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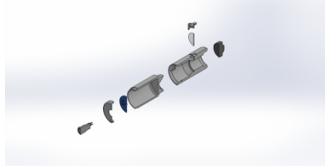
## Introduction

The World Health Organization reports that 10% of all pharmaceuticals globally are counterfeit/substandard<sup>1</sup>. London School of Hygiene and Tropical Medicine estimated that 116,000 deaths were caused specifically because of counterfeit antimalarials in sub-Saharan Africa where the problem is particularly acute<sup>2</sup>. In this report, we propose a novel device for the detection of counterfeit antimalarials in order to alleviate the problem. Our device involves utilizing a miniaturized UV spectrometer shined on a pill and then using the camera on a smartphone to capture fluorescent spectrum.

## Materials and Methods

The device was initially computer modeled using Fusion 360 and manufactured using a stereolithography 3D printer. The UV emitter produced a wavelength of 367nm. The camera used to capture the fluorescent spectra belonged to an iPhone XR.

## Results and Discussion



The device was able to accurately detect the presence of quinine and artemisinin indicating that it could be used to determine whether an antimalarial had the proper active ingredient. However, there was difficulty in terms of quantifying the amount of active ingredient. Further development of our algorithm will be required in order to accurately assess the fluorescent spectra in order to quantify the amount of active ingredient in an antimalarial.

## Conclusion

We have shown the ability to construct a low-cost device that utilizes a smartphone camera in order to detect the presence of the active ingredient in antimalarials. Our future plan is to beta test our device and revise our algorithm to quantify the amount of active ingredient. Our goal is to be able to utilize our device to reduce the number of counterfeit drugs in locations that are particularly impacted by the problem.

## Acknowledgements

We would like to thank the Michigan Business Challenge, China Business Challenge, and TechArb Venture Accelerator for providing the funding to help out with the development of this device

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## **Research Review of Sustainable Development Design in Africa: A Design Science Approach**

Authors: Thomas Barlow, Melissa Greene, and Panos Papalambros

**Introduction:** The United Nations Sustainable Development Goals (UNSDGs) describe actions for improving worldwide living conditions in a sustainable manner. Africa is recognizably one of the least developed continents with a high potential for change over the next few decades. There exists in Africa an opportunity for the design community to contribute to the United Nations sustainable development effort through research and the application of design tools, methods, and processes. The design community will play an integral part in the success of the UNSDGs so that the needs of our generation as well as the future generations will be met.

Currently, the intersection of the design community with the African UNSDGs is not well understood. A deeper understanding will allow for a more connected and global research community focused on sustainable development achieved through design. Understanding the research needs in Africa can illuminate who is actively involved in design research and what needs they are addressing. In this review, we perform a review of existing design research in Africa, identify gaps and research needs, and outline opportunities for applying design thinking to challenges associated with development efforts in African countries.

**Materials and Methods:** Design and sustainability are both broad topics that can include many different types of research efforts. Both general and narrow search terms were used as the review proceeded. This included general phrases such as “Design for Developing Countries” which were used to find more topics that were then included in the search. Design inclusion focused on the design of a product, service, or system involving any aspect from defining the need to solution implementation. Sustainability was included based on its relevance to the UN Sustainable Development Goals. This created a wide set of research topics that were focused in Africa. All the papers were then analyzed or mapped to draw insight about the nature of research of sustainable design in Africa.

**Results and Discussion:** A diverse set of papers were included in the review. These were divided into 23 general topics with 261 distinct authors. While the United States was the largest source of the papers, many were from African countries with South Africa and Kenya being most represented. Most of the papers focused on the needs of the users with some that address concepts, validation, or implementation. This dataset appears to be a representative sample of the research work being done on design for sustainable design in Africa.

From these papers, the three most prevalent research topics in order were energy, agriculture, and water. Interestingly, water related research was the most prevalent topic from non-African researchers whereas energy was the most researched topic from African based researchers. Differences between African and non-African researchers was further seen in the amount of collaborations. Researchers from Africa had more co-authors in other countries than non-African researchers. Despite this difference, most papers from both African and non-African researchers did not have African co-authors. This illuminated a possible need for reducing the barriers to collaboration between researchers and alignment between researchers in Africa and outside of Africa.

**Conclusions:** Some gaps exist in the design for sustainability in Africa including differing research focuses from African and non-African researchers, too few papers with African based co-authors, and a lack of collaboration in general. More work needs to be done to understand why certain research topics differ between regions. Understanding funding sources may help explain these differences. Also, poor collaboration seen in the low levels of co-authorship will likely limit the amount of potential impact the design community can have on sustainable design. Interestingly, those who likely need to collaborate more, non-African researchers, are collaborating less than African based researchers. This needs to change if more impactful and applicable work is to be done.

# Examining the Prevalence of Traditional Medicine Usage Among Mothers with Low Birth Weight and Premature Infants

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**Introduction:** In Ghana, traditional medicine is often used with modern medicine, especially in newborn care since mothers believe that it can resolve physical illness that is caused by spiritual ailment. This study aimed to 1) identify the prevalence of traditional medicine usage among mothers in newborn care 2) better understand the ways in which traditional medicine is administered.

