages related to girls and young women being the most vulnerable group for HIV infections, only mentioned once in the HIV-animation, was not picked up by the participants. Only a few people picked up speaking, laughing and singing as modes of TB transmission, as these words were only mentioned once in the TB-animation. Chest X-ray as a way of diagnosing TB was only illustrated with a brief scene in the animation, not accompanied by the narrator’s explanation, nor repeated as a key message. This may be the reason for the low uptake of this key message and indicates that the viewers discern key messages more effectively when the scenes not only show the action but are also explained by the narrator in detail.

Besides repeating and thoroughly illustrating key messages with scenes while narrating, our findings suggest that the animations’ language, informal tone, clear and short messages, in addition to a recognizable environment, also influenced the large knowledge improvement. The animations did not address other factors affecting healthy behaviours such as the availability of resources, community leadership, levels of self-help skills and support from family and friends (198). As the animations were created for further use in other locations, there is no guidance in the animations on where the closest health facilities can be found, what kind of services are offered there or other contact information for health facilities. Animations are one-way communication, and even if they contained important health messages for disease management and prevention but offered no individual consulting and understanding of a person’s particular situation. In Bello-Bravo et al.’s study from Niger (199), the participants who viewed the animation and had the opportunity to discuss the content with peers afterwards, attained higher knowledge scores than the group who only viewed the animation without discussion with peers. In the DigI project, no such discussion was facilitated, but could have been to boost the health knowledge and steer the health knowledge improvement into health literacy and health changing behaviour. As a recommendation, we suggest further research on methods to improve health literacy and health changing behaviour after the viewing of health animations. This is further discussed under 6.2.4.

6.2.2 InfoSpots as novel access points for information

The provision of digitally enabled health education through openly available InfoSpots in areas with no internet coverage is a novelty, and no studies report on interventions identical to ours. Our results demonstrate that the knowledge of our three target diseases was clearly retained and even increased

after a year, indicating that such knowledge transfer can be effective for long-term knowledge retention. However, we do not know whether this affected the health behaviour, as we were not able to include a study on the change of health behaviour in the current project. This is a drawback and a limitation of this research.

One third of the remaining participants (n=73) in the intervention group in the 12 months assessment reported having used the InfoSpot since rollout. Use of the InfoSpots increased the correct answers by 6.3% to 12.1% among those who reported having accessed the digitally enabled health education after rollout of the platform in the intervention villages compared to those in the intervention group reporting not having used the platform for health education. This indicates that the use of InfoSpots in the communities is an affordable and feasible way to increase community health knowledge and can play an important role related to the targets of SDG 3, with regards to health education, health information and disease prevention. However, the majority reported having used the InfoSpot at one of the local dispensaries, which indicates that they viewed the animations on a screen, and thus did not really interact with the platform. In the qualitative interviews we were often told that the InfoSpot should have a TV for the animations (which was installed after the interviews), so that more people could watch at the same time. This can also be interpreted as the participants finding it difficult to access and use the platform by tablets or smartphones. This topic is further discussed under 6.2.4. From our observations, the use of our platform and the access to InfoSpots represented for many of the participants, in both the quantitative and the qualitative components of the study, the first interaction with digitally enabled health education.

6.2.3 Local engagement and multi- and interdisciplinary approach

The findings from papers 2 and 3 demonstrate the importance of partnering with local stakeholders and the community while developing the educational packages and rolling out the project, and are in accordance with other similar studies (101,103,200). In van Pelt et al.'s study (200) the researchers recommend engaging deeply with local communities, to have clear programme goals for the desired change and to anticipate arising challenges in unexpected circumstances. The engagement is well in line with our findings and emphasizes successful strategies for both knowledge improvement and acceptance in the communities. Our recommendations for involving local stakeholders in the development of the digitised health messages supports Lwoga's findings (201) about the inclusion of people living with HIV when creating online health content for the same group. However, in the DigI project, patients were not included when the digitised health messages were created, although such inclusion could have added a layer of recognition for certain groups.

Given the multi- and interdisciplinary and multi-national background of our DigI study, the challenge of physical distance was addressed during the testing of the platform interface. Flexibility is key in co-design processes (202). The long distance between Norway, Rwanda (where the interface testing took

place) and Tanzania was not very flexible with regards to the collaboration with local stakeholders, when developing the interface for the platform. The designers were based in Rwanda and used local students with smartphones and laptops to test the platform and provide feedback. Obviously, people with both smartphones and laptops in rural Tanzania represent only a marginal proportion of the potential users of such platforms. A limitation when developing the interface is that testing was performed with people with digital skills higher than the general level in Migoli and Izazi. A human centered approach should have been applied, also when rolling out the InfoSpots (as mentioned in 6.1.4) with the health platform. Findings from the qualitative interviews underlined that access was a barrier and a showstopper for many potential users.

An essential approach in designing health animations and health platforms is the involvement of a multi- and interdisciplinary perspective. Blanford et al. (203) outlines seven areas of contrast for the meeting between the two cultures of "health" and "human-computer-interaction (HCI)" in interdisciplinary research on interactive digital health interventions. Our findings support the identified challenges by involving both IT- and health personnel but recognize the mutual interaction between the two cultures as a crucial driver for development of digital health projects. In the DigI project, the target users were perceived as the experts from the very beginning, also by the health task force. This is contrary to Blanford et al.'s third area of contrast, related to requirements and design methods, where people from the health culture think of themselves as the experts rather than the target users. Paper 2 both outlined and reasoned that the focus on the target user was the most important thing to pay attention to throughout the process of designing the health messages.

In revisiting our project process and platform, the following aspects are worthy of consideration: How to measure and assess the inclusion of local stakeholders? How to identify the critical steps where local knowledge is of substantial importance? Especially, how can we measure digital literacy skills and define the platform interface accordingly? Could the digital interventions for public health messaging also be collaboratively designed? To our knowledge, scientific research is limited in answering these questions.

It is acknowledged that qualitative data from potential users, but also key stakeholders, could have been gathered and used prior to implementing the health education intervention, as a strategy to develop the platform. This could have ensured that more people in the community, as pointed out by Creswell et al. (121), would be able to access it. We strongly recommend that this is taken into consideration prior to the design and implementation of any health education package with a digital component and recognise this as a clear omission in our project.

6.2.4 Was health literacy and digital literacy improved post intervention?

In this study, we have demonstrated that participants in the intervention group had higher knowledge scores regarding our three target diseases, HIV/AIDS, TB and TSCT, than the participants in the

control group after the implemented health education intervention. Health knowledge is the first step towards becoming more health literate, i.e. to put into practice what was learnt. Even though the most important modifiable social determinant of health is education (204), education alone is not enough to achieve major public health goals (4). Health education is always part of a system and needs a systemic approach to improve health outcomes, where quality education, economic growth and gender equality and other equity considerations are among the broader factors of a holistic system that creates health (205). The resources and time allocated to our project were not enough to follow the participants for long enough to assess any change in health behaviour, and thus to be able to judge whether health literacy resulted from improved health knowledge.

One of the initial discussions in the DigI project was if digitally enabled health education could contribute to digital literacy. Furthermore, if free access to information on a health education platform could foster digital literacy for those less literate.

As concluded by Meppelink et al. (206), spoken (narrated) animations are the best way to transfer complex health information materials to groups with lower health literacy levels. Recommendations from our study – after reviewing the results from the quantitative part, where all participants reported a positive view of animations as health education – are the same. The responses to the questionnaire, linked to health seeking behaviour, i.e. seeking medical help if symptoms occur, suggests that people may be motivated to make changes in their lifestyle after picking up key messages from the health education intervention, although this was not measured in the study. A similar finding has been highlighted by Brennan et al.'s (207) study on brain health animations for older adults, where the majority of participants reported having learnt something new from the animations, and half of the participants classified the animations as likely to change their behaviour after viewing. Van Pelt et al. (200) further points out the need to include a behaviour change specialist when developing similar programmes. Such a specialist could contribute to assessing the potential link between increased health literacy and watching digitised health messages such as animations.

With regards to knowledge uptake and retention, our study found no statistically significant differences between the groups with or without higher education (from secondary school and upwards) in the 12 month assessment. Even though participants with lower formal education had a slightly lower knowledge during the baseline assessment, the effect of the health education intervention remained high regardless of the different education levels of the participants. This is in line with Bello-Bravo et al.'s results from their studies where learning gains were consistent across education levels (103,199), indicating that animations are an inclusive approach for knowledge transfer to a range of groups.

Regarding accessing the platform, the research in Paper 3 documented that users with lower formal education had more difficulties than those with higher education in utilizing the platform. Having

access but not being able to utilise a digital device is a practical example of the required shift for digital inclusion – *from access to usage* (208) – that increasingly should be applied also in the Global South. People may have access, but several factors contribute to low usage of digitally enabled health education. In the qualitative component of our study, the guidance that happened in the InfoSpots included someone helping in accessing and navigating the platform. Our findings demonstrate that the village leader, a nurse or a teacher can be excellent motivators and instructors to navigate within the platform, find the animation the user wants to see and then press play. When creating the key performance indicators for the DigI project (209), it was assumed that rural communities would raise their digital literacy as a result of utilising the InfoSpot. However, our qualitative research clearly indicates that people without digital skills need help in utilizing devices, platform and content. Furthermore, most of the users had limited skills in accessing electronic sources for health, which is similar to the findings from Haruna et al.'s study (210). In this study on health training institutions in Tanzania, non-degree health science students lacked skills in retrieving electronic health education materials, as well as gaining access to such information. It is unlikely that the participants in our study would have more advanced digital skills than the participants in Haruna et al.'s study. Thus the point of departure for accessing electronic sources for health would be the same.

Guiding is the first step towards building digital literacy and can overcome the initial fear of digital technology. Furthermore, the guiding practice probably contributed to improved health knowledge for clients with low digital literacy. Our findings are good examples of individuals being provided with practical and technological support, as emphasised as a concluding remark in a systematic review of how to lower barriers for use in eHealth services in the US (54). Likewise, Lwoga and Chigona (90) identified the need for digital training in telecenters in Tanzania, when assessing the contribution of telecenters related to capabilities of women in rural areas. From these findings, it is clear that providing training in the use of InfoSpots would most likely increase both digital literacy and health knowledge for users with lower digital skills. The review by Njoroge et al. (60) underlines the gap in digital health studies, with a clear dominance of studies of urban areas. Digital literacy and health knowledge need specific interventions to reach out to people in underserved areas.

Literacy (reading skills) was not assessed during the quantitative analysis, but the literacy level in Iringa is estimated to be between 53% and 86% (124). However, when asking participants about their reading skills as part of the qualitative interview, all participants reported being able to read. Identifying reading skills and how to assess the literacy level among groups in, for example, rural Tanzania, needs specific attention in future studies. Animations increase health knowledge, also among illiterate people, as storytelling and visual images speak for themselves and do not require reading skills. As the knowledge did increase to the level demonstrated in the quantitative component of the study, we have clear indications that participants improved an important element of health

literacy, i.e., health knowledge, after viewing the animations. However, we do not know whether this knowledge created behavioural change.

6.2.5 Non-use, spill-over effects and unintentional purpose of-use

The InfoSpots could have been promoted better by the DigI team to get more users. Non-users reported that they would have used the InfoSpots if they had been aware of their existence, and subsequently may have benefitted from digital sources for health education, which is different from the results of the study by Obasola and Mabawonkus (83), where 67% of the mothers found the Internet / computer not useful for the dissemination of information related to maternal health. Our platform was more specific in addressing the health education needs, while Obasola and Mabawonkus focused more generally on the Internet as a provider information for health. We experienced willingness and acceptance from all participants towards digitally enabled health education and especially the tailored animations.

The majority of participants in the qualitative interviews explained that they had shared key messages from the health animations with friends and family. Similar findings were presented by Bello-Bravo et al. (103) where participants reported having disseminated information from the animations to others in their communities. It may be that the provision of digitally enabled health education, in this case animations, initiates health knowledge transfer and reaches out to a much wider audience than the users themselves. Even though we classified this as a spill-over effect in paper 3, we cannot be certain about this, and this would require further investigation. The findings from the qualitative part of this study addressing the transfer of information show the need for qualified and approved information in the health messages. Thus, provision of approved and high-quality health information is crucial for people's understanding of health, as people with less health literacy more often trust sources such as social media and blogs on health education (211). Infodemics during the COVID-19 pandemic demonstrated that defeating fake information is harder than providing high-quality information in the first place (212). An initial provision of high-quality educational materials for clients would be a good starting point to counteract Infodemics.

While the teachers at the local high school reported using the InfoSpot for Internet, preparing for class with the quizzes available on the platform, and for their own health education, the students utilized the platform differently. Some students used the animations to practice English by switching between English and Swahili, as all content was provided bi-lingually.

Even though our target users were clients in the rural areas, the qualitative findings also showed the platform's and tablets' usefulness for CHWs and healthcare workers. The platform, the digitally enabled heath education and tablet devices reduced workload, were reported to refresh the workers' own health knowledge, and contributed to the health education of the CHWs' clients. This is in line with Braun et al.'s study (213), where mobile phones were seen as an acceptable and useful family

planning tool by both clients and CHWs in Dar es Salaam. Coetzee et al. (104) reported similar findings for CHWs in saving time when mobile phones were used for health promotion in South Africa, thus enabling CHWs to perform other tasks simultaneously. A recent review by Bervell and Al-Samarraie (214) concludes that both eHealth and mHealth interventions in sub-Saharan Africa are perceived as useful for healthcare workers as ways of improving diagnosis, adherence to medication, disease control, information provision, and decision-making/referrals. However, their study also pointed to inadequate ICT infrastructure, scarcity of trained personnel, illiteracy, lack of multilingual text and voice messages as barriers to the use of both technologies.

In Webber et al.'s (215) study from Northern Tanzania the CHWs reported significant challenges with the mHealth safe birthing app, network and charging of the mobile phones used in the project, something that none of the CHWs or healthcare workers brought up in our qualitative part of the study. Similarly to the CHWs' views in Paper 3, the CHWs in Webbers' study also acknowledged the benefits of being able to provide health education digitally, and pointed out that the mHealth app simplified their workload. Our health education intervention was regarded as easy to use by the nine participants (village officers, CHWs and the healthcare workers) who had used the platform for community health education. Future work is needed to clarify the cost effectiveness of similar health education interventions as compared to traditional approaches.

7 Summary and conclusion

In this thesis the overall aim was to understand how digitised health education material for relevant target diseases needs to be designed, to investigate whether the developed health education intervention leads to an increase in health knowledge among community participants of rural Tanzania, and to explore how the intervention was received by individuals in the communities.

Using a mixed method approach with emphasis on multi- and interdisciplinarity, community participation and multinational collaboration, the current research has provided insights that contribute to the body of literature on health education interventions with an emphasis on digitally enabled health education in rural areas of a sub-Saharan setting.

The primary objective stated in this thesis was to assess the effect of the health education intervention on HIV/AIDS, TB and TSCT knowledge uptake and retention in a rural Tanzanian population. The intervention itself was twofold, with the viewing of health animations on HIV/AIDS, TB and TSCT as part 1, and voluntary free access to the InfoSpot with the health education platform as part 2. We recruited 600 participants in the intervention and control group in a non-randomised intervention study and found the intervention effective both for knowledge uptake, measured after three months, and for knowledge retention, measured after 12 months. Compared to the control group, the intervention group had significantly higher knowledge about the three target diseases after the health education intervention. In our intervention study, we also discovered a noteworthy increase in health knowledge related to the three target diseases among participants who voluntarily engaged with InfoSpots during the second phase of the intervention compared to those who did not.

The animations, presented in the local language, were co-designed with local stakeholders, who gave important feedback all through the design process, to ensure context-specific adjustment of health messages to local communities. Important key messages were repeated and illustrated in the animations, leading to substantial knowledge increase among participants in the intervention group. The second part of the health education intervention was novel and had not been implemented before in a sub-Saharan setting. The DigI project installed InfoSpots with free access to a platform with health animations on HIV/AIDS, TB, and TSCT and further health education material.

Health education ideally leads to improved health knowledge, which is one of the core components of health literacy, which may lead to a change in health behaviour. This process is essential to contribute to the health-related SDGs and improving knowledge of HIV/AIDS, TB, and TSCT among individuals and communities can support the attainment of the SDG target 3.3, which refers to ending the epidemics of HIV/AIDS, TB, and neglected tropical diseases, of which TSCT is one of the most relevant. However, it is necessary to point out that further studies are needed to assess to what degree the participants translated their increased health knowledge into a changed health behaviour.

Regarding the secondary objectives, the first one was to provide a detailed protocol describing the context and methods used in relation to the intervention. The protocol was published for the purpose of transparency. The second secondary objective was related to the development of the digitised health messages regarding HIV/AIDS, TB, and TSCT. We were able to demonstrate that a multi- and interdisciplinary approach with the DigI team and the involvement of local stakeholders in the design of the health messages were essential for the delivery of quality health animations adapted to local circumstances. The content design process, rooted in scientific evidence and best practices, involved local stakeholders' input. The human-centered design approach was applied but could have been more systematically applied during testing in the communities, especially considering users with limited digital skills.

For the final secondary objective – the exploration of the perspectives and experiences among users and non-users of the InfoSpots in Migoli and Izazi – we undertook 35 semi-structured interviews. We found that more people would have used the InfoSpots if they had been better advertised and promoted in the communities. Several of the InfoSpot users pointed out difficulties with accessing the platform, lowering the suitability of the intervention as being a digital health intervention. However, we found that the communities were creative and that those with more advanced digital skills guided InfoSpot users with less advanced digital skills. Further, we found that the most successful use of an InfoSpot was at the local high school, where both teachers and students expressed that they benefited from the InfoSpot in several ways, including development of digital skills and an increase in health knowledge. All participants in the qualitative component of the study had a positive view of digitally enabled health education, indicating that people in rural Iringa are most likely ready for a digital transition, and that new technologies for health education are welcome.

The main conclusion of the thesis is that the digitally enabled health education, including the animations, can lead to a significant increase in health knowledge. People in rural areas of Tanzania were enthusiastic and positive towards learning from the digitised health messages based on our chosen three target diseases – HIV/AIDS, TB, and TSCT. Further studies are needed to assess the change in health behaviour and in health outcomes after individuals and communities receive such interventions.

7.1 Implications of the findings

Providing quality health messages is important for changing health behaviours, promoting adherence to medical treatments, reducing stigma, and preventing diseases. Moreover, high-quality health messages should serve as the primary source of information when clients are seeking health-related information. Both the qualitative and the quantitative component included in this thesis indicated that people could learn from the InfoSpots, hence similar health education platforms may have a substantial impact on communities with low access to health education sources and can be useful for

the generation growing up in rural Tanzania. InfoSpots integrated with health education content, as provided through the DigI project, may act as learning hubs in areas without affordable internet access; however, it is crucial to ensure accessibility for the intended users.

Animations with clear, contextualised, and concise health messages in people's own language have the potential for improving health knowledge, as demonstrated through this study. However, health literacy encompasses a behavioural component, which was not addressed in this thesis. Health knowledge, while necessary and representing a core component of health literacy, rarely leads to behaviour change on its own. Hence, asserting that an increase in knowledge can directly influence SDG target 3.3 — ending the epidemics of HIV/AIDS, TB, and neglected tropical diseases such as TSCT — would represent an oversimplification. The reduction of HIV, TB, and TSCT infections, (SDG indicators 3.3.1 and 3.3.2) needs both knowledge and behaviour change of individuals and communities.

Overall, InfoSpots may contribute to the health promotion aspect of universal health coverage by providing quality health services, i.e., access to essential health education (target 3.7, indicator 3.8.1 related to coverage of essential health services) to individuals and communities. Apart from target 3.3. mentioned above, they could also contribute to the reduction of national and global health risks (target 3.d) by strengthening the capacity for health education provision. However, we are fully aware that the concept of InfoSpots as described in our study is still in its infancy and further studies in different locations and under different circumstances are needed to corroborate our results.

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Appendices

Appendix 1 - Amendments to the original project description

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Paper 1 – 4

Appendix 1

Amendments to the original Project Description approved by the Faculty of Medicine

Amendments were submitted to the faculty twice in June 2018 and in December 2020. There were only small changes; however, a sentence was added to the hypothesis in work package 2, reading from "We hypothesise that the intervention increases the proportion of correct answers, related to the intervention diseases" to: "We hypothesise that the intervention increases the proportion of correct answers, related to the intervention diseases, when comparing pre- and post-knowledge scores, also among clients that cannot read." The secondary objectives in work package 2 were changed accordingly: "To investigate if the intervention increases health literacy related to the intervention diseases among the clients that cannot read."

After internal discussions in the DigI team, it was decided not to include a question related to reading skills among the participants in the questionnaire because it was assumed that we would receive an erroneous result to this question. According to the Tanzanian researchers, the perception of what reading really encompasses would vary too much among the participants. Some participants would know how to read, for example, a leaflet with health information, while others would only know how to read, for example, their names, but then define this as being able to read. The question was rather moved to the interview guide for the semi-structured interview, to get a sense on how the intervention was perceived among the participants with low reading skills.

We also chose to focus on the long-term effect of the intervention, not the immediate after effect in the intervention group, as outlined in the project description. A long-term effect of health education is desired, and the knowledge increase immediate after viewing the animations was perceived as less important than the knowledge increase 3 and 12 months after the first part of the intervention. Thus, we used the baseline data to investigate the change from baseline to 3 months and 12 months, instead of using the baseline data to investigate the change from baseline to the immediate-after viewing the animations. The results from the 3-month assessments represent the short-term effect, or the knowledge uptake, and the results from the 12 months assessment represent the long-term effect or the knowledge retention.

Originally, a systematic review was planned as part of the PhD, and a protocol was developed and published in PROSPERO in 2018. More time than anticipated was spent on the design and development of the health messages and the study, and as reported in the amendments submitted in December 2020, thus the finalisation of the systematic review was postponed to after PhD completion.

Appendix 2 GREET checklist

GREET CHECKLIST		
BRIEF NAME	Part 1: Viewing the animations	Part 2: Using the InfoSpots
1. INTERVENTION: Provide a brief description of the educational intervention for all groups involved [e.g. control and comparator(s)].	Intervention group was shown individually (by research assistants) three animated videos with health education related to HIV/AIDS, Tuberculosis and TSCT. No intervention for the control group. Only standard care.	Intervention group had voluntary and unsupervised access to the InfoSpots with the same animations as in part 1, in addition to quizzes, text and graphics. No intervention for the control group. Only standard care.
WHY - this educational process		
2. THEORY: Describe the educational theory (ies), concept or approach used in the intervention.	No theoretical framework applied. Based on the needs assessment in the communities, low reading skills emphasized the need for cartoons and oral speech to disseminate the health messages. Storytelling used as the technique for conveying the health messages.	
3. LEARNING OBJECTIVES: Describe the learning objectives for all groups involved in the educational intervention.	Disease specific knowledge uptake and retention.	
4. EBP CONTENT: List the foundation steps of EBP (ask, acquire, appraise, apply, assess) included in the educational intervention.	1. Clinical questions with regards to prevalence, transmission, symptoms, treatment, and prevention was formulated. 2. Governmental approved health education materials was used to answer the questions. 3. The evidence was appraised by the experts in the research team. 4. Stories were developed to provide the suitable framework for disseminating the health education. 5. A non-randomized trial was planned to assess the outcome.	
WHAT		
5. MATERIALS: Describe the specific educational materials used in the educational intervention. Include materials provided to the learners and those used in the training of educational intervention providers	Colorful 2D animations, between 3 and 7 minutes long, including stories relatable for the people living in the rural Tanzanian communities.	The same animations as in part 1, in addition to graphics, quizzes and text for more formal illiterate learners.
6. EDUCATIONAL STRATEGIES: Describe the teaching/learning strategies (e.g. tutorials, lectures, online modules) used in the educational intervention.	Viewing animations for knowledge uptake, supervised by research assistants.	Unsupervised viewing of animations for knowledge uptake and retention, in addition to self-exploring a digital platform with more digitally enabled health education.
7. INCENTIVES: Describe any incentives or reimbursements provided to the learners.	No incentives.	No incentives.
WHO PROVIDED		

8. INSTRUCTORS: For each instructor(s) involved in the educational intervention describe their professional discipline, teaching experience/expertise. Include any specific training related to the educational intervention provided for the instructor(s).	Research assistants. Only trained to provide the animations and ask questions from the questionnaire.	No instructors present as this was the unsupervised part of the intervention. Some staff would be available depending on the placement of the InfoSpots. In health facilities, nurses would play the animations on a screen. In community offices, executive officers trained to provide access to the platform would guide users who could not access the platform themselves. At the school, the teacher would open the IT room for self-exploration on the platform. But no health training was given to any of the staff.
HOW		
9. DELIVERY: Describe the modes of delivery (e.g. face-to-face, internet or independent study package) of the educational intervention. Include whether the intervention was provided individually or in a group and the ratio of learners to instructors.	A tablet screen (Huawei 7"). Provided individually.	Tablet screens (Huawei 7") available for public use in the InfoSpots, and a wifi with access to the local server with the platform available for people with own devices.
WHERE		
10. ENVIRONMENT: Describe the relevant physical learning spaces (e.g. conference, university lecture theatre, hospital ward, community) where the teaching/learning occurred.	At the participants home.	InfoSpots located in the community, at the dispensary, community office or at the public school.
WHEN and HOW MUCH		
11. SCHEDULE: Describe the scheduling of the educational intervention including the number of sessions, their frequency, timing and duration.	The animations were shown once to each participants in the intervention group, in May / June 2019.	The InfoSpots with the health platform opened in November 2019.
12. Describe the amount of time learners spent in face-to-face contact with instructors and any designated time spent in self-directed learning activities.	About 16 minutes all together: 6.46 minutes on the HIV/AIDS animation, 6.36 on the Tuberculosis animation and 3.03 minutes on the TSCT animation.	Unknown
PLANNED CHANGES		
13. Did the educational intervention require specific adaptation for the learners? If yes, please describe the adaptations made for the learner(s) or group(s).	No	Yes. The intervention - if not guided by someone in the InfoSpot, required a certain digital literacy level to access the health platform.
UNPLANNED CHANGES		

14. Was the educational intervention modified during the course of the study? If yes, describe the changes (what, why, when, and how).	No	Yes. In the InfoSpots at the dispensaries, the tablets for viewing the animations and the platform was withdrawn from the waiting areas due to risk of transmission between patients. A TV-screen for showing the animations was installed.
HOW WELL		
15. ATTENDANCE: Describe the learner attendance, including how this was assessed and by whom. Describe any strategies that were used to facilitate attendance.	Participants for the study were randomly selected from household lists in the communities. The sub-village leaders in the communities assisted the research team in finding the randomly selected participants, while also assuring them that participation was voluntary, safe, and beneficial with regards to health knowledge.	Only voluntary use of InfoSpots, and no measures were taken to increase participation.
16. Describe any processes used to determine whether the materials (item 5) and the educational strategies (item 6) used in the educational intervention were delivered as originally planned.	Debrief with research assistant were held daily.	Only brief talks with community officers, teachers and health workers at the dispensaries.
17. Describe the extent to which the number of sessions, their frequency, timing and duration for the educational intervention were delivered as scheduled (item 11).	Was delivered as planned.	Qualitative interviews with InfoSpot users and non-users indicated that accessing the platform was more difficult than assumed, but findings from the questionnaire indicated that the InfoSpots was visited, and animations viewed again by more people than assumed.

Appendix 3 Questionnaire – demographic and health knowledge questions

Baseline and immediate after, intervention and control group, Iringa April 1. - May 1.

DOI

_____

Sex

- ◯ Female
- ◯ Male

Age

_____

Village

- ◯ Izazi
- ◯ Migoli
- ◯ Kimande
- ◯ Idodi

Is the person willing to participate, and has the person signed the consent form?

- ◉ Yes
- ◯ No

Why is the person not participating?

- ◯ Away from the house for more than two days
- ◯ Declining
- ◯ No eligible household members
- ◯ Has shifted to another place

What is your highest level of education

- ◯ No education
- ◯ Primary School
- ◯ Secondary School
- ◯ Post-secondary education

Occupation

- ◯ Student
- ◯ Public servant
- ◯ Farmer
- ◯ Fisherman
- ◯ Business
- ◯ Other

Other, spelace specify

_____

Religion

- ◯ Christian
- ◯ Muslim
- ◯ Other

Now, 14 HIV questions will follow

- ◉ OK

QH1: Have you ever heard of HIV and / or AIDS? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QH2: How do you think a person can get HIV? (Check all boxes that apply)

- ☐ From mosquito bites
- ☐ From witchcraft
- ☐ From sharing food with HIV infected person
- ☐ By having unprotected sex with a person infected with HIV
- ☐ Through blood transfusion from a person infected with HIV
- ☐ Sharing sharp instruments
- ☐ Mother to child transmission
- ☐ I don't know

QH3: Do you know if a HIV infected pregnant woman can transmit HIV to her baby during pregnancy,delivery and breast feeding?

- ◯ Yes
- ◯ No
- ◯ I don't know

QH4: Do you know if a HIV infected pregnant woman on ART can have a healthy baby?

- ◯ Yes
- ◯ No
- ◯ I don't know

QH5: Which group do you think is most vulnerable to HIV infection? (Check all boxes that apply)

- ☐ Girls
- ☐ Women
- ☐ Boys
- ☐ Men
- ☐ They are equally vulnerable
- ☐ I don't know

QH6: Do you think a healthy looking person can be infected with HIV? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QH7: How do you think a person knows that he or she is infected with HIV? (Check all boxes that apply)

- ☐ If the parents are HIV-positive
- ☐ If the results from a rapid test / blood sample is positive
- ☐ If the person has flu-like symptoms
- ☐ If the sexual partner is diagnosed with HIV infection
- ☐ I don't know

QH8: Does effective treatment of HIV infection by using antiretroviral therapy (ART)), reduces the risk of HIV transmission (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QH9: What kind of treatment do you think is the most effective for HIV? (Check one box)

- ◯ Herbal treatment
- ◯ Antiretroviral therapy (ART)
- ◯ Witchcraft
- ◯ Prayers
- ◯ I don't know

QH10: Do you think there is a cure for HIV/AIDS? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QH11: What do you think is the most important an HIV-positive person on treatment can do for her / his own health? (Check all boxes that apply)

- ☐ Taking the medication prescribed by a medical doctor, every day at the same time and adhere to the doctor/nurse advice
- ☐ Practicing sexual abstinence
- ☐ Using a condom
- ☐ Taking some medication in periods
- ☐ I don't know

QH12: How do you think a person can prevent getting HIV? (Check all boxes that apply)

- ☐ Practicing sexual abstinence
- ☐ Using a condom
- ☐ Never sharing sharp objects(needles,razor blades,...)
- ☐ Never sharing food or drinks
- ☐ Never buying food from a HIV-infected person
- ☐ Never having casual contact with a HIV-positive person
- ☐ Avoiding unsafe blood transfusion
- ☐ I don't know

QH13: How do you think an HIV-infected person can prevent the spread of HIV? (Check all boxes that apply)

- ☐ Using a condom
- ☐ Practicing sexual abstinence
- ☐ Never sharing sharp objects(needles,razor blades,...)
- ☐ Avoiding unsafe blood transfusion
- ☐ Using HIV-medication as prevention, by reducing the amount of virus in the body
- ☐ Staying away from other people
- ☐ I don't know

QH14: According to your opinion, what are the major sources of information about HIV/AIDS? (Check all boxes that apply)

- [ ] Health workers / counsellors
- [ ] School
- [ ] Mass media (TV, radio, newspaper,...)
- [ ] Health facilities (hospital, dispensary,...)
- [ ] Posters and brochures
- [ ] Others..... (specify)
- [ ] Friends and family (Peer groups)
- [ ] Religious groups
- [ ] Other sources
- [ ] I don't know

Now, 10 TB questions will follow

- ◯ OK

QT1: Have you ever heard of Tuberculosis (TB)? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QT2: In which ways can TB be spread from one person to another? (Check all boxes that apply)

- [ ] Coughing
- [ ] Speaking
- [ ] Sneezing
- [ ] Spitting
- [ ] Laughing
- [ ] Singing
- [ ] I don't know

QT3: Do you think TB can also spread through the following ways? (List options) (Check all boxes that apply)

- [ ] Skin to skin contact, such as shaking hands
- [ ] In pregnancy from mother to child
- [ ] Mosquito bite
- [ ] None of the above
- [ ] I don't know

QT4: What are the symptoms of TB? (Check all boxes that apply)

- [ ] Coughing that lasts two or more weeks
- [ ] Coughing up blood
- [ ] Chest pain
- [ ] Pain with breathing or coughing
- [ ] Unintentional weight loss
- [ ] Fatigue
- [ ] Fever
- [ ] Night sweating
- [ ] Chills
- [ ] Loss of appetite
- [ ] I don't know

QT5: How do you think TB diagnosis is made? (Check all boxes that apply)

- [ ] Sputum examination
- [ ] Chest x-ray
- [ ] I don't know

QT6: What would you do if you had a fever, unexplained weight loss, drenching night sweats and a persistent cough? (Check all boxes that apply)

- [ ] See a traditional healer for herbal treatment
- [ ] See a health worker to check for TB and start a TB-treatment if positive
- [ ] Will do nothing but wait, to see if this passes
- [ ] I don't know

QT7: What do you think is the most important a person with TB disease can do for her / his own health? (Check all boxes that apply)

- [ ] Taking the medication prescribed by a medical doctor, every day at the same time and adhere to the doctor/nurse advice
- [ ] Staying away from people
- [ ] Taking some medication in periods
- [ ] I don't know

QT8: TB can be cured, even in people living with HIV, with a combination of ant-TB over a period of 6 months? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QT9: What do you think a person with TB can do, in order to reduce transmission? (Check all boxes that apply)

- [ ] Cover his/her mouth and nose with the paper/piece of cloth when coughing
- [ ] Cough in a paper towel and then toss it in the pit toilet or burry it
- [ ] Cough or sneeze into the upper sleeve or elbow
- [ ] I don't know

QT10 How can TB be prevented in the general population?

- [ ] Adequate ventilated houses
- [ ] Always cover your mouth and nose during coughing and sneeze
- [ ] Avoid overcrowding
- [ ] BCG Vaccination in children
- [ ] Early TB detection and treatment
- [ ] TB preventive therapy in people living with HIV
- [ ] I don't know

Now, 17 cysticercosis questions will follow

- ◯ OK

QC1: Have you ever heard of cysticercosis? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QC2: Have you ever heard of pork tapeworm? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QC3: Do you know how pork meat with cysticercosis looks like? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QC4: Do you keep pigs at home? (Check one box)

- ◯ Yes
- ◯ No

QC5: Do you think a human being can also be infected with cysticercosis? (Check one box)

- ◯ Yes
- ◯ No
- ◯ I don't know

QC6: If yes, how can a person possibly acquire cysticercosis? (Check all boxes that apply)

- ☐ By eating raw or undercooked pork from infected pig
- ☐ By eating foods or drinking water contaminated with human faeces
- ☐ Insufficient personal hygiene, e.g. washing hands
- ☐ I don't know

QC7: Do you know how a person can acquire pork tapeworm infection? (Check all boxes that apply)

- ☐ By consuming raw or undercooked pork
- ☐ By consuming any raw or undercooked meat
- ☐ I don't know

QC8: How can one prevent a pig from cysticercosis? (Check one box)

- ◯ Cannot be prevented
- ◯ Use traditional medicine
- ◯ Prevent pigs access to human faeces
- ◯ I don't know

QC9: What are the signs of tapeworm infection in human? (Check all boxes that apply)

- ☐ Expulsion of tapeworm segment(s) in faeces
- ☐ Stomach ache, urge to vomit, weight loss, going to the toilet less often than usual and anaemia
- ☐ I don't know

QC10: In human, where do you think cysticercosis can be located? (Check all boxes that apply)

- ☐ In the muscles
- ☐ Under the skin
- ☐ In the brain
- ☐ In the eyes
- ☐ I don't know

QC11: What are the most important symptoms / signs of cysticercosis in the brain? (Check all boxes that apply)

- ☐ Epilepsy
- ☐ Severe progressive headache
- ☐ Fever
- ☐ Stroke
- ☐ I don't know

QC12: What are the symptoms of epilepsy in human? (Check all boxes that apply)

- [ ] Abdominal pain, vomiting and diarrhoea
- [ ] Fever
- [ ] Loss of consciousness and shaking of arms and legs
- [ ] I don't know

QC13: Do you know how a person with tapeworm infection and/ or cysticercosis can be treated? (Check all boxes that apply)

- [ ] Using traditional medicine
- [ ] Using modern medicine (go to hospital)
- [ ] I don't know

QC14: Which way of keeping pigs do you think is the best? (Check all boxes that apply)

- [ ] Free ranging pigs all the time
- [ ] Tethering the pigs all the time
- [ ] Housing the pigs all the time
- [ ] Housing the pigs at night and letting them to roam during the day
- [ ] I don't know

QC15: Do you know how a person can avoid tapeworm infection? (Check all boxes that apply)

- [ ] Eating meat only inspected by a government/private meat inspector
- [ ] Avoiding eating raw or undercooked meat
- [ ] Washing hands frequently, after toilet, and before preparing and eating food
- [ ] I don't know

QC16: What would you do if you encountered cysticercosis-infected meat? (Check one box)

- ◯ Burn it completely
- ◯ Cook meat thoroughly, and then consume it
- ◯ I don't know

QC17: How can you avoid pigs from eating human faeces? (Check one box)

- ◯ Tethering the pigs all the time
- ◯ Housing the pigs all the time
- ◯ Build an enclosed latrine, and use it
- ◯ I don't know

Now, it is time to show the HIV video, before you ask the following 14 HIV questions again

- ◯ OK

Appendix 4 Semi-structured interview guide

1. Do you know how to read a health information leaflet? YES/ NO

2. Have you used the DigI hotspot in the village?

YES / NO

- if not – why not, please explain? If yes, please tell me about your experiences with it.

3. If yes in no 2: Have you looked at any of the free digital health messages?

YES/NO - (if yes, which ones?)

4. If yes in no 2: When did you use the hotspots, first and last time?

5. If yes in no 2: How often have you used it?

6. What do you think of the digital health message(s)?

Please explain - at least one negative thing and one positive thing.

7. What did you learn from them? (please tell me what you remember the most)

8. Have you explained the messages to any of your family members? (If yes, please tell me about your experiences with it.) (if not, why not?)

9. What can we improve? Please tell us what you think is not functioning optimally.

10. What is not user friendly? Please tell me if there are anything that you find difficult when using the hotspots.

11. Would you recommend it for someone else to use? Why? Why not?

Appendix 5 Additional questions 3 and 12 months

3 months:

1. About three months ago, we showed you three health animations / films on this tablet. Do you feel that you learned anything from them? (Four options to be read aloud to the participants)

    a. Yes

    b. No

    c. I don't know

2. If yes, can you please tell us the three most important things that you learnt from the films: (The enumerator noted down the answer)

3. Which one of the three films do you remember the best?

    a. The HIV/AIDS animation

    b. The Tuberculosis animation

    c. The Tapeworm / cysticercosis animation

4. Was there anything you did not like with the films? If yes, please explain: (The enumerator noted down the answer)

5. Since we showed you the films, have you discussed the content in the films with friends or family?

    a. Yes

    b. No

    c. I don't know

12 months:

1. Do you personally own a smartphone?

    a. Yes

    b. No

    c. No, but I have access to a smartphone on a daily basis

2. Have you visited any of the DigI-hotspots in Migoli and or Izazi?

    a. No

    b. Migoli Dispensary

    c. Migoli village office

    d. Nyerere school

    e. Izazi village office

    f. Izazi dispensary

3. How many times in total have you visited the hotspot(s)? (The enumerator noted down the number)

4. Have you viewed any of the animations again?

a. Yes

b. No

5. Which animations have you viewed? (mark all appropriate)

a. The HIV / AIDS animation

b. The Tuberculosis animation

c. The Tapeworm / cysticercosis animation

d. Other animations (Anthrax, cholera, mother and child health)

6. Have you taken any of the quizzes?

a. Yes

b. No

7. Have you read the text related to the diseases?

a. Yes

b. No

8. Did you find it easy or hard to use the tablets in the hotspots?

a. Easy, I navigated on my own

b. Hard, I had to be guided by someone in the hotspot

9. Will you go back to the hotspot to access free digital health education again?

a. Yes

b. No

c. I don’t know

Appendix 6 KISH form

List all household members, their age and gender

	RS02 Name	RS03 Gender (HR03) 1=Male 2=Female	RS04 Age (HR04)
1		**1** 2	|___|___|
2		1 **2**	|___|___|
3		**1** 2	|___|___|
4		1 **2**	|___|___|
5		1 **2**	|___|___|
6		1 2	|___|___|
7		1 2	|___|___|
8		1 2	|___|___|
9		1 2	|___|___|
10		1 2	|___|___|

Research Assistance: Please select one person using Kish Table and using the following table.

Selection table of all household members aged 15 to 55

List all HH members in the following order:
List first all men from oldest to youngest.
Then list all the women from the oldest to the youngest

	RS02 Name	RS03 Gender (HR03) 1=Male 2=Female	RS04 Age (HR04)	RS05 Selected member (see Kish table) Yes (Selected) =1 No (Not selected) =2
1		**1** 2	|___|___|	1 2
2		1 **2**	|___|___|	1 2
3		**1** 2	|___|___|	1 2
4		1 **2**	|___|___|	1 2
5		1 **2**	|___|___|	1 2
6		1 2	|___|___|	1 2
7		1 2	|___|___|	1 2
8		1 2	|___|___|	1 2
9		1 2	|___|___|	1 2

Kish Table Sticker Here…

Appendix 7 Consent form adults, intervention group

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

FREE ACCESS TO DIGITAL HEALTH INFORMATION IN TANZANIA

This study is part of the project *Non-discriminating access for digital inclusion* (DigI), an innovation project funded by the Norwegian Government and the Norwegian Research Council. The purpose of this study is to investigate your knowledge related to HIV/AIDS, Tuberculosis (TB) and *Taenia solium* cysticercosis/taeniosis (TSCT). The University of Oslo (UiO), Norway, is responsible for the study together with the National Institute for Medical Research (NIMR) in Dar es Salaam and Sokoine University of Agriculture in Morogoro. Only the PIs from UiO and NIMR will have access to your personal information. This particular project is a PhD-project. Your household has been selected at random to take part in the study.

WHAT DOES PARTICIPATION IN THE PROJECT IMPLY?

The data collection includes a survey with questionnaires. The questions will concern your knowledge of the HIV/AIDS, TB and TSCT. Our research staff will collect your answers with small computers. After the first questions, we will offer you detailed information of the diseases through films at the small computers. After the films, we will ask you ask you the same questions again. The same films will be available, free of charge in the Wi-Fi spot in the village. You can decide yourself whether or not you want to make use of that information. We will come back and ask the same questions again after 3, 6 and 12 months. After 12 months the data collection period is over.

Your name, sex, age, education, mobile number, village and GPS coordinates will be collected. The data will be made de-identified and kept at a server at the Services for sensitive data (TSD) at the University of Oslo, Norway. This means your name and background information is stored separately from the rest of the collected data, and is only known to a selected group of researchers. As a participant in this study, you have the right to send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority (contact details under approvals) related to the handling of your personal information. Your consent to participation is the legal foundation for processing personal data, meaning that without your consent we cannot process your personal data.

POSSIBLE BENEFITS AND EXPECTED DISADVANTAGES OF TAKING PART

The expected benefits of participating in this study is increase in your health knowledge. This increase in health knowledge can help protect you and your family from the above-mentioned diseases. Increased health knowledge can also lead to earlier treatment for people with a disease, meaning that a possible benefit of taking part in this study is not only improvement of your own health, but even improvement of community health, i.e. health of the people surrounding you.

The expected disadvantages to participate are few or none. However, you are encouraged to contact the researchers if you need follow-up after your participation in this study.

VOLUNTARY PARTICIPATION AND THE POSSIBLITY TO WITHDRAW CONSENT (OPT-OUT)

Participation in the study is entirely voluntary. If you wish to take part, you will need to check the box(es) and sign the informed consent on the last page. You can, at any given time, without prior notice and without any reasons withdraw your consent. This will not have any repercussions on any future treatment or contact with health workers. If you decide to withdraw your participation in the project, you can demand that your questionnaire answers will be deleted, unless however, the data have already been analysed or used in scientific publications. If at a later point you wish to withdraw consent or have questions regarding the project, you can contact

- Dr. Bernard Ngowi, National Institute for Medical Research, Muhimbili Medical Research Centre, Tanzania, Kalenga Street, P.O. Box 3436 Dar es Salaam, Tanzania. Tel: +255 763918181. E-mail: b_ngowi@yahoo.co.uk
- National Health Research Ethics Committee (NatHREC) of the National Institute for Medical Research Tanzania, 2448 Ocean Road, P.O. Box 9653, Dar es Salaam, Tanzania. Tel: +255 22 2121400. Fax: 255 22 2121360. Website: www.nimr.or.tz.
- Christine Holst, tel +47 4823 4044, Christine.holst@medisin.uio.no

WHAT WILL HAPPEN TO YOUR INFORMATION?

The information that is recorded about your knowledge will only be used within the overall research project Digl. You have the right to access the recorded information about you and the right to stipulate that any error in the information that is recorded, is corrected. All information will be processed and used without your name, address or personal identification number, or any other information that is directly identifiable to you. The de-identified data from the surveys will be uploaded to a secure platform at the Services for sensitive data (TSD) in Norway. The Project Manager has the responsibility for the daily operations/running of the Research Project and that any information about you will be handled in a secure manner. After the project is over, your personal information will be deleted. The project will end in September 2020.

APPROVAL

The Project is approved by the Norwegian Centre for Research Data, ref 59643 / 3 / EPA,
Contact: The Data Protection Official for Research at NSD - Norwegian Centre for Research Data AS.
email: personvernombudet@nsd.no, Telephone +47 55 58 21 17

Ethical approval from the National Institute for Medical Research (NIMR), Tanzania, has been granted with the reference number NIMR/HQ/R.8a/Vol IX/2947. The study is registered in ClinicalTrials.gov ID: NCT03808597. Permission to conduct this study was given by COSTECH.

CONSENT FOR THE MINOR - PARTICIPATING IN THE RESEARCH PROJECT

I have received and understood information about the project *FREE ACCESS TO DIGITAL HEALTH INFORMATION IN TANZANIA,* and have been given the opportunity to ask questions. I give consent:

☐ to participate in the survey

I give consent for my personal data to be processed until the end date of the project, in September 2020.

City/Town and date | Participant's signature

Participants name (in BLOCK LETTERS)

I confirm that I have given information about the research project.

Place and date | Signature

Role in the research project

Section only for those who cannot read and / or write:

Thumb print under:

Witness to sign for those who cannot read and write:

_____

Appendix 8 Consent form minors, control group

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

FREE ACCESS TO DIGITAL HEALTH INFORMATION IN TANZANIA

This study is part of the project *Non-discriminating access for digital inclusion* (DigI), an innovation project funded by the Norwegian Government and the Norwegian Research Council. The purpose of this study is to investigate your knowledge related to HIV/AIDS, Tuberculosis (TB) and *Taenia solium* cysticercosis/taeniosis (TSCT). The University of Oslo (UiO), Norway, is responsible for the study together with the National Institute for Medical Research (NIMR) in Dar es Salaam and Sokoine University of Agriculture in Morogoro. Only the PIs from UiO and NIMR will have access to your personal information. This particular project is a PhD-project. Your household has been selected at random to take part in the study.

WHAT DOES PARTICIPATION IN THE PROJECT IMPLY?

The data collection includes a survey with questionnaires. The questions will concern your knowledge of the HIV/AIDS, TB and TSCT. Our research staff will collect your answers with small computers. We will come back and ask the same questions again after 3, 6 and 12 months. After 12 months the data collection period is over.

Your name, sex, age, education, mobile number, village and GPS coordinates will be collected. The data will be made de-identified and kept at a server at the Services for sensitive data (TSD) at the University of Oslo, Norway. This means your name and background information is stored separately from the rest of the collected data, and is only known to a selected group of researchers. As a participant in this study, you have the right to send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority (contact details under approvals) related to the handling of your personal information. Your consent to participation is the legal foundation for processing personal data, meaning that without your consent we cannot process your personal data.

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The expected disadvantages to participate are few or none. However, you are encouraged to contact the researchers if you need follow-up after your participation in this study.

VOLUNTARY PARTICIPATION AND THE POSSIBLITY TO WITHDRAW CONSENT (OPT-OUT)

Participation in the study is entirely voluntary. If you wish to take part, you will need to check the box(es) and sign the informed consent on the last page. You can, at any given time, without prior notice and without any reasons withdraw your consent. This will not have any repercussions on any future treatment or contact with health workers. If you decide to withdraw your participation in the project, you can demand that your questionnaire answers will be deleted, unless however, the data have already been analysed or used in scientific publications. If at a later point you wish to withdraw consent or have questions regarding the project, you can contact

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CONSENT FOR PARTICIPATING IN THE RESEARCH PROJECT

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☐ to participate in the survey

I give consent for my personal data to be processed until the end date of the project, in September 2020.

City/Town and date — Participant's Signature

Participant's Name (in BLOCK LETTERS)

Parental Permission (if under 18 years old)

I confirm that I have given information about the research project.

Place and date — Signature

Role in the research project

Section only for those who cannot read and / or write:

Thumb print under:

Witness to sign for those who cannot read and write:

_____

Appendix 9 Information letter

INFORMATION TO PARTICIPANTS IN THE GROUP 1:

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Paper 1 - 4

I

Protocol

Digital Health Intervention to Increase Health Knowledge Related to Diseases of High Public Health Concern in Iringa, Tanzania: Protocol for a Mixed Methods Study

Christine Holst[1], MPhil; Felix Sukums[2], PhD; Bernard Ngowi[3,4], MD, PhD; Lien My Diep[5], MSc; Tewodros Aragie Kebede[6], MSc; Josef Noll[7,8], PhD; Andrea Sylvia Winkler[9,10], MD, PhD

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[5]Oslo Centre for Biostatistics & Epidemiology, Oslo University Hospital, Oslo, Norway
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Abstract

Background: Traditionally, health promotion and health education have been provided to communities in the global south in the form of leaflets or orally by health care workers. Digital health interventions (DHIs) such as digital health messages accessed by smartphones have the potential to reach more people at a lower cost and to contribute to strengthening of health care systems. The DHI in this study focuses on disseminating digital health education regarding 3 disease complexes of high public health concern: HIV/AIDS, tuberculosis, and *Taenia solium* (neuro)cysticercosis or taeniasis, a parasitic zoonotic disease that requires a One Health approach. The DHI presents the participants with animated health videos (animations) and provides access to information spots (InfoSpots) with a free-of-charge digital health platform containing messages about health to rural Tanzanian communities.

Objective: The objective of this study is to measure the effect of the DHI on health knowledge uptake and retention over time in the rural communities.

Methods: This is a mixed methods study including a nonrandomized controlled trial and qualitative interviews conducted in rural Tanzania. A health platform containing digital health messages for the communities was developed prior to the study. The health messages consist of text, pictures, quizzes, and animations of everyday stories, aimed at disease prevention and early treatment. The baseline and immediate postintervention assessments were completed in Iringa, Tanzania in May 2019. The participants were interviewed by enumerators and completed questionnaires regarding health knowledge. Participants in the intervention group were exposed to 3 different health animations once on a tablet device. The participants' health knowledge was assessed again immediately after the exposure. The first follow-up survey was undertaken in August 2019. The InfoSpots with the digital health platform were thereafter launched in the intervention villages in November 2019. Qualitative interviews were undertaken in February 2020. The second follow-up was completed in June 2020.

Results: A total of 600 participants have been enrolled in the trial. We will assess (1) the difference in knowledge scores between baseline and the immediate postintervention assessments in the intervention group and (2) the difference in knowledge scores between the intervention and control groups at baseline, 3 and 6 months post-DHI rollout. Since a randomized design did not prove feasible, potential confounders (eg, age, gender, education, and time of exposure) may be introduced, and results will be adjusted. Data analysis for the 35 qualitative interviews is currently ongoing, and perspectives and experiences related to use and nonuse of the InfoSpots are being explored.

Conclusions: The data have been collected, and the analysis is ongoing in this digital health study, aimed at evaluating the effects of a DHI based on relevant health messages. The publications of results can be expected this year.

Trial Registration: ClinicalTrials.gov NCT03808597; https://clinicaltrials.gov/ct2/show/NCT03808597

International Registered Report Identifier (IRRID): RR1-10.2196/25128

(JMIR Res Protoc 2021;10(4):e25128) doi: 10.2196/25128

KEYWORDS

digital health; eHealth; mHealth; DigI; Tanzania; digital health messages; digital health promotion; digital health education; HIV/AIDS; tuberculosis

Introduction

Background

Health education is seen as an essential component in efforts to prevent diseases [1]; furthermore, it is the part of health care that is concerned with promotion of healthy behavior [2]. Health education and health promotion are two terms that are sometimes used interchangeably [3]. Health promotion has a wider meaning, defined by the Ottawa charter in 1986 as "the process of enabling people to increase control over, and to improve, their health" [4]. The World Health Organization defines health literacy as something that "represents the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health" [5]. Health literacy is a key determinant of health; limited health literacy is an underestimated problem and is associated with risky behavior, poorer health, less self-management, and more hospitalization and health care costs [6]. Health literacy is often perceived as the outcome of health education [7].

Increased health literacy levels have been demonstrated, among others, after basic education among adults [8], tailored rehabilitation education among patients who underwent a breast operation [9], education through active learning among elders in rural areas [10], and health belief model–based health education among patients with hypertension [11]. However, additional studies are needed to provide evidence on the best context-specific approach to improve impact on health literacy, health outcomes, and ultimately health disparities.

Strategies to increase understanding and individual health literacy can include delivering only a few health messages at a time, using plain and jargon-free language, resorting to visual aids, and using the teach-back method for health care workers when talking to patients [12].

Creating awareness of the prevalence, causes and transmission, signs and symptoms, and possibilities of treatment and prevention of a disease aims to provide early treatment and increase appropriate use of health care services. This is important in order to reduce the burden of infectious diseases like HIV/AIDS, tuberculosis (TB), and *Taenia solium* (neuro)cysticercosis or taeniasis (TSCT) in rural areas in the global south, where access to health care services may be starkly limited. Traditionally, health education has been the task of health workers or community health workers in such areas.

Over two-thirds (25.7 million) of all people living with HIV live in regions of Africa [13]. Young women between the ages of 15 and 24 years are twice as likely to be living with HIV as men, and in sub-Saharan Africa, girls account for 5 in 6 new infections among adolescents aged 15 to 19 years [14]. Complete and reliable information, rapid diagnosis, and early treatment and care are essential to control the virus, alleviate disease symptoms, and prevent transmission. TB treatment saved over 60 million lives globally between 2000 and 2020. However, despite TB being both treatable and curable, 1.4 million people died from the disease in 2019 [15]. The most efficient way to save lives, apart from prevention, is to diagnose and treat TB as early as possible. TSCT is an emerging but neglected parasitic and zoonotic disease (ie, both humans and animals are infected) caused by the tapeworm *T.solium*. In humans, the disease manifests mainly as neurocysticercosis (ie, the settlement of tapeworm larvae in the brain), the most frequent preventable cause of epilepsy in *T. solium* endemic areas of sub-Saharan Africa [16]. TSCT, endemic in Tanzania [17], has been listed as a priority disease for international attention towards elimination and is part of a wider aim to alleviate poverty in the same regions [18]. Iringa in southern Tanzania is endemic also for the other 2 diseases covered in this study, with one of the highest HIV prevalence estimates in the country in 2016 [19] and a notification rate for TB above the national average in 2018 [20].

Today's education channels are changing. Therefore, health education interventions must meet the target population at respective levels of access and technology [21] and rely on the characteristics of the technology available [22]. Digital health interventions (DHI) representing "a discrete functionality of the digital technology to achieve health sector objectives" [23] and electronic health (eHealth), defined as the use of information and communication technologies for health [24], are now understood as pivotal in order to provide better care to a larger

number of people, especially those most in need [25]. eHealth can be regarded as a tool to provide the public with health messages and support as well as to motivate *clients* to care about health. According to the World Health Organization [23], clients are "members of the public that are potential or current users of health services, including promotion activities," the latter playing a vital role in their health management and disease prevention decisions. eHealth includes mobile health, defined as the use of mobile wireless technologies for health [26], a useful tool to deliver education and promote health-seeking behavior and health-related lifestyle decisions, since people nowadays can be contacted more easily through their phones [27].

Within the Sustainable Development Goals endorsed by the United Nations in 2015, SGD 3, which is about ensuring healthy lives and promoting well-being for all at all ages [28], will not be achieved without giving people access to the information they need in order to live healthier lives. The use of digital tools and technology is also emphasized as a strategy for improving health literacy [29]. However, access to digital information is not enough; in order to utilize digital health resources, a basic digital literacy skill set is needed [30].

The use of smart devices and mobile data services is taken up rapidly, and it is likely that a larger part of the population in, for example, sub-Saharan Africa will have access to both of these in the near future [31]. The Tanzania Communications Regulatory Authority regularly produces reports of mobile service penetration including internet services. The reports do not provide distribution of the services by region or district. The smartphone penetration in Iringa is unknown, but in 2016, 25.3% of national mobile connections were smartphones [32]. The cost of smartphones is a critical barrier to mobile internet adoption in sub-Saharan Africa, especially among people living in rural areas [33], leaving reasons to believe that less than a quarter of the population in rural Iringa have access to other health education than via health care workers at dispensaries with various opening hours.

The Non-discriminating Access for Digital Inclusion project (hereby referred to as the DigI project) addressed this gap by providing access to free digital health messages [34] related to HIV, TB, and TSCT in 2 rural villages in Iringa, Tanzania. Eleven partners from 8 countries [35] are collaborating in the project, including local and international researchers with extensive experience within the aforementioned diseases. The multi- and interdisciplinary approach used in the development and digitization of the health messages referred to in this protocol are further described in a recent paper [36]. In the DigI project, a key performance indicator framework was developed [37], and it is assumed that the digital health intervention described in this protocol will increase digital literacy in addition to health knowledge.

Objectives

The overarching objective of this study is to assess the effect of the DHI described in the following paragraphs aiming to improve health knowledge in the rural communities of Iringa district, Tanzania. The results will contribute to the body of evidence on the impact of digital health education and promotion in a rural setting in the global south.

The effect of the DHI will be assessed by (1) the health knowledge uptake, comparing baseline assessment (T0) scores and immediate postassessment (T1) scores of the intervention group, after exposure to 3 animations (the first part of the intervention, hereby referred to as Part 1); (2) health knowledge retention, comparing baseline assessment (T0) scores with the first 3-month follow-up (T2) scores after exposure to Part 1 and with the final follow-up (T4) scores of the intervention group, 6 months post InfoSpot rollout (the second part of the intervention, hereby referred to as Part 2); (3) a comparison between the intervention and control groups regarding the changes from T0 to T2 and T4 after participation in Part 1 and Part 2; and (4) an exploration of the perspectives and experiences of the DHI among local users and nonusers using semistructured interviews (T3), after participation in Part 1 and Part 2.

Methods

This study deploys mixed methods, including a quantitative survey in a nonrandomized controlled trial, in addition to qualitative semistructured interviews.

Location

The study is conducted in the Iringa district, selected specifically because the prevalences of all 3 diseases are high and it is a rural district in which many villages do not have access to the internet. Migoli and Izazi villages were chosen as intervention villages at an early stage by the DigI team because they are easily accessible from the highway between Iringa town and Dodoma. Kimande and Idodi were chosen as control villages because they are comparable with regards to geographic, demographic, and socioeconomic features to the intervention villages and deemed to be away far enough to keep knowledge contamination by the intervention villages to a minimum. The closest intervention village (Izazi) is located about 32 km from the closest control village (Kimande). However, the road between the 2 villages spans 124 km.

See Table 1 for detailed information on the activities undertaken at the study sites, from April 2019 to June 2020. The health knowledge, health literacy, and digital literacy questions in the questionnaires are identical in T0, T1, T2, and T4.

Table 1. Activities at the study sites at each time point.

Activities	April 2019 - May 2019			August 2019	November 2019	February 2020	June 2020
	T0[a]	Part 1[b]	T1[c]	T2[d]	Part 2[e]	T3[f]	T4[d]
Intervention group							
Group involved in assessments?	Yes	Yes (supervised)	Yes	Yes	Yes (voluntarily, unsupervised)	Yes	Yes
Assessments	40 HKQ[g], 6 HLQ[h], 5 DLQ[i]	N/A[j]	40 HKQ	40 HKQ, 6 HLQ, 5 DLQ	N/A	Semistructured interviews	40 HKQ, 6 HLQ, 5 DLQ, 9 UIH[k]
Sample size, n	300	300	300	300 (minus any dropouts)	300 (minus any dropouts)	35	300 (minus any dropouts)
Control group							
Group involved in assessments?	Yes	No	No	Yes	No	No	Yes
Assessments	40 HKQ, 6 HLQ, 5 DLQ	N/A	N/A	40 HKQ, 6 HLQ, 5 DLQ	N/A	N/A	40 HKQ, 6 HLQ, 5 DLQ
Sample size, n	300	N/A	N/A	300 (minus any dropouts)	N/A	N/A	300 (minus any dropouts)

[a]Baseline assessment, which includes baseline data collection in both groups.

[b]Immediately after T0, the participants in the intervention group are exposed to 3 animations.

[c]Postassessment immediately following Part 1.

[d]T2 and T4 are the follow-up assessments.

[e]Rollout of the second part of the intervention (InfoSpots).

[f]Qualitative interviews.

[g]HKQ: health knowledge questions.

[h]HLQ: health literacy questions.

[i]DLQ: digital literacy questions.

[j]N/A: not applicable.

[k]UIH: use of the InfoSpots and digital health platform.

Description of the Digital Health Intervention

The intervention described in this protocol is composed of 2 components or parts.

Part 1

In April and May 2019, the participants had supervised exposure to 3 animated health videos (hereby referred to as animations).

The participants in the intervention group received the first part of the intervention immediately after the baseline questionnaire. They were exposed to 3 health animations on a 7-inch tablet. These animations contain health messages on (1) HIV/AIDS, (2) TB, and (3) TSCT in the local language (Kiswahili). The health messages explain aspects related to disease prevalence, causes and transmission, signs and symptoms, as well as treatment and prevention. The animations are between 3 minutes and 7 minutes long. They tell personal stories of ordinary people in the community. The stories address the particular disease and show how a person becomes infected, develops signs and symptoms, and can get medical care and how spreading of the disease can be prevented within the communities. The HIV/AIDS animation depicts the story of a woman, recently married, who discovers that she is infected with the virus. The story illustrates how one can get infected by a person one knows and trusts, but also how one can live a fairly normal life with the right medical treatment. The TB animation presents the story of a farmer who gets diagnosed with TB after showing symptoms of TB disease. The animation emphasizes disease prevention efforts covering individual, family, and community levels. The third animation tells the story of a grandfather who gets sick after consuming undercooked pork. The animation focuses on hygiene, hygienic animal handling, and medical treatment if TSCT symptoms occur. All animations can be found online, in both English and Kiswahili [34] (the English versions can be viewed in Multimedia Appendices 1-3). The health knowledge questions from the baseline questionnaire were immediately repeated after the participants in the intervention group were exposed to the animations. Subsequent to the last question, the enumerators explained where and when the information spots (InfoSpots) were planned to be installed and that the participants could access the health messages and internet for free in these local InfoSpots.

Part 2

In November 2019, we provided unsupervised community access to InfoSpots providing free health education in the form of text, pictures, quizzes, and animations.

The InfoSpots containing the digital health platform (Multimedia Appendix 4) and providing intervention villages with free access to digital health messages related to the aforementioned diseases were implemented in Tanzania in November 2019. The digital health platform is now accessible free-of-charge, either through people's own devices, such as smartphones, laptop computers, or tablet devices, or through available community tablets in the InfoSpots, provided by the DigI project to offer access for people without their own devices. In Izazi and Migoli, InfoSpots are located in the village offices, at the local dispensaries, and at the local high school (only in Migoli). The InfoSpots are available for all clients in the intervention villages, not only for the participants in the study described in this protocol.

When clients access the digital health platform, they may choose an area of interest, for example TSCT. Here, they are able to read key messages in all areas: prevalence, causes and transmission, signs and symptoms, treatment and prevention. The key messages are illustrated with snapshots from the animations. Clients are able to answer quizzes, and the correct answers are revealed at the end of each quiz. In addition to text, there are animations for each of the 3 diseases, which can be streamed over a local server. Health messages related to other diseases are also available.

Study Design

Randomization of subvillages, households (HH), or participants to either the intervention or control group within the villages was not possible, as the InfoSpots are available for all people in the intervention villages and the risk of contamination (knowledge transfer) between participants in the 2 groups would have been too pronounced. This resulted in choosing a nonrandomized design. However, a random sample of participants was selected from the villages as described in the following paragraphs.

To complement the quantitative findings, semistructured interviews with participants in the intervention villages were included to explore experiences and perspectives related to the intervention.

Study Population

In Tanzania, 38 million of the 58 million people (65.5% of the population) live in rural areas [38]. Many of the communities are hard to access due to the poorly developed infrastructure. Iringa district, with a projected population of 254,032 in 2019 [39], is located in the southern Highlands of Tanzania bordering the Mbeya, Njombe, Morogoro, Dodoma, and Singida regions. About three-quarters of the adult population are able to read, and agricultural activities play the most important roles in employment in rural Iringa, generating close to the total gross domestic product [40]. In a study from 2017, 6 of 10 adults in Iringa were likely to have at least a primary school education [41]. Almost three-quarters of households in Iringa have earthen floors, and half of the houses have mud walls [40]. One-quarter of the households are female headed, mainly due to the HIV/AIDS epidemic [42].

The latest population census in Tanzania was in 2012 [43], with a total population of 5281 in Izazi, 10,937 in Migoli, 10,202 in Idodi, and 14,420 in Itunundu, the area that covers Kimande. The total populations in the study villages were much lower than depicted in the census according to the consulted village executive officers: 6233 people in Migoli and 1839 people in Izazi. In the control villages, the village executive officers reported the populations to be 3562 in Kimande and 3601 in Idodi.

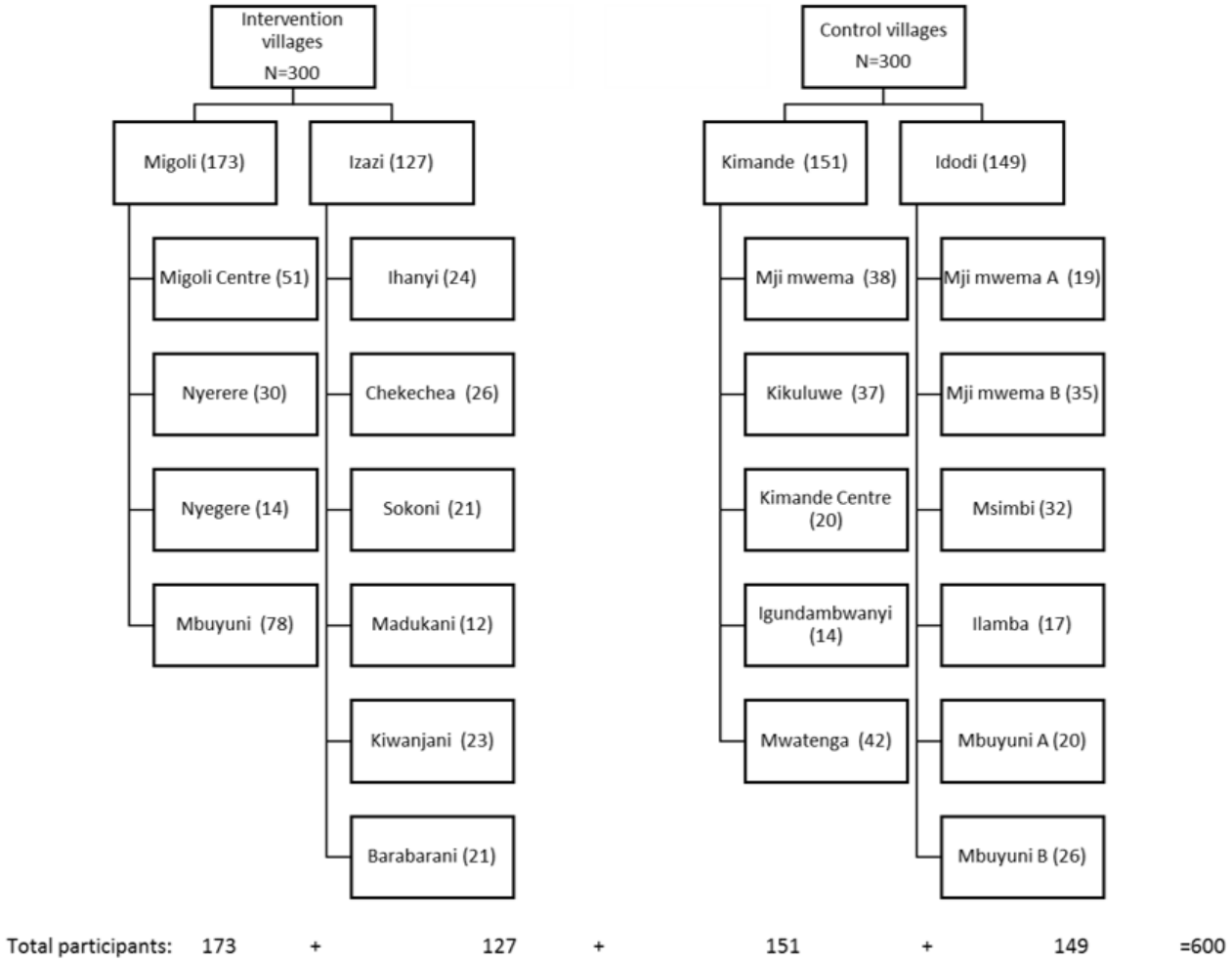
Participants and Recruitment

Participants were recruited from subvillage lists during 2 phases. The early phase took place in April 2019. Lists of HHs were constructed at the village level based on the village register of inhabitants. In all 4 project villages, migration due to work opportunities is part of the population dynamics. We experienced that the initial lists, created at the village level, consisted of numerous HHs that had already moved to other places and that some of the randomly selected HHs were absent. Consequently, additional lists were created in May 2019, achieved by the subvillage chairpersons going door to door in their respective communities to complete and update the list of the subvillage HHs. The HHs with participants that were already enrolled in the study were removed from the updated subvillage lists but kept in the study, and additional HHs were selected to meet the required sample size. These 2 lists are the foundation of the selected HHs from each subvillage, according to probability proportionate to size [44]. Please see Multimedia Appendix 5 for the sampling plan containing calculations of the proportions to be selected from each subvillage and the flow diagram of participants from each village and subvillage in Figure 1.

The sampling unit in this study is the HH, randomly selected by a random number generator from the subvillage lists. We used the Kish grid [45], which is a sampling method using a preassigned table of random numbers when selecting the one participant per HH [46].

During the process, the subvillage chairpersons guided each of the 6 enumerators to each of the selected HHs in their respective subvillages. All communication between the research team and the participant was conducted in the local language. The enumerators were properly introduced by the village chairpersons, and the HHs were reassured of the trustworthiness of the research project by the chairpersons. Following a brief presentation of the study by the enumerator, the approached HH member, normally the head of the HH, sat with the enumerator and listed all HH members so that the enumerator could randomly select a participant from the HH via the Kish selection method.

Figure 1. Participants from the respective groups, villages, and subvillages.



The inclusion criteria are (1) aged 15-45 years; (2) permanently living in the randomly selected HH or, at least, planning to not move during the next 8 months; (3) being capable and willing to sign an informed consent form or, in the case of illiterate participants, to sign with their thumbprint.

The exclusion criteria are (1) aged >45 years or <15 years; (2) planning to be absent from the village for more than 3 weeks in the upcoming 8 months; (3) not being able or willing to give written informed consent or, in the case of illiterate participants, a thumbprint.

The participants in the intervention group were assessed for baseline health knowledge (T0) related to the intervention diseases in Migoli and Izazi (the intervention villages) before being exposed to the 3 animations. The latter represent the first part of the DHI, Part 1, or "description of the intervention." Consequently, the participants of the same group were given the same questions as in the baseline questionnaire. We call this the immediate post assessment (T1). T0, Part 1 of the DHI, and T1 all took place on the same day for the each of the participants in the intervention group. The control group consists of another 300 individuals in the control villages Idodi and Kimande. In the control villages, the participants were assessed for their baseline health knowledge (T0) in the same way as in the intervention group and were given the same questionnaire.

The participants in both groups were followed up in T2 with the same questions as in T0. When the data collection from T2 was completed, village InfoSpots with access to the digital health platform with the health messages were launched in the intervention villages. This represents the second part of the DHI: Part 2. Follow-up surveys with the same questions as in T0 were repeated in both groups 6 months after the rollout of Part 2 (T4), in June 2020.

The participants in the qualitative component were randomly selected from the list of participants enrolled in the quantitative study or were recruited on site as users of the InfoSpots.

Outcomes

The intervention period lasted from April 2019 until June 2020. Primary outcomes of this study are focusing on health knowledge retention in the intervention group compared to the control group, 6 months after Part 2, which is 12 months after Part 1. Secondary outcomes are focusing on immediate health knowledge uptake in the intervention group only, as a result of the exposure to the animations in Part 1.

Ethics and Informed Consent

This protocol is registered in Helseforsk, University of Oslo, Norway, and the project has been assessed by the Norwegian Centre for Research Data (NSD), reference number 59643.

Ethical approval from the National Institute for Medical Research in Tanzania has been granted twice with the reference number NIMR/HQ/R.8a/Vol IX/2947. The study is registered in ClinicalTrials.gov with ID: NCT03808597. Additionally, the first author was provided with a research permit from the Tanzanian Commission for Science and Technology.

All participants were briefed about the aims of the study, their voluntary participation, and their rights as participants according to The European Union General Data Protection Regulation (GDPR). The participants were informed about the types of personal data collected (name, sex, age, education, religion, mobile number), where the data was going to be kept, and for how long and who would have access to these data. In addition to this oral briefing, participants were given a letter containing the information, along with the contact information of the local research entity. Informed consent forms were signed by all participants willing to participate in the study and by one enumerator. The forms were developed with support from NSD.

We are fully committed to good ethical and legal practice. All information about the participants will be dealt with confidentially and will remain deidentified for 2 years after the end of the entire project. The deidentification code and the collected sensitive data will be stored separately in the University of Oslo's Services for Sensitive Data (TSD) [47]. In 2022, the deidentification code will be deleted, and the material will remain anonymous for public reuse. A possible benefit for the participants taking part in this study is an increase in knowledge of the highly prevalent diseases of HIV/AIDS, TB, and TSCT. The InfoSpots with the digital health platform will continue to be available after the intervention period is over. No intervention was given to the control group, but when data collection ended in June 2020, the InfoSpots with the same digital health platform were implemented in the control villages.

This study focuses solely on the participants' health knowledge, not on the participants' own health status or personal health data. The study participants were not given any compensation for taking part in the study.

Data Collection

The data collection consists of a quantitative part, spanning from April 2019 to June 2020, and a qualitative part, conducted in February 2020.

Collection of Quantitative Data Through Questionnaires

The questionnaire (Multimedia Appendix 6) used in T0, T1, T2, and T4 contains health knowledge questions concerning all 3 diseases, covering the domains of prevalence, causes and transmission, signs and symptoms, as well as treatment and prevention. The prevalence questions explored whether the participants had heard about the diseases. In the causes and transmission domain, we questioned the participants about how the disease transmits or what the cause of the infection is. The participants were asked to describe signs and symptoms for the relevant disease and how the diseases are diagnosed. Further, we asked questions related to treatment and cure. Lastly, the participant answered questions regarding different prevention strategies, both for individuals and communities. The questions can have one or several correct answers. The enumerators read the questions to the participants but did not inform people about the possible answers. All questions are thus open-ended. The questionnaire contains questions accompanied by a list of possible answers, so the enumerator can check the answer provided by the participant.

We used 13 questions in the HIV/AIDS section: 1 related to prevalence, 4 related to causes and transmission, 2 related to signs and symptoms, 3 related to treatment, and 3 related to prevention. We also asked the participants where they could find sufficient and reliable health information on HIV/AIDS in their communities. In the next section, the participants answered 10 questions related to TB: 1 in the prevalence domain, 2 in the causes and transmission domain, 2 related to the signs and symptoms, 3 related to treatment and, finally, 2 regarding prevention. The last section was comprised of 17 questions related to TSCT. Since this is a relatively unknown disease, we came up with 4 questions related to the prevalence of the disease, in the case of both pork tapeworm and cysticercosis. We used 4 questions in the causes and transmission domain, 4 questions in the signs and symptom domain, 1 question related to treatment, and 4 questions concerning prevention. The participants also answered 6 health literacy questions, in addition to 5 digital literacy questions.

During T4, we asked the participants of the intervention group whether they had taken advantage of the InfoSpots and the digital health platform and which part of the platform they had accessed, before repeating the questionnaire.

The study questionnaire, containing health knowledge questions regarding our 3 diseases of interest, digital and health literacy, and the use of the InfoSpots, was developed within the DigI group over a 6-month period in 2018. We used validated questions from earlier studies [48] and reports (TACAIDS/Ministry of Home Affairs, 2012; International Organisation for Migration, 2014) from various collaborations with DigI team members, as much as possible.

The DigI group had developed the key messages we wanted to convey in the health animations [36] from reliable and approved health education sources. Some of the questions were derived from this work. One key message within the HIV section, for example that girls and young women are the most vulnerable group, was emphasized in the HIV animation, and the question derived from this key message simply reads, "Which group do you think is most vulnerable to HIV infection?"

When collecting data from the questionnaire, an Android App called KoBoCollect [49] was used. The questionnaire was uploaded to KoBoToolbox [50], software for conducting field data collection in challenging environments. This is a free, open-source tool that allows users to create and deploy questionnaires to be used in an area with no internet connection.

Accessing KoBoToolbox is only possible with a username and password. The questionnaire was shared with the enumerators, who were able to submit data but could not access the collected information. Once the tablets were connected to Wi-Fi or mobile internet, the app automatically transferred the collected data to the online platform KoBoToolbox.

During the first survey round, the participants were given questions concerning their demographic information. This personal information — name, mobile phone number, and village — was registered on the HH list but not in KoBoCollect. Neither was it uploaded to KoBoToolbox, so to reduce the risk of data privacy violation. A digital object identifier (DOI) was created for each participant, and the DOI was registered in KoBoCollect along with age and sex. Thus, no personal information was uploaded to KoBoToolbox. The personal identification key was stored directly in TSD via the tablets and not transmitted via email.

The reason for asking the participants for their names and mobile phone numbers was to be able to relocate the participants in the follow-up surveys. During the follow-ups in T2 and T4, the research staff had lists with names and DOIs. When entering the data from the follow-ups, the enumerators only had to identify the participants according to the list and to use the DOI when collecting new data in KoBoCollect.

Collection of Qualitative Data Through Semistructured Interviews

In order to complement the quantitative data, 35 semistructured interviews with people from the intervention villages were conducted at T3 (ie, 3 months after Part 2). The main aim was to understand the respondents' perspectives on the intervention [51]. Results from this data collection will provide in-depth information on how the intervention was perceived and received in the communities. It may also shed light on the possible effects of the intervention, raise opportunities and problems, and provide a different view on the use of the InfoSpots along with the digital health messages.

An interview guide (Multimedia Appendix 7) was prepared in order to steer the conversations and to make sure that no question remained unanswered or unclear. The interviews were conducted between clients in the intervention villages and the first author of this paper, in collaboration with a Tanzanian Kiswahili translator. The participants were picked randomly from the same lists as in the quantitative study and by convenience sampling in and around the InfoSpots, to include users not associated with the quantitative study. The semistructured interviews were recorded with a recording app from the University of Oslo and transcribed afterwards. The records and transcriptions were stored separately from the deidentification code, in TSD, to ensure anonymity and fulfil the data handling requirements of the GDPR. The deidentification code will be deleted 2 years after the project is completed. Afterwards, the data will remain anonymous in the NSD archives.

Training and Piloting of the Questionnaire

A 3-day training for the enumerators was held in Morogoro, Tanzania, in March 2019; 6 enumerators took part. The enumerators were familiarized with the tablets and the questionnaire installed on the tablets. They practiced the registration in TSD and learned how to provide the participant with the relevant information and contact details, in addition to obtaining informed consent. Mock interviews, using the tablets with a training version of the questionnaire, followed by submission of questionnaires via KoBoCollect, were staged.

The team went to the piloting site, Luhindo primary school, located about 40 minutes from Morogoro, on the second day. Partners from Sokoine University of Agriculture had arranged to pilot the questionnaire with a group of people working and living in the Morogoro area. Altogether, 50 submissions were entered into KoBoCollect.

On the final day of training, the Kish selection method was practiced. Registration of all participants from the pilot into TSD the day prior was performed, assuring that the personal data were stored carefully in TSD whilst their anonymous answers to the disease knowledge, digital literacy, and health literacy questions were transferred to KoBoToolbox.

All the posed questions were reviewed by the pilot participants. Seven questions were altered, and some alternative responses were added.

Prior to the training, the study tools had been translated from English to Swahili. After the training, the questionnaire was revised in the local language and translated back to English. This procedure was also applied to the consent forms and information letter.

Data Analysis Plan

Analysis of Quantitative Data

We will assess the effect of the DHI by calculating the number of correct answers and the knowledge scores in both groups at all set time points. The first calculation will be related to the baseline assessment (T0) in the intervention and control group, the immediate postassessment (T1) in the intervention group, followed by the number of correct answers and scores at 3 months (T2) post Part 1 and 6 months (T4) post Part 2, in both groups. The scores will be calculated with 1 point for each correct response and summarized for each disease and the various domains (eg, causes and transmission or signs and symptoms). The number of correct answers and scores will be applied when comparing the 2 groups and the same group at different time points. The number of correct answers and the scores will be used to follow individual participants over time, as well as to indicate the trends in the increase in health knowledge uptake and retention at community level.

A sample size of approximately 460 participants was required to detect a difference of 15% to 20% between 2 groups with and without intervention, assuming that the proportion of correct responses was 50% in the group without intervention. A 2-sided significance level of .016 and 80% power were used. The significance level was set at .016 (using Bonferroni correction) to compensate for 3 time points since it was not known which time point would become relevant for the comparison between the groups. We decided to include 600 participants to increase precision of the key estimates and take dropouts into account.

The data will be analyzed in Stata/SE version 16. The McNemar test for paired data will be applied to determine marginal homogeneity of 2 dichotomous variables. The scores will be assessed against other variables such as age, education level, and gender. Summary tables with calculated averages (mean,

median, and mode) will be created. We will compare between the groups at baseline, 3 and 12 months, with and without adjusting for variables that could have influenced the respective changes. Mixed-effect models will be used to estimate the difference and monitor the alterations of variables for each question, domain score, and overall score.

Analysis of Qualitative Data

The data from the interviews will be analyzed in the software NVivo. A coding frame will be developed, and a content analysis method will be applied [52]. Themes of interest from the interview guide, as well as new themes found in the data, will be analyzed to contextualize the participants' perspectives and experiences. When analyzing and summarizing the interviews, a table will be developed with excerpts from the most important findings of the qualitative research, alongside quotes from the interviews.

Results

The data collection was completed recently, and no results can be presented at this stage. Recruitment started April 1, 2019 and ended May 25, 2019. The 600 participants recruited have been followed over 1 year. However, 106 participants dropped out before T4, leaving 494 participants for complete follow-up analysis. The InfoSpots were launched in the intervention villages in November 2019 and in the control villages in June 2020. By enabling free-of-charge use of the InfoSpots for all community members, the approach is inclusive and not only focused on empirical findings.

The 35 qualitative interviews were undertaken in February 2020. All data are currently being analyzed, and the results are expected to be published in 2021.

Discussion

The primary aim of this study is to evaluate the effect of the DHI on the rural population in Iringa, Tanzania.

The quantitative part will provide a broad, "hard scientific" overview of the trends in correct answers (ie, knowledge scores) over time within and between intervention and control groups. By counting the number of correct answers before and after the intervention and comparing the knowledge scores of the respective groups, we will be able to see whether the intervention has successfully increased health knowledge in the intervention group.

As the quantitative approach only focuses on numbers, not the people themselves, the team decided to also include a qualitative component. Semistructured interviews will allow the researchers to apply an informal tone with the participants, and the findings will add meanings, opinions, values, feelings, and personal experiences to the quantitative research. The interviews can also function as arenas for discussion and may contribute to the validation of the quantitative findings.

The use of mixed methods will provide a well-founded understanding of the project results [53]. Combining the quantitative with the qualitative findings will lead to a robust set of data, not just to evaluate the DHI but also as a basis for adjusting the intervention regarding implementation of both the digital health messages and the InfoSpots with access to the digital health platform. Drawing upon findings from both research approaches to improve the intervention, the project demonstrates a participatory and community-based component that has the potential to lead to a better, context-specific impact on digital health education of local communities.

Limitations

This study has several limitations. The results may not be applicable to the greater rural population in Tanzania, since only a small number of villages and subvillages were included in the study. Although the study accounted for anticipated dropouts by including 100 additional participants in the study sample, this is an environment in which people shift location frequently. The rate of dropouts may be larger than anticipated in T2 and T4. People in the communities migrate as a result of the season, rainfall, drought, or harvest. A high dropout rate may introduce bias. Dropout analysis will be conducted.

Another limitation is that the participants in the intervention group may have influenced other potential participants of the same group. Data collection for T0 and T1 in the intervention villages was ongoing for 2 months. It is possible that some participants in the intervention group may have contaminated the findings by talking about the health animations they were exposed to in Part 1. Also, the research team cannot control the participants from the intervention group, who might travel to the control villages and inform recruited participants about the DHI.

Conclusions

We anticipate that our study will contribute to increasing knowledge of HIV/AIDS, TB, and TSCT as well as increasing overall health and digital literacy for individuals and communities in Iringa, Tanzania. By providing health messages in a digital format, the participants and their immediate surroundings will increase their health-related knowledge, which has potential to lead to an adaptation in health-seeking behavior, although this was not investigated in our study. Digitization of health information aimed at people in rural areas of sub-Saharan Africa may also contribute to strengthening of health systems, especially in low-income settings.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

"The story of tapeworms" - TSCT animation.
[MOV File , 78062 KB-Multimedia Appendix 1]

Multimedia Appendix 2

"The story of HIV" - HIV animation.
[MP4 File (MP4 Video), 58029 KB-Multimedia Appendix 2]

Multimedia Appendix 3

"The story of TB" - TB animation.
[MP4 File (MP4 Video), 28571 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Screenshot of the digital health platform - health information.
[PNG File , 622 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Sampling plan.
[DOCX File , 15 KB-Multimedia Appendix 5]

Multimedia Appendix 6

Study questionnaire (HIV / TB / TSTC knowledge questions used at T0/T1, T2 and T4).
[PDF File (Adobe PDF File), 398 KB-Multimedia Appendix 6]

Multimedia Appendix 7

Interview guide for qualitative study.
[DOCX File , 12 KB-Multimedia Appendix 7]

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Abbreviations

DHI: digital health intervention
DigI: Non-discriminating Access for Digital Inclusion
DOI: digital object identifier
eHealth: electronic health
GDPR: The EU General Data Protection Regulation HH: Household
NSD: Norwegian Centre for Research Data
TB: tuberculosis
TSCT: *Taenia solium* (neuro)cysticercosis or taeniasis
TSD: Services for Sensitive Data (at University of Oslo)

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II

Tutorial

Development of Digital Health Messages for Rural Populations in Tanzania: Multi- and Interdisciplinary Approach

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Abstract

Background: Health workers have traditionally delivered health promotion and education to rural communities in the Global South in paper leaflet formats or orally. With the rise of digital technologies, health promotion and education can be provided in innovative and more effective formats, which are believed to have a higher impact on disease prevention and treatment.

Objective: The aim of this tutorial is to illustrate how a multi- and interdisciplinary approach can be applied in the design process of digital health messages for use in the Global South.

Methods: The multi- and interdisciplinary team of the Non-discriminating access for Digital Inclusion (DigI) project digitalized and customized available government-approved paper-based health promotion messages into a screen-suitable format. The team worked closely together and used its diverse expertise to develop digital health messages with disease-specific content in Tanzania's national language (Swahili) as well as English. The development process included the following phases: a local needs assessment; identification of government-approved health promotion materials in a nondigital format; identification of key health messages; creation of a practical and engaging story, easy to understand for the general public; drafting of a storyboard for an animated video with review, feedback, and revisions; forward and backward translation; audio recording of the story in both languages; finalization and presentation of the animations; development of relevant questions related to the health messages in each domain; and development of web and mobile apps to access the digital health messages.

Results: Between 2017 and 2019, we developed key health messages, quizzes, and animated health videos to address HIV/AIDS, tuberculosis, Taenia solium cysticercosis and taeniasis, and anthrax, all of which are of public health importance in Tanzania. Feedback from local stakeholders and test users was included in various phases of the process. The 4 videos and other content are available in local information spots on a digital health platform (DigI platform), established by the DigI project, in both Tanzanian Swahili and English.

Conclusions: Our methodological multi- and interdisciplinary approach ensures that the digital health messages for the public are clear, high quality, and align with the government's objectives for health promotion. It also demonstrates the diversity of scientific disciplines required when collaborating on a digital health project. We recommend this approach to be applied to the development of other digital health messages for a wide range of diseases.

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KEYWORDS

digital health; eHealth; mHealth; Tanzania; health education; HIV/AIDS; tuberculosis; cysticercosis; tapeworm; anthrax; mobile phone

Introduction

Background

The World Health Organization (WHO) emphasizes the use of digital technologies to enable people to access information, goods, and services to improve their lives [1]. Sustainable Development Goals number 3 (good health and well-being) [2] and number 9 (industries, innovation, and infrastructure) [3] are both linked to digital health. More specifically, this is reflected by strengthening the capacity for early warning, risk reduction, and management of national and global health risks (target 3.D) and significantly increasing access to information and communication technology (target 9.C). Digital health is connected to multiple disciplines and critically depends on the country and the health system context [4]. Multidisciplinary research is about coordinating efforts that bring several disciplines together to provide complementary contributions in the service of a common goal [5] and is essential in the progress of any high-quality cross-cutting research project today. Interdisciplinarity relates to analyzing, synthesizing, and harmonizing the efforts into a common coordinated and coherent entity [6], and has previously been defined as "a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." [7]

It is well known that health promotion and participation in health promotion activities will be revolutionized by digital innovations and that health literacy increases when people begin using digital tools to access information and make informed decisions related to their own health [8]. However, low levels of literacy and digital skills are barriers to accessing digital information, especially in rural areas of low-income countries [9]. Thus, it is important that the design of a digital solution is inclusive and ensures that users develop the skills needed to take advantage of such digital opportunities [10].

Designing digital health messages for a Global South audience can be challenging considering the abovementioned shortfalls in literacy, digital literacy, access to internet, and access to devices. Power structures, poverty, gender inequality, and health inequities at large, including poor infrastructure, complicate the situation for several groups, including those marginalized. However, the future of health education and health promotion participation in sub-Saharan Africa may very well be digital [11]. The importance of early partnering with local stakeholders and users in a co-design process is crucial for success [12]. In the next section, we will present our project exemplified by a case study from Tanzania, before illustrating how we developed content for a global digital health intervention using a multi- and interdisciplinary approach.

The Non-Discriminating Access for Digital Inclusion Project: Digital Health Promotion and Education in Tanzania

In Tanzania, community health workers and health facilities, in addition to nongovernmental organizations, have traditionally provided health promotion and education orally or in printed format (leaflets, billboards, banners, posters, etc) to neighborhoods and communities [13]. The Tanzanian digital landscape is evolving rapidly, and together with significant economic growth [14], we have witnessed increasing penetration of mobile phones in both urban and rural areas and one of the most advanced mobile money markets in sub-Saharan Africa [15]. Tanzania, East Africa's third largest economy with 54.2 million people, had 43.6 million mobile phone subscribers as of June 2018 (80% of the population), compared with 40.1 million a year earlier and in contrast to only 10.2 out of 40.7 million people (25% of the population) in 2007 [16]. However, only 13% of subscribers reported to own a smartphone in 2017 [17]. The Tanzania Digital Health Strategy 2019-2024 seeks to expand the use of digital health technologies to promote healthy behavior through access to health information, education, and communication [18]. The Tanzanian government intends to scale up and intensify the achievements of the previous eHealth Strategy 2013-2018, which implemented various electronic information systems (including the use of television, radio, social media, etc) to provide and promote health education. Although community-based health services focus on health promotion and disease prevention, mobile health and social media can be more widely used to provide quality health

education, information, and communication, enabling communities to adopt healthier behaviors and to increase their health literacy. Impactful health messages are clearly needed in the global fight against infectious diseases such as HIV/AIDS, tuberculosis (TB), and zoonosis (diseases that affect animals and humans) such as Taenia solium cysticercosis and taeniasis (TSCT) and anthrax. The Tanzanian Health Sector Strategic Plan states that the disease control programs for HIV/AIDS and TB have been successful in the areas of early detection and treatment. However, further improvements are needed in the field of prevention [13]. As for TSCT, which is recognized as a neglected tropical disease by the WHO [19], prevention is crucial because the disease is highly endemic in Tanzania [20]. Anthrax is an emerging neglected zoonotic disease, endemic in the African region and present in the north of Tanzania (especially in the Maasai communities) where repeated outbreaks in livestock, wildlife, and humans have made clear the need to strengthen prevention strategies [21].

The Non-discriminating access for Digital Inclusion (DigI) project, in which the development of health messages described in this paper is part, represents a classical multi- and interdisciplinary project funded as an innovation project, with the aim of connecting rural villages to digital information. The DigI project's multi- and interdisciplinary team, comprising 11 partners from 8 countries, includes scientists in the disciplines of humanities, social sciences, formal sciences, and applied sciences. These main disciplines include a variety of subdisciplines: medicine and health, epidemiology, public health, veterinary medicine, electronic engineering, visual and creative arts with graphic and interaction design, human-computer interaction, communication, education or educational technology, information science, internet science, and ethics. Elements from anthropology, human geography, health psychology, and sociology of health and illness have been applied in the various steps of planning and implementation of this project. Through our collaboration of Tanzanian, German, Norwegian, Rwandan, and American partners, our objective is to develop digital health messages by converting printed materials into digital formats such as animated videos (animations), quizzes, graphics, and texts. The majority of the DigI partners either belonged to the information technology (IT) and design task force, or the health task force. The Tanzanian and German project partners with backgrounds in health and medicine provided expertise on HIV/AIDS, TB, TSCT, and anthrax. The team was able to draw on their many years of experience working with each disease in the target areas. The selected diseases in the DigI project are endemic in the chosen geographical areas and thus are important diseases in the Tanzanian public health context. All these diseases are of high priority and require preventive strategies including information dissemination to communities and populations.

A digital health education platform, the DigI platform [22], herein referred to as *the platform* was planned and developed between 2017 and 2019 by the DigI team. It consists of a dashboard (Multimedia Appendix 1) where viewers can navigate between various pages with information about the diseases. The platform features texts, quizzes, graphics, and animated videos that are available for all. The platform with the health messages described in this paper was established as part of an information spot (InfoSpot) in the rural villages of Selela and Esilalei in the Arusha region (for anthrax) and Migoli and Izazi in the Iringa region (for HIV/AIDS, TB, and TSCT) in November 2019. It is possible to access the health messages on the platform, even if the user is not connected to the internet, because the platform is also locally stored on a village server.

In this tutorial, we want to share our contextualization of digital health message creation for a broader audience to illustrate how it is beneficial to take advantage of the various backgrounds in a multinational and multi- and interdisciplinary digital health project. Each step of the process is illustrated with a general takeaway message and lessons learned from our project.

Methods

Definition of Terms

In this paper, the terms health promotion, health education, health communication, health information, health literacy, health message, and digital literacy are used. Here, health education and health promotion are 2 terms that are sometimes used interchangeably [23], whereas health information and health communication are broad terms simply referring to all information and communication related to health. Moreover, health literacy can be explained as a result of successful campaigns of all the aforementioned terms, and health messages are pieces of information designed for health behavior change. In Multimedia Appendix 2 [23-32], we have provided definitions of the terms to offer the reader a more detailed explanation of their differences.

Development of the Digital Content

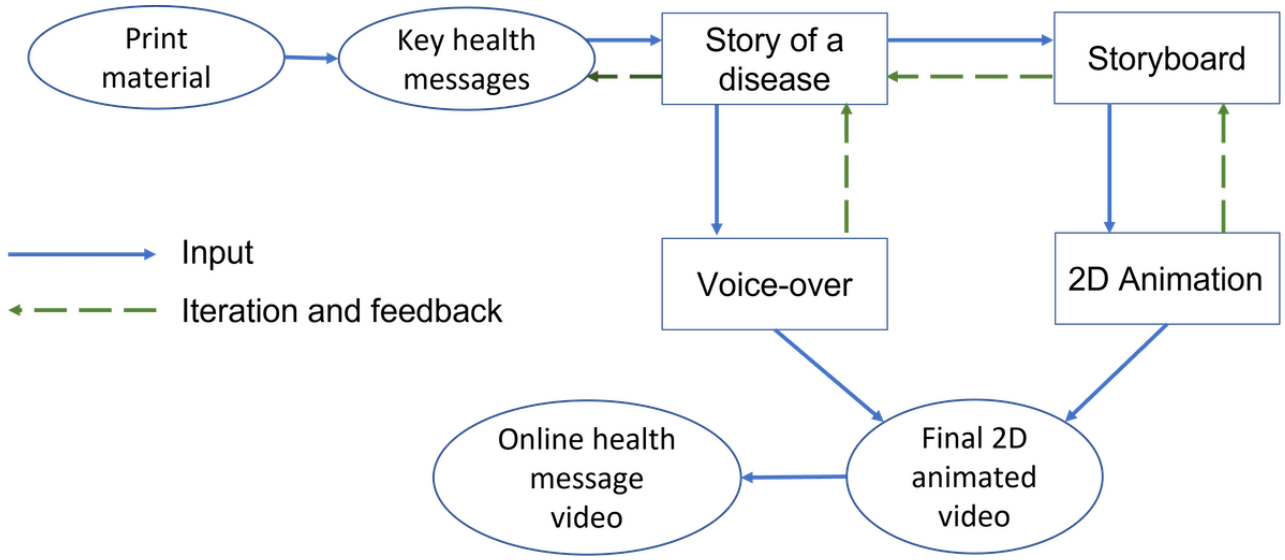
Overview

On the basis of the information in the print materials, the digitization process began by creating a narrative story capturing the key health messages, with elements of storytelling to maintain the *clients'* attention. *Clients* is defined as "members of the public that are potential or current users of health services, including promotion activities" [33]. The stories were adapted to a rural Tanzanian village-life setting, making them valid and authentic for the clients, with an emphasis on keeping the stories simple, truthful, and emotional at times. On the basis of these imaginary stories, storyboards (drawings with captions below each image or scene) were produced to visualize the narrative so that the DigI team could provide more informed feedback. Once the storyboards were approved, the next step consisted of developing animated videos with voiceover narrations in both English and Swahili. The DigI team iterated a series of design-test-evaluate-design cycles, whereby a story was tested and improved accordingly. The digitization process is illustrated in Figure 1.

The exact approach to content creation was established based on the internal discussions. We aimed to meet clients' needs, values, language, and culture and emphasized the rural Tanzanian context throughout the development process.

In the following 10 sections, each phase of our methodological approach is described in detail, with general advice and takeaway messages for each section.

Figure 1. Health message digitization process.



A Local Needs Assessment

A human-centered design process [34] is required when developing apps to meet user requirements. In our project, a survey was conducted at the very beginning to gather users' needs in the project villages, and a participatory and community-driven approach was deliberately preferred to the introduction of the digital health project from outside [35]. Before developing the digital health messages, several site visits were undertaken by health- and IT-researchers in the project. During these visits, local needs and wishes were gathered through discussions with local stakeholders, such as village leaders, health workers, and other community members. During the needs assessment, it became clear to the DigI team that the preferred health education format was animation. The locals explained the difficulties with low literacy in rural societies, suggesting cartoons or films for learning about health. Tanzanian Swahili was obviously a prerequisite, as the vast majority of people in Tanzania do not speak English. Although some ethnic groups have their own languages, most people understand Tanzanian Swahili. Some village stakeholders also expressed the need for other information, such as village news, village meetings, and agriculture information.

Our general advice based on our experience is to spend substantial time exploring the local needs and involving local stakeholders as partners to form the process and shape the end product from the very beginning.

Identification of Government-Approved Health Promotion Materials in a Nondigital Format

Health strategies and guidelines may vary from one country to another, and it is important to pay attention to the efforts that have already been laid down by policy makers, health workers, and researchers at a national level when mapping the local environment. Our video animations represent up-to-date, high-quality, and clear health messages that are based on approved health information materials, as a point of departure for digitization. The messages are taken from leaflets, posters, brochures, banners, guidelines, and strategies, all carefully reviewed for key health messages aimed at a public health audience (Figure 2). We used the Ministry of Health, Community Development, Gender, Elderly and Children–approved health education messages for HIV and TB. HIV health education messages were obtained from the National AIDS Control Programme [36]. In addition, posters and presentations were obtained from the National Tuberculosis and Leprosy Control Programme, whereas the National Strategic Plan V (2015-2020) for Tuberculosis and Leprosy [37] were used as source documents. The health educational material for TSCT was provided by the Cysticercosis Working Group in Eastern and Southern Africa, and the United Republic of Tanzania One Health Strategic Plan 2015-2020 [38] was used for inspiration. The leaflets for the prevention and control of anthrax in humans and animals were jointly prepared by the Ministry of Health, Community Development, Gender, Elderly and Children, Ministry of Livestock and Fisheries, and the Ministry of Natural Resources and Tourism supported by the Food and Agriculture Organization of the United Nations and WHO country offices in Tanzania, using a One Health approach. The hard copies were converted to soft copies and shared with the DigI team for conversion into digital formats.

From this step, we recommend exercising caution and respect toward the national health authorities. National strategies and guidelines may contain important health messages to be conveyed, especially to target populations, because of context-specific reasons, and may differ from international and global guidelines.

Figure 2. Examples of the education material used as a point of departure for digitization (Taenia solium cysticercosis and taeniasis on the left and tuberculosis on the right). Sources: Cysticercosis Working Group in Eastern and Southern Africa and Ministry of Health, Community Development, Gender, Elderly and Children, respectively.

Identification of Key Health Messages

Establish the most important key messages that you want to convey, depending on the health topic and target population. In our project, we dealt with infectious diseases for a rural population in Tanzania, thus dividing our key health messages into the following domains: (1) prevalence of the disease, (2) cause or transmission of the disease, (3) signs or symptoms of the disease, (4) treatment of the disease, and (5) prevention of the disease.

Once the domains were identified, we extracted key health messages from the materials described in the previous section. In the course thereof, short paragraphs, emphasizing the most important messages for each domain, were created. This is transferable to all health topics: to keep it short and simple.

The first domain intends to raise local awareness and includes health messages regarding the disease and its prevalence in the area. The second domain contains information on how diseases spread and infect others. The third domain describes the signs and symptoms of the disease, to help with early detection and management of the disease. Health messages encourage and motivate clients to seek medical advice if symptoms appear. The fourth domain is related to the treatment of diseases. The last and perhaps most important domain includes information on how people can protect themselves and their families and how the disease can be prevented from spreading between individuals and within communities.

This work established the basis for the written key health messages on the platform and in the animated health videos and moreover identified the most important information that the DigI team health task force wanted to provide to clients. The key health messages typically consisted of 50-150 words and were available on the platform. An example of a key health message (from the domain of symptoms in the TB section) is as follows:

> *Most TB patients show the following signs and symptoms: cough for more than 2 weeks, fever for more than 2 weeks, weight loss, night sweats and lymph node enlargement. People with these signs and symptoms should immediately visit a health facility for proper TB diagnosis and treatment.*

Our general advice based on our experience is to rather focus on few key messages at the time and keep the messages short and simple so as to not overload the audience with information.

Creation of a Practical and Engaging Story, Easy to Understand for the General Public

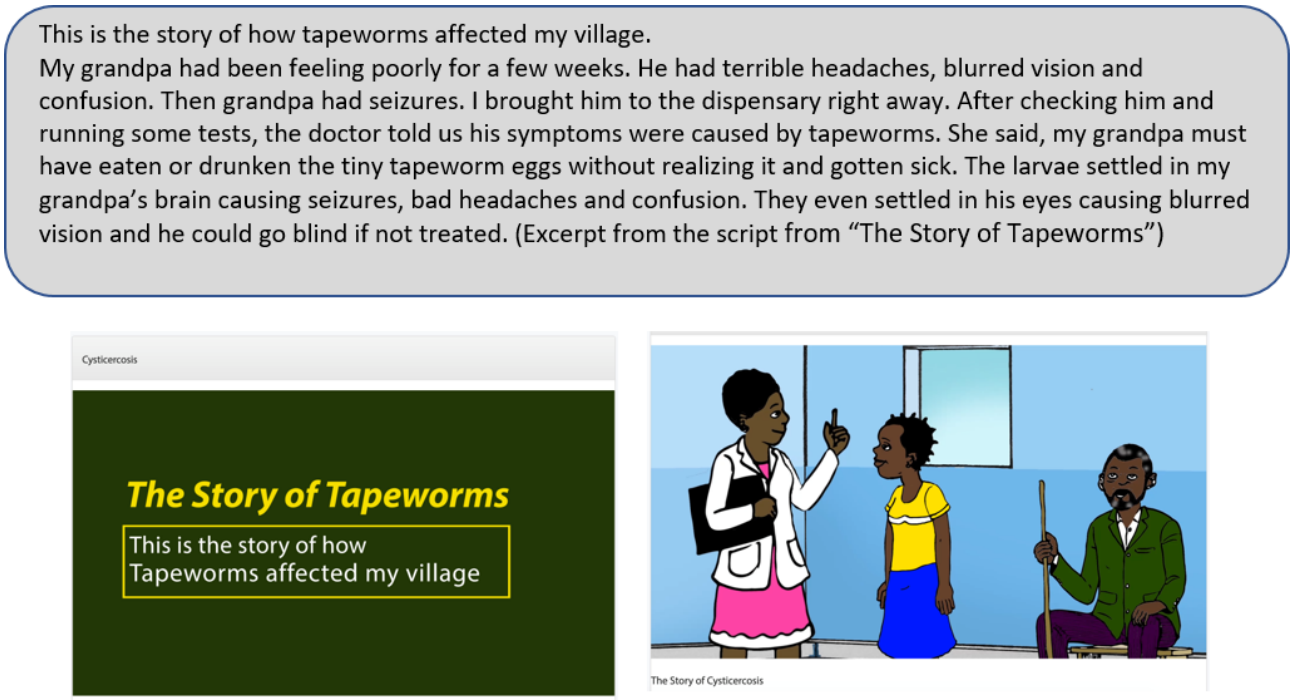
Throughout time, people have learned from stories. Stories can be a powerful way to pass on knowledge and specific messages to other people [39]. In our project, we used storytelling techniques to draft a compelling everyday narrative story that clients could recognize and relate to. All animations were cooperatively developed within the DigI team; however, some partners led the process of writing the story. The draft was discussed by the DigI team. Thereafter, health content was assured by the health task force. After drafting the content of the story, our team worked on creating a word document that contained the script for each story. In our case, the script comprised facts about the disease and a creative mixture of characters, actions, and location settings within the context of a village in rural Tanzania. The scripts were carefully revised by Tanzanian DigI members to ensure local compatibility.

The stories are presented by a narrator and include references to family members as well as the community affected by the diseases (see TSCT example in Figure 3). The narrative includes elements to attract and maintain clients' attention by describing

everyday activities and the realities of life in a rural sub-Saharan community.

Our general advice based on our experience from the story creation is to include a variety of stakeholders to revise the scripts. Specialists and locals can contribute equally, but with different perspectives. Specialists want to ensure that the health content is being presented in an adequate way and that no key messages are left out, whereas locals can point out words and phrases that are difficult to understand. It can be useful to ask questions such as “Are all key messages promoted clearly? Is the language understandable and the story credible?”

Figure 3. Excerpt from “The Story of Tapeworms”.

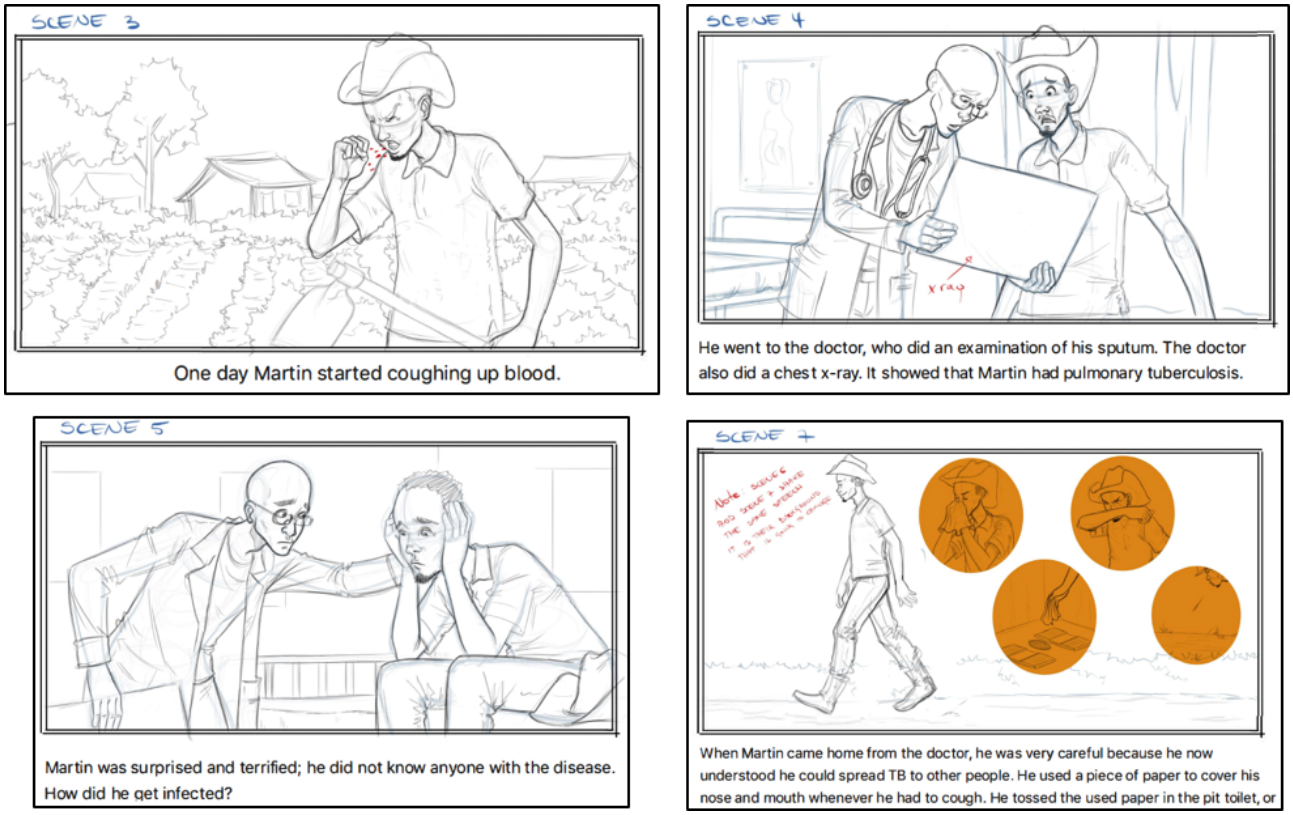


Drafting of a Storyboard for an Animated Video with Review, Feedback, and Revisions

After the script is approved, a storyboard needs to be created if the aim is to create a film or animation. A storyboard is a drawing with text below, illustrating scenes such as farming scenes that may be a common experience for rural clients (Figure 4). It is advisable to share the storyboards with the target population early on to obtain feedback in this design phase. In our project, we planned to use simplified human line drawings but were advised by the local population to incorporate more genuine characters to get the communities more involved when viewing the animations. We also received feedback from the same group to make the characters and environment more similar to those found in rural Tanzania. This included, for example, changing the façade of the health facilities and the clothes of the characters. The core health messages from the written material were left untouched, as these messages were approved, and changing them would require new ethical approval. Following an iterative process of design-test-evaluate-design, an animated video was created based on the original script, revisions, and feedback from the DigI team members and local stakeholders.

Our general advice based on our experience is to establish the storyboards as soon as the script is approved. The storyboards make the animation visualization more realistic and can be effective in identifying scenes of importance for key message uptake. It is beneficial to include target users in this stage to point out recognizability and authenticity, or lack thereof, in different scenes.

Figure 4. Extracts from the storyboard used in the creation of "The Story of Tuberculosis." TB: tuberculosis.



Forward and Backward Translation

Working in 2 languages can be challenging and may complicate the process. Hence, qualified translators with experience in the field are needed to ensure that translation is consistent throughout the various versions of the script. In our project, the health messages and story scripts were created in English and then translated to Swahili for the target audience. The process was as follows: English health messages and story scripts were given to a person to translate them into Swahili. Thereafter, the Swahili versions were given to another person to translate them back into English. Further, the back translation was compared with the original English health messages and story scripts to ensure that the messages were the same. The Swahili messages were also read by the medical doctors who spoke Swahili to ensure that the messages had the same information as the English messages.

Our experience indicated that alterations of the script were done several times, also after translation; thus, it is important to ensure that the final script represents the same key messages in both languages.

Audio Recording of the Story in Both Languages

When the script and translations are final, it is time to record the story. Although it is recommended to use a professional recording studio, the most important factor is to be able to present the audio file without background noise and with a clear and understandable narrator. In our project, we used professional narrators, and voiceover recordings were produced in both English and Swahili. Technically, recording itself was a straightforward process. It was emphasized that the narrators spoke slowly and clearly in an informal tone. The audio file was carefully revised by team members who were Swahili natives and near-natives in English. We recommend paying particular attention to the initial revision process of the audio file. There are cases where a written sentence conveys health messages more effectively than when reading aloud, and to save costs, it may be useful to read the script aloud to team members before recording it.

Finalization and Presentation of the Animation

Once the voice recordings and animation scenes are ready, the animated video can be fully produced and shared with the team for revision and improvement. In our case, all team members carefully reviewed the English version of the draft video. After at least 2 rounds of revisions, the final animated videos were produced and then presented to an audience in rural Tanzania. The *Story of Tapeworms* animation was completed in 2018. The *Story of HIV/AIDS* animation and the *Story of TB* animation were finalized in March 2019. The *Story of Anthrax* animation was completed in May 2019. The animations can be found in Multimedia Appendices 3-10.

Generally, this phase can be costly, but it is worthwhile to address small changes in the final product, which can be of importance for knowledge transfer.

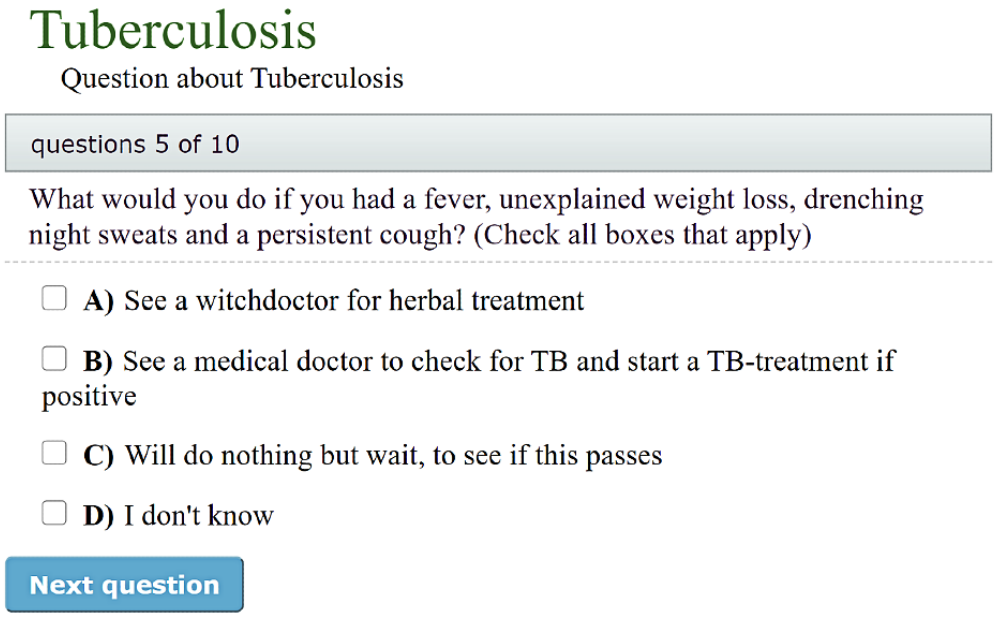
Development of Relevant Questions Related to the Health Messages in Each Domain

To increase knowledge uptake, it may be useful to establish questions from digital health messages, such as animations, and present them to the audience in a quiz format, for example, after the audience has viewed the animation. We derived knowledge questions related to different diseases from the key health messages for each domain. These questions were constructed

for research purposes to test people's knowledge before and after being exposed to our digital health messages in a quantitative study. The same questions were published on the platform in a quiz format so that users could test their own learning. We ensured that the questions did not use medically advanced wording or information. In particular, the health task force assessed their quality as they related to the health content, and the social scientists made the questions easier to understand for the clients. An example of a quiz question is shown in Figure 5.

Our experience is that the questions created should not be too difficult, but should reflect the health messages, and work as reinforcers of the information provided in the animations.

Figure 5. Sample questions presented on the platform. TB: tuberculosis.



Development of Web and Mobile Apps to Access the Digital Health Messages

Access to information can be a bottleneck in disease prevention in the Global South. Animations and other digital formats for health education in the local language are only useful if they are accessible to the target audience. Hence, in the DigI project, it was equally important to develop an easy-to-use digital platform so that people in rural areas could access health messages. Key requirements for the success of the platform included that it would be easy to learn *how to use* it and that it could be used with a basic level of digital literacy (Multimedia Appendix 2). Given that most people are likely to access health messages on a mobile phone, we adopted the *mobile-first* design approach, creating a responsive web application and an Android-based mobile app. The web application presents health messages interactively, whereby a user is presented with an animated video, key health messages, graphics, and a quiz.

As part of the human-centered design process [34], the project team specified the requirements of web and mobile app systems based on inputs from village stakeholders in Migoli and Izazi in the Iringa region. The proposed designs were iteratively improved from a conceptual design to low-fidelity prototypes and high-fidelity interactive prototypes using Adobe XD [40]. The low-fidelity prototypes were simple sketches and wireframes to present early user interface designs for discussions in the DigI team. These helped in gathering user feedback and suggestions on what could be improved. Furthermore, high-fidelity prototypes presented more enriched user interfaces, with interactivity for the test users to experience the interaction with the designed tool. In addition to testing and evaluation by the medical task force and other team members in Tanzania, user-based testing was conducted using the IT task force to uncover potential usability problems. User testing focuses on efficiency, effectiveness, and overall user satisfaction. Using purposive sampling, a total of 12 test users, aged 15-25 years, participated in 2 rounds of usability testing conducted in Kigali (Rwanda) as part of an iterative design process. All test participants had postprimary school education, but none had completed secondary school. The first high-fidelity prototypes were tested by 8 participants (3 women and 5 men) in October 2018, and the second improved versions of the web and mobile app were tested by 4 participants in July 2019. The findings indicated that it was easy to access health information on the platform, view the videos, and read key health messages for different diseases. Test users reported that it was easy to navigate the system and that the content was logically structured. However, some respondents said that "it was hard to find the videos" in the early versions of the platform. Hence, global navigation was redesigned, adding on the top menu a direct link to a page with videos for all diseases. Test participants also suggested making two separate videos for each disease: one video for a story and another with only the health messages. However, after deliberations, the project team decided to keep 1 integrated animation per disease, not too long to keep the audience's attention. Furthermore, test users suggested additional requirements, such as the possibility of self-diagnosis through search functionality on symptoms. This indicated the user's perception of the platform as a health system. Subsequently, we used design constraints to prevent users from attempting to do anything that the system is not intended for,

to make clear that the goal of the platform is to provide health information rather than medical diagnosis. It is in this regard that global navigation includes links to *Health Information*, including videos, text, and quizzes, in addition to a contact form, but there is no search bar. However, given the small screen size of mobile devices, the mobile app includes a search field to help users easily access information on the diseases included in the platform.

The test participants were given a number of tasks to carry out, while a usability evaluator observed their performance to find any problems with the software under testing. Although posttest focus group interviews were conducted to gain insights into users' impressions, a self-reporting web-based survey helped to collect users' opinions on a Likert scale. The resulting web designs, shown in Figure 6, have been deployed on village servers so that clients can access health messages [22] from an InfoSpot free of charge, or on the internet. The viewer can explore video animations, key health messages, and quizzes when clicking on the different diseases. The cholera animation was developed by The Global Health Media Project before the DigI project and was included on the platform as an add-on. The dashboard also provides the user with an option to view more videos.

Given that an increasing number of people have access to low-cost mobile devices, an Android mobile app, shown in Figure 7, was also created to present the same health messages as on the platform. Mobile app users have the option to download all the videos on their devices so that they can view them without an internet connection or being close to the InfoSpot. One of the possible scenarios for using the app is that someone visits an InfoSpot with Wi-Fi, then installs the app and downloads all videos for later viewing together with the family back home.

On the basis of our experience, we recommend digital health content developers to assess the access and context that users have to any digital information source. Digital health education projects are only useful if the target population is able to access health messages either supervised or unsupervised.

Figure 6. The platform user interface. The dashboard on the main health page is shown on the left. On the right, an example of the key health messages and quiz questions within the transmission domain of Anthrax is portrayed.

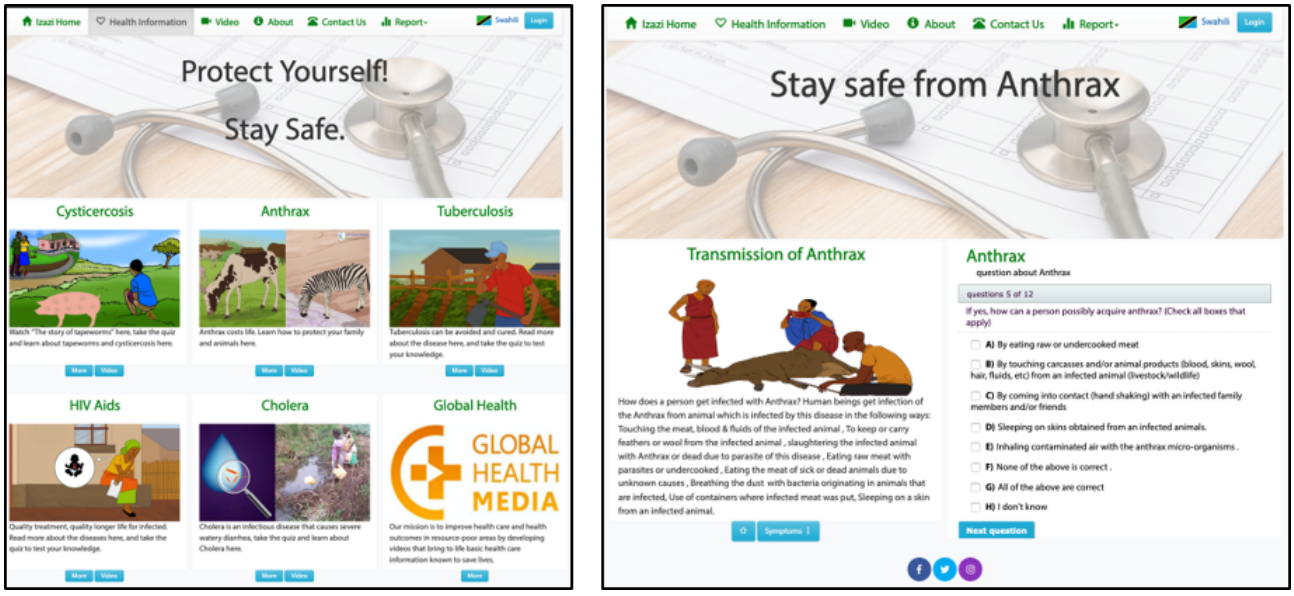
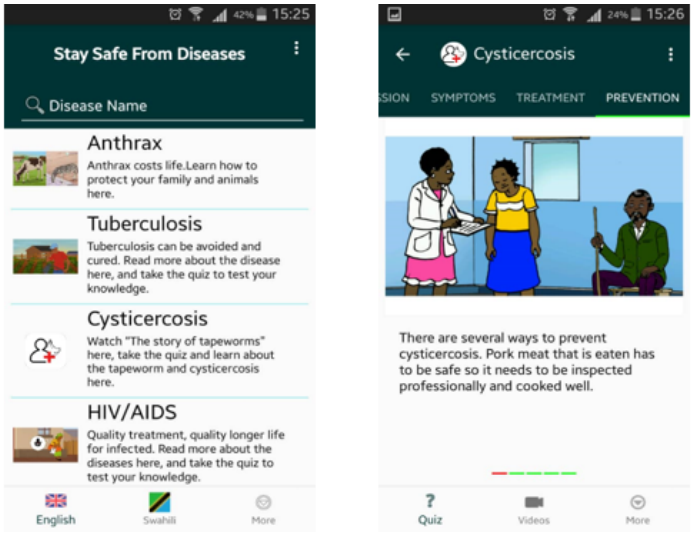


Figure 7. Health Messages mobile app "Linda Afya".

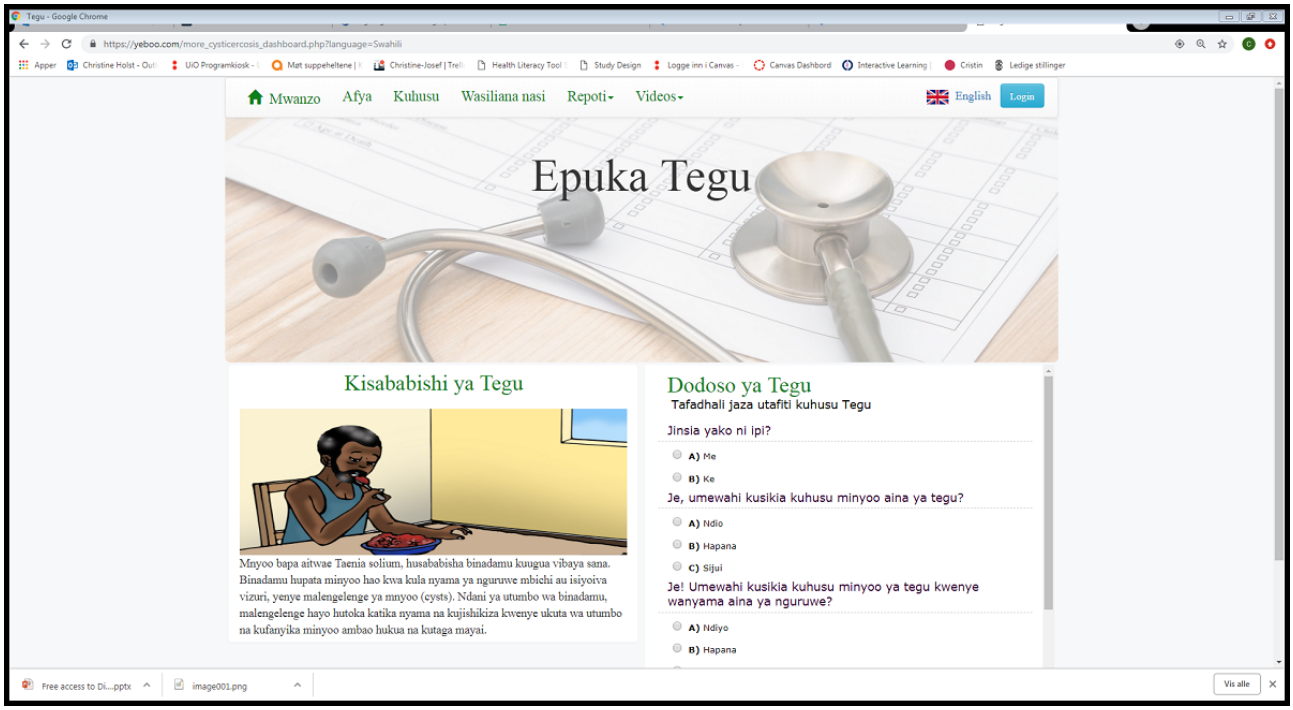


Results

The resulting apps developed through the above-described process can be found via the internet [22] or accessed via Wi-Fi in InfoSpots using locally stored village servers in rural Tanzania. When accessing the platform, the client is introduced to diseases of public health importance in Tanzania (as shown in Figure 6). At any time, the client can change the language from English to Swahili or from Swahili to English. The diseases are HIV/AIDS, TB, TSCT, and anthrax, with all digital information developed as part of the DigI project. In addition, users can find more videos on a variety of health topics, including a cholera animation. The client has 2 choices per disease: *Video* and *More*. When clicking on the *Video* button, an animated video starts immediately. When clicking on the *More* button, the client is taken to a page addressing the specified disease. The client can then navigate through the 5 domains, read about the key health messages, and take the quiz for each disease. Graphics from the animations are used as illustrations for the domains (Figure 8).

In November 2019, seven InfoSpots were available and accessible with the platform, in Esilalei, Selela, Migoli, and Izazi. InfoSpots are still accessible and available for the local population. As of September 3, 2020, the mobile app had been installed by 425 users in 3 months since the launch of the latest version in June 2020. By February 1, 2021, the app store listing had been visited by 1531 people, out of which 1127 were users registered in Kenya. The app can be installed worldwide by searching the app called *Linda Afya* on the Google Play app store.

Figure 8. Swahili Taenia solium cysticercosis and taeniasis health education on the platform.



Discussion

Principal Findings

In this paper, we have provided a tutorial for the various steps in the development process of digital health messages for a rural population in sub-Saharan Africa. The result of our project is a functional health education platform, and the feedback from the local stakeholders and test users was included to improve the platform's usability and impact for the target users. In this section, we present a discussion of the chosen approach used in this project.

A multi- and interdisciplinary approach has become increasingly important in complex research and innovation projects [41]. The advantage of multi- and interdisciplinary collaborations is the ability to draw from each other's knowledge, perspectives, and experiences and channel it toward a joint objective. In this project, the collaboration among team members with medical, social sciences, and IT backgrounds was especially beneficial. Throughout, close collaboration among the local and international health experts, translators, and village stakeholders was important for good results. Furthermore, the storyboard, animated videos, web-based platform, and mobile app could not have been created without input from the visual designers and IT task force. The high quality of digital health messages could not have been achieved without advice from the Tanzanian members of the health task force. International advice on local health matters may differ from the national health advice. Hence, local health researchers were also irreplaceable in identifying the guidelines and written government-approved materials related to each disease. When identifying the key information and creating short, clear messages for the basic health promotion material, the team benefited from members with experience in communication and linguistics. This was important because medical doctors, researchers, and health workers tend to use language with terminology that is difficult for the general public and patients to understand, which can have an exclusive effect [42].

A mixed methods study is currently ongoing within the DigI project to gather evidence for health information uptake and retention based on the above-described animations and access to the platform in 2 villages in rural Tanzania [43]. The data are currently being analyzed, and results are expected late this year. This evaluation will play an important role when revising key messages to become even clearer for the local population. By performing iterations in response to feedback from local communities over time, a human-centered design of global health education is emphasized with its ultimate goal of empowering communities [12].

Regarding the technical aspects of the animation development process, there are various lessons learned that we want to share. We started with the identification of relevant key health messages and then created local stories around those messages, as described above. We had wishes and recommendations from the local community that increased the technical difficulty level but were crucial for the reception in the communities. The many inputs from local stakeholders were acted upon as the DigI team emphasized a co-design process.

Feedback from people in rural areas indicated that the proposed platform should provide information in three main categories: (1) village information, (2) health information, and (3) information on social life and activities. On the basis of this, the design team created templates and user interfaces. In the next stage of the co-design process, people were presented with the interfaces, and they gave positive feedback that the platform was easy to use. However, it seemed difficult to collect the necessary information for publication on the platform, particularly concerning the villages' information and social information. The involved users had limited digital literacy for creating and updating information, for example, using the social media feeds provided by the platform. The research team realized the need to work with a selected group of individuals in each village to increase the usefulness and acceptance of the platform.

The inclusion of digital literacy training programs for the local population is a key factor in the successful implementation of digital health projects. Undoubtedly, the importance of digital literacy is evident when it comes to the use of digital health technologies by people with lower literacy levels, as these technologies could help overcome limitations and surely include new groups in the information society. The DigI team also set up the Key Performance Indicators framework for digital society development and, specifically, to provide a success indicator framework for this project. One of the most relevant success indicators is the level of digital literacy skills, and the health knowledge retention of the participants after the digital skills programs were obtained. Digital literacy goes hand in hand with digital inclusion and social empowerment; thus, it is important that Key Performance Indicators become an integral part of digital literacy initiatives and projects [24].

The drafted stories seemed only to meet the agreement of the full team after several rounds; therefore, the iterative process went on for a long time. In retrospect, the drafting of the storyboards should have been done at an earlier stage within the project, as this process would have provided the group with a good overview of the key health messages and scenes that we wanted to disseminate to the local population. It would have been much easier to imagine the final result if it had been possible to review the different scenes of the animation at an earlier stage.

The translation process of the first animation (TSCT) was performed too early. As the DigI team worked in English and the editing process went on over time, we had to update the Swahili version several times. When the final script was completed in English, the translators had to go through the Swahili version again to ensure that the 2 scripts convey the same story. Consequently, at the stage of the actual recording, the TSCT animation had to be recorded twice because the spoken version sounded different from how it was read. We also had to make adjustments to some wording to avoid misunderstandings. Rerecording was costly and time consuming and could have been avoided. In the following productions, we were more careful with the voiceover recording in the working language and the finalization of the script before translation.

The IT, social science, and health researchers in the DigI project undertook a participatory research approach and spent substantial time partnering with the local population to identify the preferences for digital health message design and knowledge gaps. The WHO has recommended a similar approach of using the existing Ministry of Health documentation and the engagement of different stakeholders [44]. Members of the community, including health workers, school teachers, village leaders, and community leaders, are also key stakeholders to be involved through discussions and interviews to prepare appropriate and relevant health messages and other information. It is essential to engage communities through representatives, including community leaders, to cocreate digital content but also to reach expert consensus on health messages after receiving feedback from the communities. Another important aspect to be considered is user adoption of the messages, whereby health messages are expected to be disseminated to, and accessed by, all or a large proportion of the targeted audience via the platform.

A study that introduced a remote measurement technology platform reported that during the introduction of the remote measurement technology, a multi-stakeholder approach, including patients and research clinicians, provided knowledge about varying requirements for the design and development of the platform [45]. The involvement of patients empowered them to understand the value of the system and to provide their views and needs, thus facilitating the development of a user-adapted platform. Furthermore, the need has been emphasized for developers of digital health information to use numerous innovative strategies to meet both the needs and expectations of targeted audiences [46]. During consultative meetings in the early phases of our project, village leaders indicated the need to use the platform to disseminate news and information to villagers. This included schedules for village meetings, agricultural information on the market, and prices of their products, which were initially not foreseen by the experts. This once again indicates that it is paramount to involve the right people at the right time in an iterative manner to co-design information to be included in an intervention [47]. This multi-

and interdisciplinary approach allows for continuous improvement to meet the needs of the targeted audiences.

Conclusions and Future Plans

The digital health messages, video animations, quizzes, and web applications described in this paper were created through an integrated approach based on various scientific disciplines in addition to engagement of and input from village stakeholders and test users, thus taking advantage of the network and expertise of the DigI team members.

We believe that the methodological approach described in this paper, referring to the digitization of approved printed health education materials, should be promoted. The production process resulted in high-quality educational material that can be used in different forms and in different settings, such as stationary health messages on an internet platform or animated videos telling the story of four diseases in their local context in rural Tanzania. Potentially, health animations developed through the approach described in this paper could also be used in national knowledge portals, as the health messages they contain have been fully approved.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Screenshot of the platform.
[PNG File , 587 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Definition of terms.
[DOCX File , 22 KB-Multimedia Appendix 2]

Multimedia Appendix 3

HIV/AIDS health animated video (English).
[MP4 File (MP4 Video), 58029 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Tuberculosis health animated video (English).
[MP4 File (MP4 Video), 28571 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Taenia solium cysticercosis and taeniasis health animated video (English).
[MOV File , 78062 KB-Multimedia Appendix 5]

Multimedia Appendix 6

Anthrax health animated video (English).
[MOV File , 38758 KB-Multimedia Appendix 6]

Multimedia Appendix 7

HIV/AIDS health animated video (Swahili).
[MP4 File (MP4 Video), 56923 KB-Multimedia Appendix 7]

Multimedia Appendix 8

Tuberculosis health animated video (Swahili).
[MP4 File (MP4 Video), 36238 KB-Multimedia Appendix 8]

Multimedia Appendix 9

Taenia solium cysticercosis and taeniasis health animated video (Swahili).
[MOV File , 43603 KB-Multimedia Appendix 9]

Multimedia Appendix 10

Anthrax health animated video (Swahili).
[MP4 File (MP4 Video), 60353 KB-Multimedia Appendix 10]

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Abbreviations

DigI: Non-discriminating access for Digital Inclusion
InfoSpot: information spot
IT: information technology
TB: tuberculosis
TSCT: Taenia solium cysticercosis and taeniasis
WHO: World Health Organization

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Article

Utilizing community InfoSpots for health education: perspectives and experiences in Migoli and Izazi, Tanzania

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Summary

Limited access to health education can be a barrier for reaching the Sustainable Development Goals, especially in rural communities in sub-Saharan Africa. We addressed this gap by installing community information spots (InfoSpots) with access to the internet and a locally stored digital health education platform (the platform) in Migoli and Izazi, Tanzania. The objective of this case study was to explore the perspectives and experiences of InfoSpot users and non-users in these communities. We conducted 35 semi-structured interviews with participants living, working or studying in Migoli or Izazi in February 2020 and subsequently analysed the data using content analysis.

The 25 InfoSpot users reported variations in use patterns. Users with more education utilized the platform for their own health education and that of others, in addition to internet surfing. High school students also used the platform for practicing English, in addition to health education. Most InfoSpot users found the platform easy to use; however, those with less education received guidance from other users. Non-users reported that they would have used the InfoSpot with the platform if they had been aware of its existence. All participants reported a positive view of the digital health messages, especially animations as a health knowledge transfer tool. In conclusion, different and unintended use of the platform shows that the communities are creative in ways of utilizing the InfoSpots and gaining knowledge. The platform could have been used by more people if it had been promoted better in the communities.

Lay Summary

Access to good-quality health education is crucial for reaching the Sustainable Development Goals. We installed community information spots (InfoSpots) with access to the internet and a locally stored digital health education platform (the platform) in two rural villages in Tanzania in November 2019. This qualitative case study was conducted in Migoli and Izazi in February 2020, and 35 people participated in semi-structured interviews. Content analysis was performed with the software NVivo, and quotations were used to illustrate the themes. Twenty-five participants were classified as InfoSpot users. Variations and creativity in use patterns were reported. Less educated users were guided by others, while users with more education used the platform for their own and for the education of others, in addition to internet surfing. The students who used the InfoSpot for health education and for practicing English demonstrated unintended use of the platform. All non-users reported that they would have used the InfoSpots if they had been aware of their existence. All participants, users and non-users, reported a positive view of the digital health messages, especially animations as a health knowledge transfer tool. The use of such platforms can be an important factor in disease prevention.

Key words: global health, disease prevention, community health promotion, Africa, ICT

BACKGROUND

Increased health literacy gained through community health promotion activities, such as health education, may function as an accelerator towards achieving targets related to Sustainable Development Goal 3—to ensure healthy lives and to promote well-being for all at all ages—and has great potential to affect a range of other SDGs (WHO, 2017). Access to good-quality health education for disease management and prevention in the global south can be a challenge for rural people. According to the World Bank, 65% of the population in Tanzania live in rural areas (The World Bank, 2020), and healthcare workers at dispensaries or community health workers at village offices are normally the primary providers of health promotion information to such communities (MoHSW and United Republic of Tanzania, 2015). This includes information to groups or individuals, orally or via leaflets.

Tanzania is aiming for increased use of digital health and has outlined the potential of digital health education for communities to adapt healthier behaviours and increase health literacy in their Digital Health Strategy 2019–24 (MoHCDGEC, 2019). mHealth, defined as the use of mobile wireless technologies for health (WHO, 2019), can be useful to deliver health education and improve health-seeking behaviour and health-related lifestyle decisions, because they make people more reachable (Hall *et al.*, 2014). The adaptation of smartphones and tablets for health education in low-resource settings is promising (McHenry *et al.*, 2019), and health-seeking behaviour may change after a target group has been exposed to health messages that provide relevant information to the target population (Lester *et al.*, 2010; Free *et al.*, 2013). By providing relevant information, digital health can contribute to prevention and management of diseases (Ahern *et al.*, 2006).

This case study is part of the Non-Discriminating access for Digital Inclusion (DigI) project. The project provides free access to community information spots (InfoSpots) with a digital health education platform (the DigI Platform: Non-Discriminating access for Digital Inclusion, 2021), herein referred to as 'the platform', addressing health education gaps in rural areas of Tanzania. The platform can be viewed as a website containing animations, text and quizzes related to several diseases. All InfoSpots have one or two tablet devices for public use, and people can connect to the platform with their own devices without any costs. Lightweight webpages can also be accessed free of charge, while heavy content pages (i.e. streaming) are accessible through a voucher system. The platform is always accessible, as it is stored on a local server, and the utilization of the platform is always free.

The project was rolled out in the communities of Izazi and Migoli in 2019. The villages are located in the Iringa district of the Iringa region in Tanzania. The project has installed one main InfoSpot in each village, at the Nyerere high school in Migoli, and at the village office in Izazi. Three additional InfoSpots have been installed in the villages, in both of the local village dispensaries and in the village office in Migoli.

Within the DigI project, a quantitative study is ongoing to assess the effect of an adapted digital health education intervention, with 298 participants recruited from Migoli and Izazi. The diseases addressed in the

intervention are HIV/AIDS, Tuberculosis and *Taenia solium* cysticercosis/taeniosis (TSCT). All three diseases are endemic to the Iringa region (TACAIDS and ZAC, 2017; NTLP, 2018; Ngowi *et al.*, 2019). Thus, preventive strategies are important. The intervention consists of two parts: (i) a one-time exposure to three health animated videos (animations) on a tablet device (April/May 2019) and (ii) free access to the platform in the InfoSpots, rolled out in October and November 2019 in Migoli and Izazi. The InfoSpot and the platform was promoted by project members and enumerators working with the DigI project in Migoli and Izazi prior to the rollout.

Several studies have been conducted earlier on mHealth projects in sub-Saharan Africa, primarily using text messaging ('SMS'). L'Engle *et al.* (2013) conclude that mobile phones are suitable for health education in Tanzania, while Obasola and Mabawonku (2018) from Nigeria report that mobile phones are viewed as useful, but the internet is not useful related to maternal health education. Community health workers in Uganda have shown enthusiasm for a community-based mHealth HIV/AIDS care programme (Chang *et al.*, 2013), and healthcare workers in Tanzania report mHealth tools to be powerful and to simplify work (Shao *et al.*, 2015). A systematic review by Njoroge *et al.* (2017) from Kenya found that fewer eHealth (including mHealth) projects were implemented in marginalized areas and least urbanized counties than in urban areas. Some studies have explored animations from a health education perspective. Coetzee *et al.* (2018) conducted a study in a township in South Africa that showed that health education videos (about HIV, nutrition, alcohol and breastfeeding) provided on a tablet device are an acceptable and feasible way of health promotion. Hébert *et al.* (Hébert *et al.*, 2020) concluded that health animations, as health knowledge transfer tools, are effective for improving knowledge among health professionals in Burkina Faso. Research from Niger (Bello-Bravo *et al.*, 2019) suggests that the use of animated videos as a knowledge transfer tool is an inclusive strategy for low-literate learners, such as farmers in resource-poor settings in the global south.

To our knowledge, no studies report the use of established physical InfoSpots with free access to health education and the internet in rural sub-Saharan areas. Our case study fills this gap by exploring the participants' perspectives and experiences related to the digital health intervention among users, non-users and key persons in Migoli and Izazi.

METHODS

This case study aimed to explore the perspectives and experiences of rural people in Migoli and Izazi in Tanzania, with regards to being a user or a non-user of the InfoSpots with the platform. The case study is part of a mixed method study, and is described in a published protocol (Holst *et al.*, 2021).

A user would be a person that had accessed the InfoSpot and the platform at least once. A non-user would never have utilized the InfoSpot, but he or she may have been exposed to the health animations in the digital health intervention study.

A qualitative approach using content analysis was chosen (Bengtsson, 2016). We conducted 35 semi-structured interviews with people living or studying in either of the two villages to capture perspectives and experiences from users and non-users. All interviews were conducted in February 2020. The research team consisted of National Institute for Medical Research (NIMR) and University of Oslo. NIMR facilitated an interpreter and a coordinator in the field during data collection. Researchers by NIMR introduced the participants to the study in the local language. Thirty of the interviews were conducted in Swahili, two in English and three with both English and Swahili. The interviews took place in private settings at the InfoSpots and offices nearby.

Recruitment of participants

We interviewed people from two groups:

Group 1: Participants enrolled in the quantitative study ($n = 11$). The participants were randomly sampled from participant lists from the quantitative study. All participants in this group had been exposed to the first part of the digital health intervention (the viewing of the three animations), but not all had visited the InfoSpots after rollout.

Group 2: Key people ($n = 24$) who were connected to our DigI project. This group includes InfoSpots users, i.e. villagers, healthcare workers at the dispensaries, students and teachers at the high school in Migoli, and village officers and leaders from both villages. We recruited on location, using convenient sampling (Lavrakas, 2008) around the InfoSpots in the village marketplace, school and dispensaries. As we had focal persons (village and sub-village leaders) in or around the InfoSpots related to our project, we employed snowballing to reach additional participants.

Conduct of the interviews

During the interviews, we used a semi-structured interview guide with 11 topics (see Supplementary Annex S1). In the interviews with the non-users, we excluded the topics related to the use of InfoSpots, and rather

focused on the reasons for non-use and the participants' perspectives on digital health education, including animations. All interviews, except one, where the participant refused recording, were recorded. In addition, notes were taken during the interviews. Simultaneous translation was utilized throughout all the interviews that were conducted in Swahili in order for the non-native researcher to follow-up with probe questions. At the end of each interview, the participants were asked if they had any questions or further comments. After each interview, the research team had a debrief session where the most important topics were discussed. In this session, all unforeseen interviewee' perspectives or experiences were also recorded in the field notes.

In Group 1, we reached data saturation point (Saunders *et al.*, 2018) after 11 interviews. In Group 2, we interviewed as many people as possible to capture the different perspectives among the participants.

Analysis of the interviews

All interviews were thereafter transcribed and translated by a trained sociologist at NIMR with fluent language skills in both English and Swahili. The transcripts were carefully reviewed by the first author and other members of the DigI team. Thereafter, a coding frame for the data was developed, and the data were systematically coded using the software NVivo. CH derived themes of interest from the interview guide as well as new themes from the data and analysed both to contextualize the participants' perspectives and experiences.

Ethical aspects

This study has been assessed by the Norwegian Centre for Research Data (NSD), reference number 59643. Ethical approval from the National Institute for Medical Research (NIMR), in Tanzania, has been granted with the reference number NIMR/HQ/R.8a/Vol IX/2947.

We explained the objectives of the study to each participant and that participation was voluntary. All participants received information about the study orally, in addition to an information sheet, before they read through and signed the consent form. For the students below 18 years of age living at the boarding school, consent was provided by the teacher in addition to the participant. The participants were ensured confidentiality and anonymity and that their feedback would be handled with care and only used for research purposes.

In the quotes utilized in this paper, the participants' age has been modified within a range of ±5, and the occupation is only stated if this does not reveal the participants identity.

Table 1: Characteristics of the participants ($n = 35$)

Characteristics	*n*
Age	
15–19	6
20–24	4
25–29	3
30–34	13
35–39	4
40–45	3
Above 45	2
Gender	
Females	14
Males	21
Education	
Primary school (both completed or some)	14
Secondary school (in or completed)	8
Post-secondary education	13

RESULTS

Demographic information

We interviewed 35 people, 14 women and 21 men, between 15 and 55 years (see Table 1 for characteristics of the participants). Among the participants were 8 students, 5 farmers, 4 healthcare workers, 4 teachers, 4 officers/village leaders and 10 others with different occupations: fishermen, vendors, butchers, mechanics, craftsmen and community health workers. Of all the participants, 25 (71%) were classified as InfoSpot users, and 10 (29%) were non-users. All participants either went to high school, worked or lived in Izazi or Migoli. Fourteen of the participants reported to have primary education (completed or some years), 8 were in or had completed secondary education, and 13 participants reported to have post-secondary education (including 7 healthcare workers and teachers).

All participants reported that they could read and understand a leaflet with health information. The majority of the respondents reported to frequently use the internet, mostly through smartphones. WhatsApp, Facebook, Instagram, YouTube and Google were often mentioned as services and sites the participant would use.

A healthcare worker elaborated:

> *I normally use internet in two main ways. First, in learning different contents in relation to my profession, disease management, and doses [of medicine]. Second, I use internet in social media as entertainment.* Healthcare worker (26 years)

Nine participants reported that they had not used internet earlier. Most were farmers and vendors, and

they reported that they did not have a smartphone. All had primary education. From the users who had not used internet previously, one participant was under the age of 20, the rest was between 31 and 42 years of age.

Non-use and use of the InfoSpots

Study participants shared their perspectives and experiences related to use and non-use of the InfoSpots and the platform. Out of five InfoSpots in Izazi and Migoli, only three were currently operative and in use. These were the main InfoSpots in Nyerere High School in Migoli and at the village office in Izazi, in addition to the InfoSpot in Izazi dispensary. At the high school and at the village office in Izazi, people accessed the platform to get health information on a daily basis.

InfoSpot non-users

The two InfoSpots in Migoli dispensary and Migoli village centre, both remotely connected to the high school, were not in use while the data collection for this paper was ongoing. At the dispensary, the staff had been changed since the rollout of the InfoSpot, and the knowledge on how to access the platform had not been transferred. The system was operational but not used. Two participants from the dispensary were subsequently categorized as non-users, as they had never accessed the platform earlier. In the Migoli village centre, the equipment was stored in a small shop. The radio signals could not reach this InfoSpot.

Of the 11 participants in Migoli and Izazi who were exposed to the health animations in the quantitative study, only 3 had later accessed the platform since the exposure intervention in April/May 2019. The eight others were therefore classified as non-users of the InfoSpots. We asked a participant if he had used the InfoSpot with the platform in his community, and he replied:

> *No, I haven't. Apart from the interview we did last time where you showed us the videos, we were not aware about a system installed and a platform we could access and learn things*. Villager (30 years)

Many participants, users and non-users, pointed out that people were not informed about this activity in the communities. Some participants suggested that the project needed to put more emphasis on advertisement in front of the InfoSpots and at village meetings. An officer explained:

> *The contents are good with everything with it. But my concern is when introducing projects like this, you should prepare something like advertisement, a banner or flyer, so that people can easily be informed about it. I don't know how far you reached in making something like that?* Officer (32 years)

All of the non-users reported that they did not know that the InfoSpot was open, in use and available for all. When we asked if they would have gone for health education if they had known it was open, all said yes. A fisherman explained:

> *I haven't been to visit them because I wasn't informed, second due to the nature of what I do for a living. Most of the time I am not around at home due to economic hardships. Regardless of that, if I had been aware of the platform, I would have visited it*. Fisherman (28 years)

InfoSpot users

The 25 participants classified as InfoSpot users reported variations in use patterns. Some of the users, the leaders and teachers, had been using the InfoSpots to access a variety of webpages on the internet, in addition to the platform with the health messages, but 21 of the users reported only using the platform with the health education. The onset of use among the users was gradual. Four of the users had started to use the InfoSpot when it was installed in August 2019, by only accessing the internet and not the platform. Eight of the users started when the platform was rolled out later in November, and 13 users reported using the InfoSpot for the first time in December, January or early February. Related to the frequency of the use, 13 users said that they used the InfoSpot daily or weekly, all of whom had secondary school or higher education, while 12 users reported to use the InfoSpot occasionally. The difference in use is elaborated below.

Nyerere High School

At Nyerere High School, a secondary boarding school with two levels (O' Level with Form 1–4 and A' Level with Forms 5 and 6) and more than 1000 students and 25–30 teachers, the system was working well, with all features intact. Two tablets were in use in the school's IT classroom. The students were not allowed to have their own smartphones at this boarding school. Some teachers reported to have accessed the internet and platform with their own devices. The students reported that they only used the platform, while some teachers reported that they had also accessed other websites on the internet. The teachers reported using different components of the platform in class: They would use the written health messages to prepare for class and use the

quiz for themselves and in class for the students. A teacher elaborated on their use of the InfoSpot and platform:

> *Yes, I use it when I'm at work; but sometimes, after working hours, we usually come back here for remedial classes or to supervise students, so I usually decide to read a topic, for example, on tuberculosis; and to measure if I read well, I take a quiz, submit it and get feedback, so it helps.* Teacher (27 years)

The students reported using the platform to learn about the diseases by viewing the animations, taking the quiz and reading the key messages. We learnt that students also used both English and Swahili when they accessed the health content on the platform:

> *I watched using both languages. For example, if I'm watching it in English, and let's say I don't understand causes of disease written in English, I just translate it to Swahili. That's what I do, so I use both languages.* Student (15 years)

The majority of the students interviewed (six out of eight) reported using both languages while using the platform. Another student explained:

> *It is easy because there are two languages on the platform, Swahili and English. So, anyone who has a problem with English can use Swahili and understand it well, and one with problems with Swahili can use English.* Student (16 years)

All students who reported using a smartphone back home told us that the platform was simple to use. A student explained:

> *It is not hard [to use the platform] because the majority of our generation have knowledge of the internet, so it's easier to visit a platform like this without any complications, and search for things in a user-friendly manner.* Student (20 years)

A teacher elaborated on the user-friendliness according to age:

> *Yeah! It's very easy, but I found some difficulties in some of the students who are still young, for example form one and form two. Most of them are not familiar but for the form three and the form four students, they are familiar.* Teacher (27 years)

Izazi village office

In the Izazi village office, the system was operational, and it was used both when the DigI project topped up the internet credits allowing full internet access to be available and when users were only given access to the platform. Two tablets were in use. In this InfoSpot, the use was different than at the high school. The leaders and users with more formal education reported using all features of the InfoSpot; they were going online to use the internet and WhatsApp, in addition to accessing the platform for health education for themselves and for teaching others. Both the available tablets and users' own smartphones were used in this InfoSpot. Different groups, including farmers, officers and community health workers (not health professionals, but volunteers in the community), used the InfoSpot. A community health worker pointed out that the use of the InfoSpot had reduced their health education workload:

> *Well, for us it has reduced our burden to teach people; instead of us teaching them about health by using words and talking, now they can just watch informative videos for diseases like Tegu [Swahili for pork tapeworm/cysticercosis], HIV/AIDS, and TB, and I think it's easy for them to learn and understand this way.* Community health worker (22 years)

The same participant explained that she used the platform to rehearse before teaching others:

> *Since December I used to come frequently! Because most of the time, I have classes to teach, so I come here to learn more before I teach in class.* Community health worker (22 years)

We met a farmer who came into the village office to meet the village leader. After a talk in the office, the farmer was given the tablet device with the animations ready to watch. Most of the participants in the Izazi village office reported that the InfoSpots were easy to use, while some of the participants reported that a leader, in order to access the platform and to see the animations, guided them. The farmer explained:

> *Well, to be honest, I am not competent with electronic gadgets, so there was a person who was helping me to use it.* Farmer (42 years)

Several participants reported on the same topic:

> *There were ladies guiding us, they showed us how to navigate from one video to another.* Villager (25 years)

Another villager explained it this way when we asked if the tablets were easy to use for the people in the community:

Um, it depends on how familiar the person is. For the knowledgeable ones, it becomes easier and vice versa, that is true. Villager (27 years)

Izazi dispensary

At Izazi dispensary, the platform was available and accessible, but the tablet used in the very beginning after the rollout of the platform was no longer in use by the patients in the waiting area, due to risk of contamination between patients. The tablet was now rather used by the healthcare workers to refresh their own memory and to educate groups of people in the community. We learnt from the healthcare workers that they would bring the tablets with them when going on outreach and show animations for people out in the rural areas. The animations were stored as offline content on the tablet. In addition to that particular use, the healthcare workers would place the tablet on a small table in the waiting area for the health education of waiting patients. A healthcare worker explained how they would use the tablets to save time, and the animations for public health education, and when encouraging people to change their health behaviour:

For example, before the tablets, we were having the program that provides education each morning, and from there, we go to provide services. You may find that we talked about cholera one day and about another disease another day. We were doing… like, public health education. But after receiving the tablets, we put them [patients] in groups of five people and we showed them clips which are in series. And sometimes, when we see a person coughing without covering the mouth, we show him the clip and they understand. Healthcare worker (32 years)

A healthcare worker explained that they would use the platform to refresh their own memory:

It helps us a lot because sometimes it reminds even us of diseases that we learned about in school a while ago. Healthcare worker (41 years)

A third healthcare worker pointed out the low levels of digital skills in the rural areas, and explored reasons for non-use:

People in the communities need training in how to use both the device and platform. Some have never used it before, not even smartphones. Healthcare worker (26 years)

Perspectives on animations as a learning method

Almost all participants (33 out of 35), whether they were InfoSpot users or not, had viewed the animations at least once and reported a positive view of digital health education and the use of animations for health knowledge transfer. Many of the participants pointed out that it was easy to learn from the animations, as the viewer could see the actions of the characters in the animations, and that this had an impact on the learning. A vendor in Migoli explained:

You see, watching a video, you see each and everything, all demonstrations. For instance, a video says, 'in order to prevent yourself from this disease, you have to do this and that by seeing the actions', but when you are just reading a leaflet, it's common to forget details. So, the best way to learn is by TV. Even myself, after watching the videos, I grasped new things. Villager (19 years)

A student said it this way:

This approach in learning is very nice because it creates a long term memory, different from reading only. Student (19 years)

Sharing health messages and recommending others to use the platform

The vast majority of participants reported that they had shared their new knowledge obtained through watching the animations with others, often friends or family. All InfoSpot users had recommended using the platform to others. A farmer explained why he had recommended to others to use the platform:

I thought it was the best method because, directly, the service is at the hospital where we can get tested. The demonstrations in the video speak a lot, that's why I encouraged others to come watch, learn, and understand. Farmer (32 years)

A student explained how he/she had tried to recruit fellow student to access the InfoSpot:

Yeah! I am trying to convince my fellow student to use this, but I succeeded to get only ten students who frequently visit [the platform] due to insufficient number of tablets. Student (21 years)

A teacher explained how he had downloaded the content on his smartphone to show others in the community:

I used to download videos and save them and watch them offline and share with the family members. Teacher (32 years)

DISCUSSION

The digital health intervention in the overarching DigI project is a unique combination of the provision of health education in animation format, access to the

internet and a digital health education platform. Smartphones, laptops and desktop computers to access the internet are more commonly used among the high school students (although not at school) and the participants with more education (healthcare workers, teachers, officers) than for the less formally educated participants (farmers, fishermen, craftsmen and vendors, among others). All of the participants who reported never having used the internet before had primary school education only. This is part of what is commonly known as the digital divide referring to the gap between those who are able to benefit from the digital age compared to those who are not (Hilbert, 2011). In the literature, we find technological, immaterial, material, social and educational types of inequalities that may account for the digital divide (Van Dijk, 2006). All these types of inequality can be used to explain the difference in access to technology and the internet across regions, and are highly relevant for this case study, related to the use of the InfoSpots and perspectives regarding the digital health intervention. In Obasola and Mabawonku's study, the perceptions and willingness to use ICT for maternal and child health information was explored, and almost 70% of the mothers reported the internet not to be useful, especially in the rural areas where connectivity, and use of internet, was low. In the DigI project, we deliberately addressed areas where internet connectivity and usage were low. It became clear that besides the lack of connectivity, other deficiencies limited the farmers' technological opportunities, as the majority of non-users had limited or no access to a smartphone or other devices to access digital information.

When the platform in this project was rolled out in the InfoSpots, a small launch party in both Migoli and Izazi celebrated the opening. The interviews were undertaken in February 2020, leaving only a short time for adaptation of the utilization of the platform in the villages. The time between November (2019) and February (2020) was characterized by more rainfall than normal (FAO, 2020), which could have contributed to a higher workload for the farmers. Being a farmer in rural Tanzania is demanding, and the need for internet on a daily basis may be limited. However, and unlike in the Nigerian study (Obasola and Mabawonku, 2018), our non-users indicated that they would have used the InfoSpots for health education if they had known that they were available, and therefore, we assume that they perceive the platform to be useful.

As a recommendation, the InfoSpots could have been promoted better in the villages, for example at village meetings and by posters in and around the InfoSpots. At the same time, it is hard to reach all village people, as the different seasons demand different efforts in animal husbandry and harvesting. The DigI project did not directly target farmers or vendors, but we found that they were eager to learn and would recommend the use of the InfoSpots with the health animations to others. The same findings have been reported in a study from Niger, where farmers reported higher preferences for animations as a learning method and would recommend animations as a form of teaching for others (Bello-Bravo *et al.*, 2019).

Different use of the InfoSpots across groups in the communities

Our case study found that utilization of the InfoSpots differed by location, age and occupation. Reports by students on the non-intentional use of animations in both languages, e.g. to practice English, was surprising and unexpected. The applicability for other learning scenarios shows that providing a digital health intervention addresses multiple outcomes. In this case, learning the English language from a digital platform can be seen as a great add-on, which can help facilitate the aim of increasing health knowledge, general education and digital literacy. It also indicates the large potential for the younger generation to take advantage of such community InfoSpots. All participants from the high school area reported that tablets were easy to use, and that they navigated within the platform themselves, which suggests that such health interventions can be especially beneficial to secondary and high schools.

In the Izazi village office InfoSpot, the leaders and community health workers often introduced the animations to the villagers who came into the offices for various reasons and guided interactions with the platform. Thus, the digital health content was provided in a supervised form, which may limit opportunities for individuals to increase their digital literacy skills, by playing around with the tablet to explore the platform. Supervision may occur out of necessity and again reflects the digital divide and the gap in digital and technological literacy. However, the guidance of villagers into the platform shows creativity and enthusiasm from the leaders in the community for the ways to adapt and facilitate community education. It could very well be that this represents the first step towards an increase in both health knowledge and digital skills.

Patients at the dispensary were not allowed to use the tablet while waiting for their appointment due to the risk of contamination. Our team subsequently followed the local recommendation and placed TV screens with animations for health education in health facilities as a more appropriate solution than tablets. Our findings

that healthcare workers and community health workers found that the use of tablets reduced their workload by saving time on health promoting activities, supports previous findings from South Africa, where video teaching tools helped community health workers with administrative duties and reduced the time of household visits (Coetzee *et al.*, 2018). The community health workers could do the needed administration while the households they visited were busy seeing the health video. In our case, the healthcare workers would show the animations to groups while doing other work in the dispensary. Healthcare workers interviewed in this case study also reported using the animations to refresh their own knowledge, especially related to diseases that do not have a public focus, i.e. TSCT. Refreshing knowledge as unintended use shows that the value of the platform was also beneficial to healthcare workers and indicates yet another creative use of the platform in rural communities. Knowledge updates for community health workers and professional healthcare workers, as well as digital health information on new or emerging diseases, for example COVID-19, may strengthen the healthcare workers' knowledge. Thus, our case study supports that providing platforms in communities may represent an important part of community health education.

Limitations

This case study has several limitations. The answers that we received may have been biased. As the interviewer represented the donor organization, people's answers could have been influenced by that. In rural TZ, people may 'agree' with you, saying yes because they think that it is what they should say. For example, some of the participants answered 'yes' to the question, 'Have you visited any of the InfoSpots around the village?' But when we asked which one and when, we could not get an answer. It may very well be that the participant wanted to show interest and tried not to be rude. We utilized probing questions to deepen the knowledge on the use and non-use and to explore the participants' personal thoughts and perceptions about the project.

At the school, we had to ask if we could speak to some of the girls after having interviewed five boys in a row. This may raise a question about the sampling. We were introduced to the students by the teacher. It may have been important for the teachers to give us great examples of the students, since the DigI team had already provided equipment and access to the internet.

CONCLUSION

The findings from this case study show a variation in the use of the platform through InfoSpots among the various user groups. What is in common is the perceived value of the health education through animations, which was seen as easy to understand. Young participants, like the high school students, found the InfoSpots easy to use and had no difficulties navigating the platform with the available tablet devices. This group used the platform for health education and for learning English, while their teachers used the platform to prepare for class and to surf the internet. More formally educated participants, village leaders or healthcare workers often guided less educated participants within the platform. The use of InfoSpots in Izazi depends on the more educated users digital skills, while the InfoSpot in Migoli is more independently used, indicating that the younger people and more educated groups benefit more from the platform than the older and less educated participants, from a digital skills perspective. Healthcare workers in the dispensary used the platform to refresh their own memory, in addition to educating groups in the communities and village meetings. Community health workers further reported that the animations contributed to saving time on health promotion activities. These findings demonstrate that the communities are creative in the ways of using the InfoSpot and the platform for educational gains, and thus achieve both health knowledge, other education and digital skills. The non-users interviewed in this case study pointed out that they would have used the InfoSpots if they had known they existed, which points to the value and importance of promoting digital health interventions.

All participants in this case study had a positive perception of the digital health education intervention. The use of animations to transfer health messages to individuals and communities was especially appreciated. In conclusion, this case study demonstrates that animations for health knowledge transfer through InfoSpots in the communities are appropriate for providing health education. Digital health promotion through animations has the potential to reach both more and less educated groups in rural Tanzania.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Health Promotion International* online.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. The founding sponsors had no role in the design of the case study; in the collection, analyses or interpretation of data; in the writing of the manuscript and in the decision to publish the results. J.N. obtained funding and was project leader, C.H. was project coordinator and B.N. and A.S.W. were supervisors and team members in the DigI project 2017–20.

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IV

Original Paper

Improving Health Knowledge Through Provision of Free Digital Health Education to Rural Communities in Iringa, Tanzania: Nonrandomized Intervention Study

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Abstract

Background: Community health education is one of the most effective measures to increase health literacy worldwide and can contribute to the achievement of specific targets of the Sustainable Development Goal 3. Digitalized health education materials can improve health knowledge as a dimension of health literacy and play an important role in disease prevention in rural sub-Saharan settings.

Objective: The objective of this research is to assess the effect of a digital health education intervention on the uptake and retention of knowledge related to HIV/AIDS, tuberculosis (TB), and *Taenia solium* (neuro)cysticercosis and taeniosis in rural communities in Iringa, Tanzania.

Methods: We conducted a nonrandomized intervention study of participants aged 15 to 45 years, randomly selected from 4 villages in Iringa, Tanzania. The intervention consisted of 2 parts. After the baseline assessment, we showed the participants 3 animated health videos on a tablet computer. After a period of 6 months, free access to community information spots (InfoSpots) with an integrated digital health education platform was provided to the intervention villages. Participants in the control group did not receive the intervention. The primary outcome was the difference in disease knowledge between the intervention and control groups, 12 months after baseline. Data were collected using an open-ended questionnaire, with correct or incorrect answers before and after intervention.

Results: Between April and May 2019, a total of 600 participants were recruited into the intervention (n=298, 49.7%) or control (n=302, 50.3%) groups. At baseline, no statistically significant differences in knowledge of the target diseases were observed. At 12 months after intervention, knowledge about HIV/AIDS, TB, and *T. solium* (neuro)cysticercosis and taeniosis was 10.2% (95% CI 5.0%-15.4%), 12% (95% CI 7.7%-16.2%), and 31.5% (95% CI 26.8%-36.2%) higher in the intervention group than in

the control group, respectively. In all 4 domains (transmission, symptoms, treatment, and prevention), an increase in knowledge was observed in all the 3 diseases, albeit to varying degrees. The results were adjusted for potential confounders, and the significance of the primary results was maintained in the sensitivity analysis to assess dropouts. The participants who reported using the InfoSpots in the 12-month assessment further increased their knowledge about the target diseases by 6.8% (HIV/AIDS), 7.5% (TB), and 13.9% higher mean proportion of correct answers compared with the participants who did not use the InfoSpots.

Conclusions: Digital health education based on animated health videos and the use of free InfoSpots has significant potential to improve health knowledge, especially in rural areas of low- and middle-income countries.

Trial Registration: ClinicalTrials.gov NCT03808597; https://clinicaltrials.gov/ct2/show/NCT03808597

International Registered Report Identifier (IRRID): RR2-10.2196/25128

(J Med Internet Res 2022;24(7):e37666) doi: 10.2196/37666

KEYWORDS

digital health; digital health promotion; eHealth; mobile health; mHealth; Tanzania; health education; HIV/AIDS; tuberculosis; cysticercosis; tapeworm; mobile phone

Introduction

Background

Health education, defined as "any combination of learning experiences designed to facilitate voluntary adaptations of behaviour conducive to health" [1], encourages behavior that promotes good health and prevents disease [2]. Health literacy is a concept defined differently across the literature but can be summarized as "an asset for improving people's empowerment within the domains of health care, disease prevention and health promotion" [3]. Health literacy acquired through health education affects individual, family, and community health and has great potential for contributing to the achievement of specific targets of the Sustainable Development Goal (SDG; SDG 3) [4]. Health knowledge can be seen as a consequence, antecedent, or dimension of health literacy [5] and includes specific information such as prevalence, risk factors, transmission, and prevention [6]. The vast majority of people in rural communities in sub-Saharan Africa, Tanzania being the focus of this study, need health education, which is primarily provided by community health workers and individuals at health facilities, schools, and nongovernmental organizations.

The southern and eastern regions of Africa are most affected by HIV/AIDS. In 2020, 20.6 million people were living with HIV/AIDS, and 670,000 new infections and 310,000 AIDS-related deaths were registered [7]. Tuberculosis (TB) claimed 1.5 million lives worldwide in 2020 [8]. In addition, TB is the leading cause of death among HIV-infected individuals, often owing to late diagnosis, nonadherence to medication, and drug resistance. *Taenia solium* cysticercosis and taeniosis (TSCT) is considered a neglected tropical disease and is a food-borne parasitic disease that not only has a significant impact on human health by causing neurological signs or symptoms, including epileptic seizures and intestinal infection resulting in anemia and malnutrition, but also has an impact on animal health and community livelihood and can therefore be considered a one health disease par excellence [9].

The digital health landscape in Tanzania is changing in parallel with increasing mobile phone use and internet penetration. In December 2021, the country had 54.1 million mobile phone subscribers [10], with most connections in rural areas based on 2G. Coupled with significant economic growth and Tanzania's recent shift from low-income to lower-middle–income status [11], there is great potential to reach people through their mobile phones. Adapting smart devices for health education in resource-poor areas is promising and has proven effective [12].

Few studies have addressed the development [13] and use of animated health videos (animations) to improve client knowledge in this region [14-18]. Investigating the impact of a digital health education platform in rural sub-Saharan areas with low internet connectivity is novel and forms the basis of our study.

Objectives

The objective of the study in "the nondiscriminating access for digital inclusion" project ("DigI study") was to assess the uptake of knowledge with regard to HIV/AIDS, TB, and TSCT and its retention over time through a digital health education intervention with animations and provision of free access to community information spots (InfoSpots) with an integrated digital health education platform.

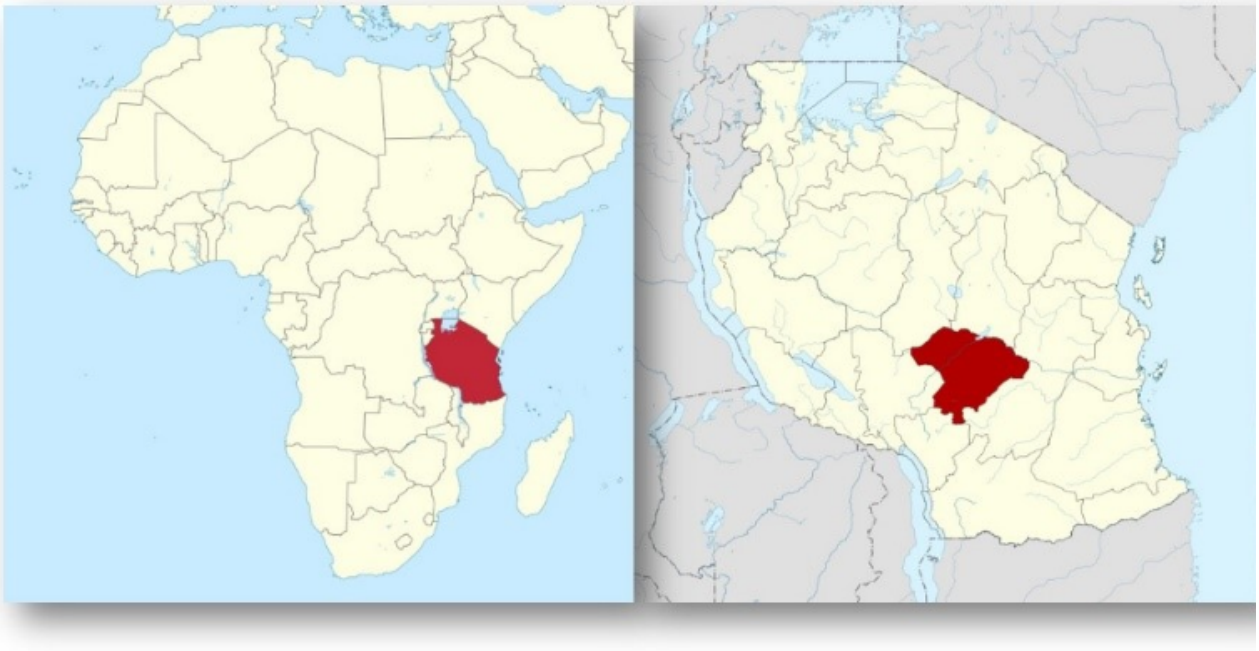
Methods

Study Design and Setting

As published in the DigI study protocol [19], this was a nonrandomized intervention study formatted as a community-based and longitudinal study. The study was undertaken in 4 villages with their 21 subvillages in the Iringa region located in the southern highlands of mainland Tanzania. The Iringa region is endemic to HIV/AIDS [20], TB [21], and TSCT [22], making prevention strategies for the target diseases essential. The Iringa district is a rural area in the northern Iringa region, where agriculture and livestock are the main sources of income [23]. All the 4 villages included in this study had health facilities.

Households in Migoli and Izazi (Figure 1) became the intervention group, whereas households in Kimande and Idodi formed the control group. The intervention and control villages were purposively chosen based on technical installation reasons and a traveling distance of >2.5 hours by car between the intervention and control villages.

Figure 1. Geographic location of the study site. From left to right: Tanzania within Africa and the Iringa district within Tanzania. Both illustrations are from Wikimedia Commons contributors (CC BY-SA 3.0).



Participants

In April and May 2019, a total of 991 households were assessed for their eligibility to participate in the study. People aged between 15 and 45 years living permanently in randomly selected households from all subvillages were eligible for inclusion in the study. People who planned to move to areas outside the villages during the data collection period were not eligible to participate. A female or male member per household was randomly selected using the Kish-grid method [24] to participate in the study based on multilevel sampling.

Intervention

The DigI study intervention consists of 2 parts: animations with key messages on HIV/AIDS, TB, and TSCT and the digital health education platform. The first part of the intervention—3 stories told with animations about the target diseases (Figure 2)—was presented to participants by Tanzanian members of the study team. The animations were shown on a tablet to the participants privately in their homes after the baseline assessment using the questionnaire. The animations, lasting between 3 and 7 minutes, included key messages for 4 domains (transmission, symptoms, treatment, and prevention) in each disease (HIV/AIDS, TB, and TSCT).

The DigI team applied an interdisciplinary approach when creating digital health messages based on a process involving local stakeholders and government-approved health promotion materials in a nondigital format [25]. All the animations were bilingual in Swahili and English [26]. All participants in the intervention group viewed animations in the Tanzanian Swahili language.

The second, unsupervised and voluntary part of the intervention started 6 months after the baseline assessment, with the rollout of the digital health education platform (the platform) in the already established InfoSpots in the intervention villages. The platform [27] could be accessed openly and free of charge via the participants' own smartphones or via public tablets provided at the InfoSpots. In addition to the animations in the first part of the intervention, the platform contained additional text information, graphics, and quizzes. We installed 5 InfoSpots in Migoli and Izazi, covering village offices and health facilities as well as Nyerere High School in Migoli. The animations (English versions) and a screenshot of the platform can be found in Figure 3 and Multimedia Appendices 1-3.

The control villages did not receive any intervention. Communities in the region usually access general information, health information, and education and communication materials through various channels. These channels include radio, television, newspapers, community meetings, and outreach from schools via children as well as when visiting health facilities.

Figure 2. Examples of illustrations of key messages from the animations. Important key messages were, for example, “never share sharp objects” and “avoid unsafe blood transfusions” for HIV/AIDS, “cover mouth and nose with paper or cloth when coughing or sneezing” for tuberculosis, and “cook meat well” for Taenia solium cysticercosis and taeniosis. These key messages were well illustrated, narrated, and repeated in the animations.

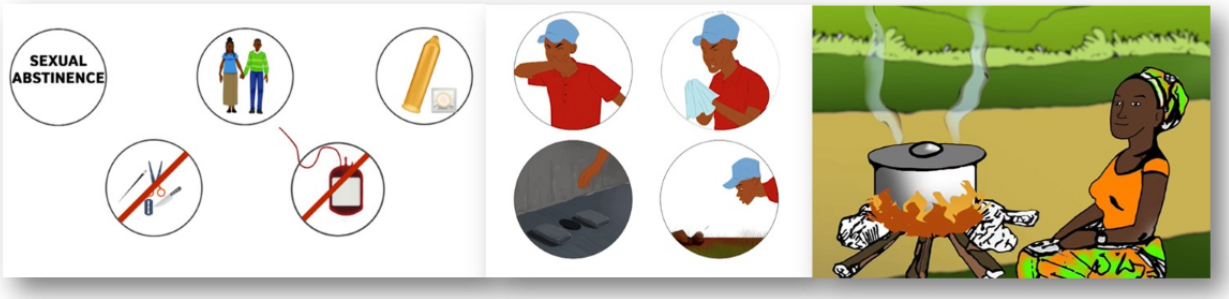
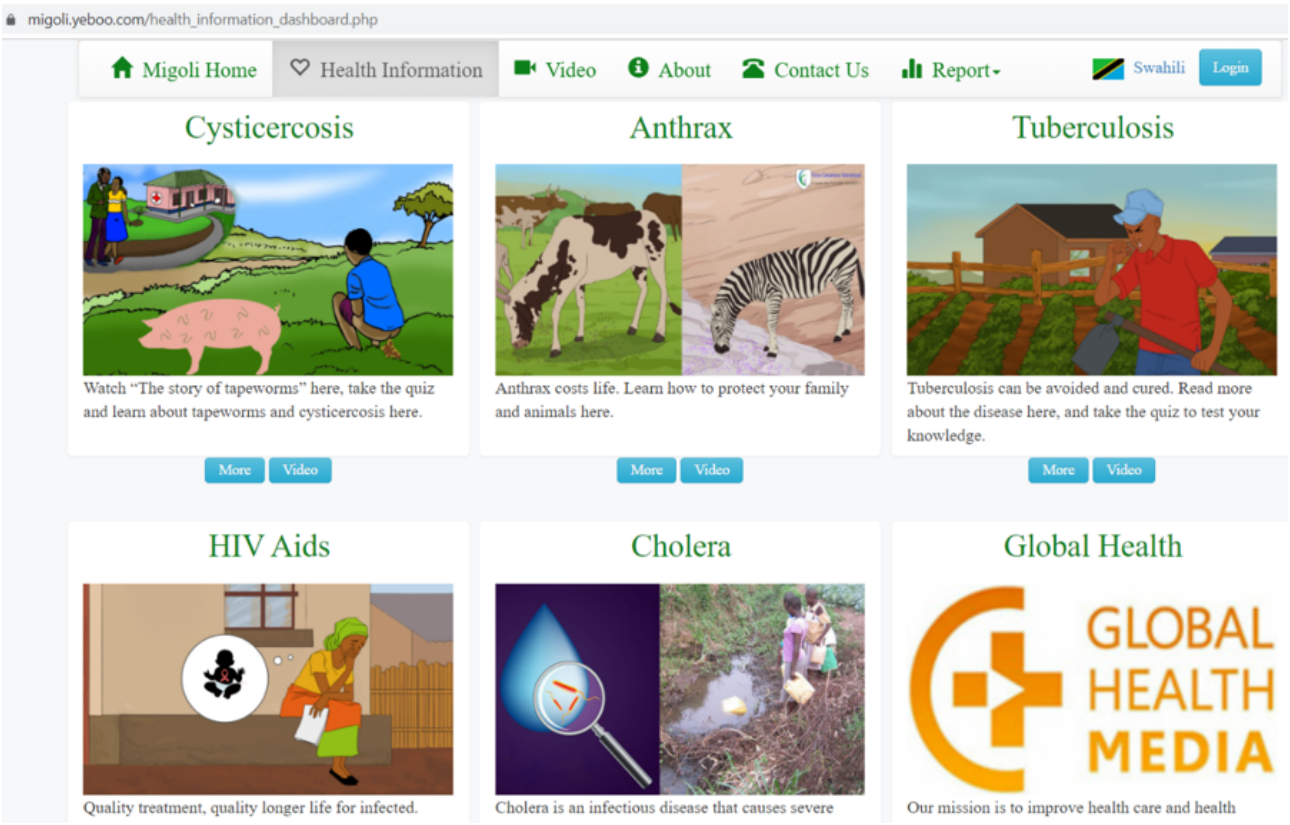


Figure 3. Screenshot of the platform.



Questionnaire

An open-ended Swahili-based questionnaire was used for data collection. The questionnaire was designed by Tanzanian and international experts in English (Multimedia Appendix 4), based on questions from previous studies [28,29] (The International Organisation for Migration, unpublished data, January 2014) and expanded through additional questions derived from approved health information provided by the Tanzanian Ministry of Health. The questions were translated to Swahili and back-translated into English again. A pilot study (in Swahili) was conducted with 50 participants before data collection [19]. A total of 7 questions were adapted to increase the participants’ comprehensibility. The questionnaire contained questions that could have more than one correct answer. Answers to the questions were binary (correct or incorrect. The questions were asked face to face and the enumerator entered the participant’s answers into a digital form. To analyze the health knowledge of the participants, we used 12 HIV/AIDS-knowledge questions, with 23 possible correct answers, 8 TB questions with 30 possible correct answers, and 13 TSCT questions with 22 possible correct answers. The overall Cronbach α, per disease, ranged between .79 and .87.

Outcomes

The primary outcome of the DigI study was the difference in the overall proportion of correct answers per target disease between the intervention and control groups 12 months after baseline assessment. The main hypothesis was that the proportion of correct answers in the intervention group would differ from the proportion of correct answers in the control group at 3 and 12 months. The secondary outcome was the difference in the proportion of correct answers in the 4 domains of each disease: transmission, symptoms, treatment, and

prevention. The secondary hypothesis was that there would be differences among the groups' proportion of correct answers per domain. For all outcome variables, the questionnaire and corresponding correct responses were used.

To investigate the effect of the digital health education intervention, we assessed the disease knowledge of both the intervention and control groups at baseline and at 3 and 12 months after the first part of the intervention. Participants in the intervention group were further asked questions related to their views regarding animations at the 3-month follow-up and their use of the InfoSpots at the 12-month follow-up.

Statistical Methods

For the sample size calculation, we assumed a proportion of 50% of correct answers in the group without intervention and a difference among the groups of 15% to 20% after the intervention. The power was set to 80% and a 2-sided significance level of 5% (using Bonferroni correction) was applied. The target sample size was 460. To increase the precision of the key estimates and account for dropouts, 600 participants were recruited.

Sociodemographic sample characteristics were described by frequency with percentage or mean with SD. Differences in sociodemographic characteristics among the groups were tested using Pearson chi-square test (for categorical variables) and a 2-independent sample 2-tailed *t* test (for age). For each disease, the total number of correct answers was summed for each participant and divided by the maximum number of correct answers to generate the overall proportion of correct answers. The same calculations were performed to generate the proportion of correct answers for each domain per disease. Assuming missing data at random, a mixed effects linear regression model for continuous outcomes was used to examine the difference in the average proportion of correct answers between the intervention and control groups. The analysis was performed with and without adjusting for age, sex, education, and occupation as potential confounders that could have influenced the outcome. In the mixed model of linear regression, the subvillage, household, and time point were specified as random variables and the group, as a fixed variable. Unstructured and exchangeable variance-covariance structures for the households and time were chosen. To assess the impact of time with and without adjusting, an interaction term "group×time" was added to the mixed model. The results of the analysis using mixed effects linear regression were reported as the average difference among the groups, and 95% CI were calculated. The *P* value was also reported for additional information. Loss to follow-up was addressed by sensitivity analysis assuming a worst-case scenario, with all answers being incorrect after the dropout of the participant. The differences in the proportion of correct answers between the participants who used the InfoSpots and those who did not were described using mean and SD. Analyses were performed using Stata/SE (version 16; StataCorp) [30].

Ethics Approval

The Tanzanian National Health Research Ethics Sub-Committee granted ethical clearance (NIMR/HQ/R.8a/Vol. IX/2947) in November 2018 and extended its clearance in February 2020. The Tanzania Commission for Science and Technology issued a research permit in March 2019. The DigI study was registered at ClinicalTrials.gov (NCT03808597) before enrolling the first participant. Each participant was informed orally and in writing in Swahili. Informed consent to participate in the study was obtained in writing, and parental consent was required for participants aged <18 years.

Results

Study Population

A total of 600 participants were recruited into the study, of whom 560 (93.3%) were interviewed at 3-month follow-up and 493 (82.2%) at 12-month follow-up (see Figure 4 for a flowchart of the study).

The descriptions of the 2 study populations are presented in Table 1. The main differences were in education and occupation, which we adjusted for in our analysis.

Figure 4. Flowchart of the study. The figure shows the number of households assessed for inclusion before a random generator selected the 298 households for the intervention group and 302 households for the control group. One participant per household was included in the study. Further, the figure shows the remaining participants at the 3- and 12-month assessment.

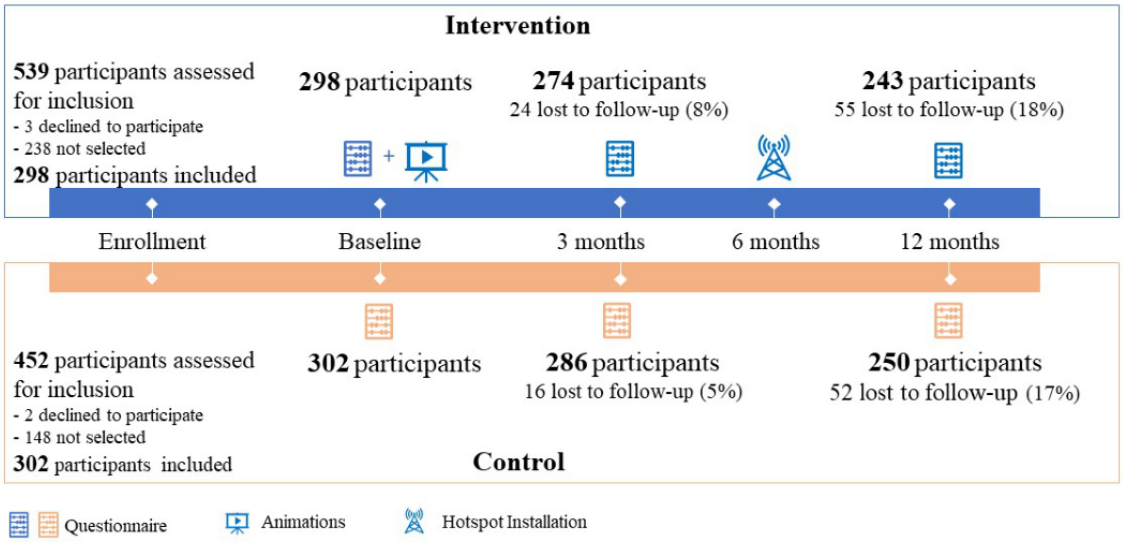


Table 1. Baseline demographic characteristics of participants aged 15 to 45 years living in the intervention and control villages.

Characteristics	Total (N=600)	Intervention (n=298)	Control (n=302)
Sex, n (%)			
Female	362 (60.3)	193 (64.8)	169 (56)
Male	238 (39.7)	105 (35.2)	133 (44)
Age (years), mean (SD)	30.0 (8.3)	28.7 (8.1)	30.8 (8.3)
Village, n (%)			
Migoli	173 (28.8)	173 (58.1)	N/A[a]
Izazi	125 (20.8)	125 (41.9)	N/A
Idodi	150 (25)	N/A[a]	150 (49.7)
Kimande	152 (25.3)	N/A	152 (50.3)
Education, n (%)			
No education	79 (13.2)	56 (18.8)	23 (7.6)
Primary School	427 (71.2)	181 (60.7)	246 (81.5)
Secondary or higher education	94 (15.7)	61 (20.4)	33 (11)
Occupation, n (%)			
Petty traders	151 (25.2)	135 (45.3)	16 (5.3)
Farmers	321 (53.5)	65 (21.8)	256 (84.8)
Other	128 (21.3)	98 (32.9)	17 (9.9)

[a]N/A: not applicable.

Knowledge Outcomes

At baseline, all (600/600, 100%) participants reported that they had heard of HIV/AIDS. Overall, 91% (546/600) of the participants had heard of TB, but only 9% (54/600) of the participants had heard of cysticercosis, and 13.2% (79/600) of the participants had heard of the pork tapeworm. Overall, only 3% (18/600) of the participants said that they knew what pork with cysticercosis looked like. The baseline knowledge, calculated as the unadjusted mean percentage of correct answers, was similar in both groups, although it was slightly higher for TB and TSCT in the intervention group than in the control group. The overall proportions of correct answers at the disease level are presented in Table 1 and Figure 5. The equivalent responses broken down at the domain level are presented in Table 2.

At the 3-month assessment, correct answers regarding HIV/AIDS in the intervention group increased to a mean percentage of 54.7% (SD 17%), whereas they remained at 47.1% (SD 16.6%) in the control group (adjusted difference 8.3, 95% CI 3.2-13.4). The intervention effect was larger in the TB section, with an increase from baseline of 15.5% to 34.4% (SD 15.4%) in the intervention group compared with a 1.5% increase in the control group (adjusted difference 15.8, 95% CI 11.7-20.0). For TSCT, the first part of the intervention led to a 31.3% knowledge increase, reaching 41% (SD 20.2%) in the intervention group, whereas only a limited increase of 2.5% was measured in the control group (adjusted difference 31.2, 95% CI 26.9-35.6) after 3 months.

At the 3-month assessment, 97.1% (266/274) of the participants in the intervention group reported learning through animations, and 74.1% (203/274) reported having discussed health messages with friends and family.

Figure 5. Box plot and density plots for knowledge and by disease, group, and time point: (A) HIV/AIDS, (B) tuberculosis, (C) Taenia solium cysticercosis and taeniosis.

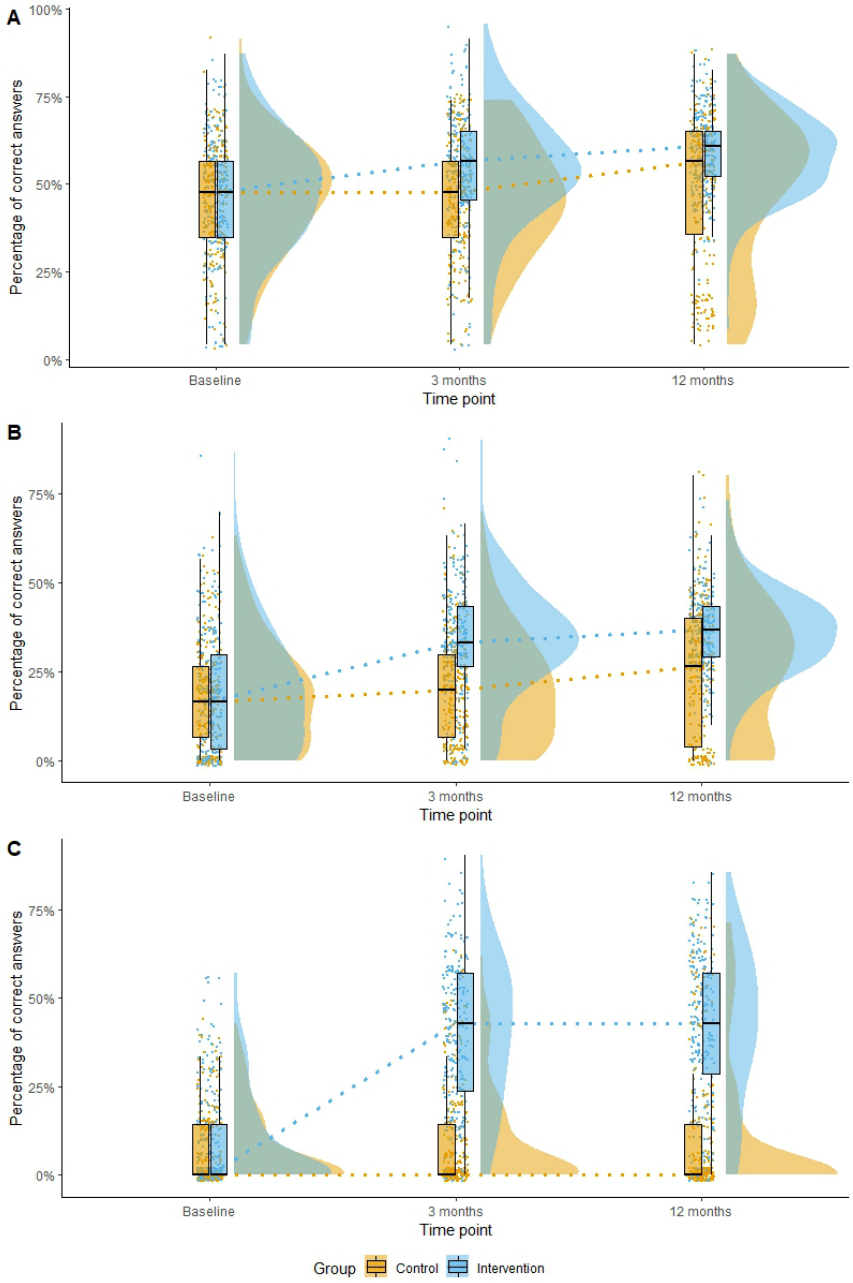


Table 2. Overall intervention effect for knowledge about the target diseases and mean percentage differences among the groups (N=600).

Target disease and time point	Correct answers, mean (SD)		Crude difference, mean (95% CI)	Adjusted difference, mean (95% CI)	*P* value (adjusted model)
	Intervention	Control			
Overall HIV/AIDS					<.001
Baseline	47.6 (17.4)	48.3 (15.6)	−0.1 (−6.5 to 6.3)	0.3 (−4.7 to 5.4)	
3 months	54.7 (17.0)	47.1 (16.6)	8.0 (1.6 to 14.4)	8.3 (3.2 to 13.4)	
12 months	59.8 (11.9)	50.2 (21.1)	9.9 (3.4 to 16.3)	10.2 (5.0 to 15.4)	
Overall tuberculosis					<.001
Baseline	18.9 (16.2)	18.3 (14.7)	1.3 (−3.6 to 6.1)	2.0 (−2.1 to 6.1)	
3 months	34.4 (15.4)	19.8 (15.0)	15.2 (10.3 to 20.0)	15.8 (11.7 to 20.0)	
12 months	35.8 (11.5)	25.1 (18.5)	11.3 (6.3 to 16.2)	12.0 (7.7 to 16.2)	
Overall *Taenia solium* **cysticercosis and taeniosis**					<.001
Baseline	9.7 (14.9)	7.6 (12.1)	2.4 (−1.7 to 6.4)	2.6 (−1.6 to 6.8)	
3 months	41.0 (20.2)	10.1 (15.1)	31.1 (26.9 to 35.3)	31.2 (26.9 to 35.6)	
12 months	42.1 (22.0)	11.0 (20.0)	31.4 (26.8 to 35.9)	31.5 (26.8 to 36.2)	

Participants in the intervention group were able to maintain their knowledge of the disease, as documented at the 12-month assessment. Participants in the control group were found to have a slight increase in knowledge of 1.9% (HIV/AIDS), 6.8% (TB), and 3.4% (TSCT) from baseline, which was significantly lower than the increase of 12.2% for HIV/AIDS (adjusted difference 10.2, 95% CI 5.0-15.4), 16.9% for TB (adjusted difference 12.0, 95% CI 7.7-16.2), and 32.4% for TSCT (adjusted difference 31.5, 95% CI 26.8-36.2) in the intervention group. After 12 months, participants in the intervention group retained a mean proportion of correct answers of 59.8% for HIV/AIDS, 35.8% for TB, and 42.1% for TSCT.

The intervention effect was statistically significant in the crude analyses and remained statistically significant after adjusting for age, sex, education, and occupation. Figure 5 shows the corresponding raincloud plot illustrating the median percentage of correct answers in both groups at all time points.

The intervention effect in the transmission HIV/AIDS domain was statistically significant, with an adjusted mean difference of 6% (95% CI 1.7%-10.4%) after 3 months and 6.4% (95% CI 1.9%-10.9%) after 12 months. In this domain, the effect remained unchanged over time (*P*=.06), in contrast to the other domains, where the effect either increased or decreased between 3 and 12 months. The effect was significant for all TB domains, although knowledge increase at 12 months was reduced compared with that at 3 months. However, as with the overall scores, the strongest effect was observed for TSCT, for which there were low baseline levels of disease knowledge. The adjusted mean percentage difference between the 2 groups reached 40% in 3 out of the 4 domains after 3 months and in 2 out of the 4 domains after 12 months. See Table 3 for all domain level values.

A sensitivity analysis assessing the dropout of 107 participants (n=55, 51% in the intervention group and n=52, 49% in the control group) and assuming a worst-case scenario showed an unchanged effect for HIV/AIDS, a 3% reduction in the intervention effect for TB, and a 5.8% reduction in the intervention effect for TSCT.

At the 12-month assessment, 30% (73/243) of the participants in the intervention group reported having accessed the InfoSpots with the health education platform. Of these, 53% (39/73) had viewed HIV/AIDS animation, 37% (27/73) had TB animation, and 44% (32/73) had TSCT animation. Those who visited the InfoSpots further increased their knowledge by 8.5% (HIV/AIDS), 6.3% (TB), and 12.1% (TSCT), whereas participants who did not visit the InfoSpots remained at the same knowledge level (Table 4).

Table 3. Intervention effect and mean percentage differences among the groups at the domain level.

Domains and time point	Correct answers, mean (SD)		Crude difference, mean (95% CI)	Adjusted difference, mean (95% CI)	*P* value (adjusted model)
	Intervention	Control			
HIV/AIDS					
Transmission					.06
Baseline	49.5 (20.0)	47.8 (18.7)	2.0 (−4.0 to 7.9)	1.9 (−2.3 to 6.2)	
3 months	54.0 (19.4)	47.8 (20.2)	6.2 (0.2 to 12.1)	6.0 (1.7 to 10.4)	
12 months	59.2 (16.8)	52.5 (21.3)	6.4 (0.4 to 12.5)	6.4 (1.9 to 10.9)	
Symptoms					<.001
Baseline	79.2 (33.4)	81.1 (30.9)	−1.4 (−11.5 to 8.7)	−2.2 (−11.1 to 6.8)	
3 months	88.0 (28.3)	71.8 (37.1)	16.5 (6.4 to 26.7)	15.5 (6.5 to 24.6)	
12 months	93.6 (19.0)	75.0 (40.6)	18.8 (8.5 to 29.1)	17.9 (8.6 to 27.1)	
Treatment					<.001
Baseline	70.5 (29.5)	73.7 (27.6)	−2.4 (−12.6 to 7.8)	−2.8 (−11.9 to 6.3)	
3 months	77.2 (25.1)	67.3 (30.5)	10.6 (0.4 to 20.8)	10.1 (1.0 to 19.2)	
12 months	90.7 (18.1)	72.8 (37.2)	18.5 (8.1 to 28.8)	18.1 (8.8 to 27.3)	
Prevention					<.001
Baseline	35.3 (19.2)	36.8 (17.7)	−0.8 (−6.6 to 5.1)	0.2 (−4.7 to 5.1)	
3 months	43.9 (19.1)	37.5 (16.3)	7.0 (1.2 to 12.8)	7.9 (2.9 to 12.8)	
12 months	46.8 (15.6)	39.0 (19.9)	8.4 (2.5 to 14.2)	9.2 (4.2 to 14.3)	
Tuberculosis					
Transmission					<.001
Baseline	17.6 (22.9)	17.0 (17.3)	1.6 (−2.9 to 6.1)	2.1 (−1.7 to 6.0)	
3 months	29.6 (17.5)	18.8 (14.5)	11.5 (7.3 to 15.7)	12.1 (8.5 to 15.6)	
12 months	28.7 (14)	21.1 (16.2)	8.5 (4.2 to 12.7)	9.0 (5.3 to 12.6)	
Symptoms					<.001
Baseline	14.4 (15.5)	13.8 (13.4)	1.3 (−3.2 to 5.7)	1.8 (−2.1 to 5.6)	
3 months	28.7 (18.1)	15.2 (14.5)	14.0 (9.5 to 18.5)	14.4 (10.5 to 18.4)	
12 months	28.1 (15.0)	19.9 (18.4)	8.6 (4.0 to 13.3)	9.1 (5.0 to 13.2)	
Treatment					<.001
Baseline	54.8 (38.3)	53.8 (37.4)	2.3 (−9.0 to 13.5)	4.5 (−6.1 to 15.0)	
3 months	82.2 (28.6)	53.6 (38.4)	29.5 (18.5 to 40.5)	31.6 (21.2 to 41.9)	
12 months	89.0 (20.7)	61.6 (40.7)	28.4 (17.2 to 39.6)	30.4 (19.9 to 41.0)	
Prevention					<.001
Baseline	13.6 (18.5)	13.5 (16.9)	0.5 (−4.1 to 5.1)	1.1 (−3.0 to 5.2)	
3 months	29.2 (16.3)	15.3 (16.2)	14.1 (9.6 to 18.7)	14.6 (10.5 to 18.7)	
12 months	33.2 (13.4)	22.5 (19.8)	10.9 (6.3 to 15.6)	11.4 (7.3 to 15.6)	
Taenia solium **cysticercosis and taeniosis**					
Transmission					<.001
Baseline	8.7 (19.4)	4.7 (14.1)	4.2 (−1.3 to 9.7)	4.1 (−1.5 to 9.7)	
3 months	50.1 (28.7)	8.3 (19.1)	42.0 (36.2 to 47.7)	41.7 (35.9 to 47.5)	
12 months	51.4 (27.0)	10.0 (23.4)	41.5 (35.4 to 47.6)	41.2 (35.0 to 47.3)	
Symptoms					<.001

Domains and time point	Correct answers, mean (SD)		Crude difference, mean (95% CI)	Adjusted difference, mean (95% CI)	*P* value (adjusted model)
	Intervention	Control			
Baseline	6.0 (9.9)	5.6 (8.8)	0.9 (−1.8 to 3.7)	1.0 (−1.7 to 3.8)	
3 months	22.5 (19.9)	7.6 (10.6)	15.3 (12.4 to 18.3)	15.4 (12.4 to 18.5)	
12 months	27.1 (22.2)	8.1 (15.4)	19.5 (16.2 to 22.8)	19.6 (16.1 to 23.1)	
Treatment					<.001
Baseline	7.4 (26.2)	5.0 (21.8)	2.4 (−3.3 to 8.0)	2.8 (−3.5 to 9.2)	
3 months	65.6 (47.6)	16.2 (36.9)	49.3 (43.2 to 55.7)	49.5 (42.5 to 56.5)	
12 months	72.8 (44.6)	26.0 (44.0)	46.5 (39.0 to 53.9)	46.7 (38.7 to 54.6)	
Prevention					<.001
Baseline	16.6 (24.0)	14.0 (22.4)	2.5 (−3.3 to 8.3)	2.8 (−2.9 to 8.5)	
3 months	55.4 (22.7)	14.6 (21.6)	40.7 (34.8 to 46.5)	40.8 (35.1 to 46.6)	
12 months	50.1 (26.4)	13.7 (25.5)	36.3 (30.2 to 42.5)	36.5 (30.5 to 42.6)	

Table 4. Comparison of knowledge about the 3 target diseases, shown as mean percentage of correct answers, between participants who used the information spots (InfoSpots) and those who did not at the 12-month assessment.

Target disease and time period	InfoSpots users (n=73), mean (SD)	Non–InfoSpots users (n=170), mean (SD)
HIV/AIDS		
3 months	55.1 (18.0)	53.1 (16.0)
12 months	63.6 (11.1)	56.8 (11.6)
Tuberculosis		
3 months	34.8 (16.5)	33.9 (15.1)
12 months	41.1 (11.4)	33.6 (10.8)
Taenia solium **cysticercosis and taeniosis**		
3 months	38.5 (20.3)	39.9 (20.3)
12 months	50.6 (17.6)	36.7 (21.8)

Discussion

Principal Findings

The DigI study is the first of its kind to assess health knowledge uptake and retention following a 2-pronged digital health education intervention consisting of watching health animations and accessing a free digital health education platform (InfoSpots) in rural Tanzania.

Participants in the intervention group attained significantly higher levels of knowledge than those in the control group, with the adjusted differences among the groups being 10.2%, 12%, and 31.5% for HIV/AIDS, TB, and TSCT, respectively, after 12 months. We observed increased knowledge of all 3 diseases in all domains. The effect on knowledge retention was particularly strong for TSCT, with a low level of knowledge at baseline, as shown by the increase from 9.7% to 42.1% after 12 months.

Looking at the domains, the effect was strongest in the 3-month assessment for all TB and 3 out of the 4 TSCT domains. In contrast, for all HIV/AIDS and TSCT symptoms domains, an increased effect was observed at the 12-month assessment, indicating that the use of InfoSpots for health education may have contributed to the retention and enhancement of health knowledge. In fact, the InfoSpots users showed further increase in knowledge at 12 months compared with those who did not use InfoSpots. This increase in knowledge was more pronounced for HIV/AIDS and TSCT than for TB. However, this does not exclude the possibility that the participants accessed other knowledge sources over the course of the study. This may also explain the slight increase in knowledge in the control group at 12 months, which was 1.9%, 6.8%, and 4.4% for HIV/AIDS, TB, and TSCT, respectively. We were unable to assess why the participants in the control group improved their knowledge. They were not asked any questions about whether they had talked to other villagers about diseases or had otherwise obtained information. Contamination among the groups is unlikely, given the long distance of at least two and a half hours by car. Between the baseline and the 12-month assessment, 107 out of 600 participants dropped out, accounting for 17.8% of the initial participants. All participants were contacted by subvillage leaders via their mobile phone number. The reasons for dropping out were, in most cases, migration for work opportunities in other villages, as the data collection lasted for more than a year

in an area characterized by seasonal workers in agriculture, fishing activities, and petty trading.

The intervention effect was independent of age, sex, education, and occupation and demonstrated that digital health education is applicable and useful for all people despite sociodemographic differences.

Comparison With Prior Work

The DigI study shows that animations with short, clear, and basic health messages have significant potential to improve health knowledge in the short to long term, as confirmed by previous studies in a sub-Saharan setting [14-18]. Despite challenges in comparing our results directly with other intervention studies using animations for health knowledge transfer—owing to differences in health promotion content, interventions, target groups, and research design, 3 studies are worth mentioning. Adam et al [18] observed a small significant increase in knowledge among pregnant women in a month, but not 5 months, after their video breastfeeding intervention. Lund et al [16] found a 38% increase in maternal health knowledge among health care workers in their intervention study 12 months after introducing a safe delivery app with animations for health knowledge improvement, whereas Bolan et al [17] researched the same app and found a 17% to 19.5% increase in their 3-month assessment. Although health care workers may have some prior medical knowledge, the results indicate that the study population and setting, and most probably other factors, may impact knowledge uptake and retention and always need to be considered.

Strengths and Limitations

Overall, the DigI study, which offers digital health education both directly and via local InfoSpots, is unique and novel and could inform the rethinking of health education delivery in rural areas of low- and middle-income countries as a whole. It seems that simple animations co-designed with local stakeholders, provided in Swahili with local characters in a recognizable environment [25], can contribute to improvement in health knowledge. The repetition of key messages in animations and illustrative scenes accompanied by the narrator's explanations (Figure 2) could be key factors for better knowledge uptake and retention.

Community health workers, equipped with a digital tool, could share tailored health messages while simultaneously sensitizing individuals to the use of a locally adapted digital health promotion platform that can be deployed at strategic locations within the communities. In fact, we were able to show that InfoSpots users were creative and enthusiastic when using the platform and that the animations were well accepted as a knowledge transfer tool in the communities [31]. Although InfoSpots require cross-sectoral collaboration among community leaders, internet providers, and the health and educational sectors, if co-designed and promoted together, they have the potential to create ownership and thus achieve long-term sustainability. Furthermore, such InfoSpots can contribute to the development of digital skills and provide people with access to essential information, thus supporting the achievement of SDG 3, SDG 4, and SDG 16.

The DigI study has some limitations that require further investigation. First, the selection of intervention and control villages was nonrandomized and performed for technical reasons related to the installation of the InfoSpots. The demographic data showed differences between the intervention and control groups in terms of age, sex, education, and occupation. This may have affected the external validity of the DigI study's research design. However, our adjusted results showed that none of the possible confounding factors affected the intervention effect. Participants were randomly selected from all villages and subvillages, which is a strength that reduces the selection bias. Furthermore, with this study design, it was not possible to assess whether improved health knowledge and resulting health literacy may have an impact on the burden of disease from our 3 target diseases in the communities. Increased health knowledge does not guarantee a change in health behaviors. To initiate and sustain behavior change, multiple interventions at various levels are required [1], and this project only focused on interventions that improve health knowledge.

Future Directions

In summary, the DigI study showed that the unique combination of animated health videos shown to participants in their homes and the use of free InfoSpots with an integrated digital health platform improved knowledge about the 3 target diseases, not only in the short term but also over a longer time frame. Furthermore, implementing health access points such as InfoSpots in rural Tanzania, with animations and other digital health education materials in their own language, may contribute to achieving SDG 3 and in our case, particularly target SDG 3.3—ending the epidemics of HIV/AIDS, TB, and neglected tropical diseases by 2030. However, further studies are required to demonstrate the impact of the promising digital health intervention of the DigI study on health-seeking behavior and thus on disease prevention and management.

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Data Availability

Deidentified participant-level data and the data dictionary will be made available on request, with a signed data access agreement after December 2022. Please email the corresponding author for their access.

Authors' Contributions

CH, FS, BN, LMD, JN, and ASW contributed to study concept and design. CH collected the data. CH, DS, and LMD analyzed and interpreted the data. CH and DS drafted the manuscript. All the authors critically revised the manuscript for important intellectual content. DS and LMD performed statistical analyses. JN obtained funding. CH, FS, BN, JN, and ASW provided the administrative, technical, and material support. BN, FS, and ASW supervised this study.

Conflicts of Interest

None declared.

Multimedia Appendix 1

HIV/AIDS health animated video (English).
[MP4 File (MP4 Video), 58029 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Tuberculosis health animated video (English).
[MP4 File (MP4 Video), 28571 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Taenia solium cysticercosis and taeniosis health animated video (English).
[MOV File , 78062 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Study questionnaire (HIV, tuberculosis, or Taenia solium cysticercosis and taeniosis knowledge questions used at baseline and at 3 and 12 months).
[PDF File (Adobe PDF File), 398 KB-Multimedia Appendix 4]

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Abbreviations

InfoSpots: information spots
SDG: Sustainable Development Goal
TB: tuberculosis
TSCT: Taenia solium cysticercosis and taeniosis

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