**Materials and Methods:** An observational cohort study was conducted in which surveys were administered to mothers (N=386) who birthed low birthweight or premature babies at Suntreso Government Hospital and Kumasi South Hospital in Kumasi, Ghana from April 2018 to July 2019. The survey collected demographic information, baby feeding practices, and presence of illness. Pearson's chi-square ( $\chi^2$ ) tests were used to determine statistically significant differences in traditional medicine usage by variables of interest at the  $p < .05$  level. All analyses were conducted by using IBM SPSS Statistics 21. A power analysis was conducted to determine the appropriate sample size. Participants provided written consent and the study was approved by the University of Michigan IRB. Materials included paper surveys, a tape measure, scale, a laptop computer, and compensation for the study participants.

**Results and Discussion:** Overall prevalence of traditional medicine usage was low (4.8%). Traditional medicine usage was significantly higher among participants less than 20 years old ( $\chi^2 = 30.444, p < .001$ ), traveled between 90 minutes to 2 hours to the hospital ( $\chi^2 = 22.055, p < .01$ ), and reported food uncertainty ( $\chi^2 = 75.413, p < .01$ ). Traditional medicine was administered orally, nasally, anally, and through bathing.

**Conclusions:** Younger individuals may rely on older adults who have traditional beliefs for advice on how to care for their baby. Individuals that travel 90 minutes – 2 hours to the hospital and individuals that experience food uncertainty may lack access to modern medicine and therefore use traditional medicine. The strength of this study lies in its examination of demographic variables which broaden our understanding of associations among traditional medicine and variables. The study had limitations, because of the quantitative nature of the survey researchers were unable to examine the rationale behind mothers' traditional medicine usage. Opportunities exist for further research on 1) why certain groups have a higher prevalence of traditional medicine usage 2) the ways in which traditional medicine usage may impact infant growth among these low birth weight and premature infants.

**Acknowledgements:** This research was funded by the Office of Health Equity and Inclusion Diversity Fund Grant at the University of Michigan Medical School and the United States Fulbright Program Grant.

## The Mbale Center for Innovation and Design: An Initiative in Eastern Uganda

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### Introduction

Uganda, a vibrant country in East Africa, has the second youngest – and fastest growing – population in the world. Over 50% of its 43 million citizens are 15 years of age or younger. Nearly 800,000 Ugandans turn 18 years old each year, and despite a 67% unemployment rate in Kampala (which is even higher for young women), many youth move to the capital from rural areas due to even poorer livelihood development options in rural and village settings, draining talent from these communities. In addition, 90% of the country relies on wood fuel for their water treatment and household cooking needs, leading to 23,000 premature deaths every year due to the unhealthy smoke from these traditional open fires. As a result, Uganda also experiences high deforestation rates, and the population is expected to triple over the next 30 years – further increasing pressure on the country's natural resources. MAPLE Microdevelopment, an NGO that was established in Uganda in 2009, works with community-based microfinancing groups in Mbale, a city on the eastern Ugandan border within the Mt. Elgon region. Recently, communities that benefit from MAPLE's financial literacy programs have expressed concerns regarding their ecological, economic, and social well-being and have asked for additional hands-on services.

### Materials and Methods

During February and March 2019, the lead author traveled to so-called *innovation hubs* and *design centers* in Kenya and Uganda and interviewed directors and staff regarding their practices, advice, and experiences. After two weeks of travel and roughly ten interviews, the lead author and second author then worked in Mbale, Uganda with the MAPLE staff and community members for two months to anecdotally assess the feasibility of the ideas and practices that were mentioned and recommended by the interviewed experts.

### Results and Discussion

So-called *innovation hubs* and *design centers* are increasingly being established across Uganda and Kenya to promote local design and social innovation. However, these centers are often situated in urban environments with a focus on high-tech solutions and digital technologies. We identified a need for a low- to mid-tech design and innovation center in Mbale, a region with a unique combination of highly entrepreneurial citizens and ecological problems, such as lack of clean water and affordable energy. We developed a community-based design model focused on the following six principles: (1) Receive and invitation to help, (2) Engage in community dialogues, (3) Strengthen economic resilience, (4) Engage youth (18-28 years old), (5) Start small using co-design principles, and (6) Build on local expertise and provide capacity building as needed.

### Conclusions

Currently, no center for innovation exists in a rural, fragile ecological zone such as the Mt. Elgon region where engineers, NGOs, and others can meet with villagers to co-design and test solutions to problems. By involving young adults and other residents of rural villages in the design process, the Mbale Center for Innovation and Design (MCID) project intends to change this by serving several complimentary functions for post-secondary youth aged 18-28:

1. A makerspace equipped with tools to prototype and manufacture physical products.
2. An assembly and distribution center for Institutional Energy Solutions (IES), a cookstove manufacturing company, where participants will be hired assemble stoves with maker space tools, then distribute them to Ugandan customers, all while learning manufacturing and sales skills.
3. A tailored Creative Capacity Building training (developed at M.I.T and used globally) to empower participants as successful entrepreneurs and creative thinkers. By providing hands-on experiences and practical tools (physical, intellectual, and social), our initiative will empower creative design thinking and community action related to environmental preservation and economic agency.

## Reconstructing and forecasting the water balance of Lake Chilwa (Malawi)

Authors: Zihao Chen<sup>1</sup>, Hong Xuan Do<sup>1</sup>, Andrew Gronewold<sup>1</sup>, Mexford Mulumpwa<sup>2</sup>, Geoffrey Chavula<sup>3</sup>, Cosmo Ngongondo<sup>4</sup>

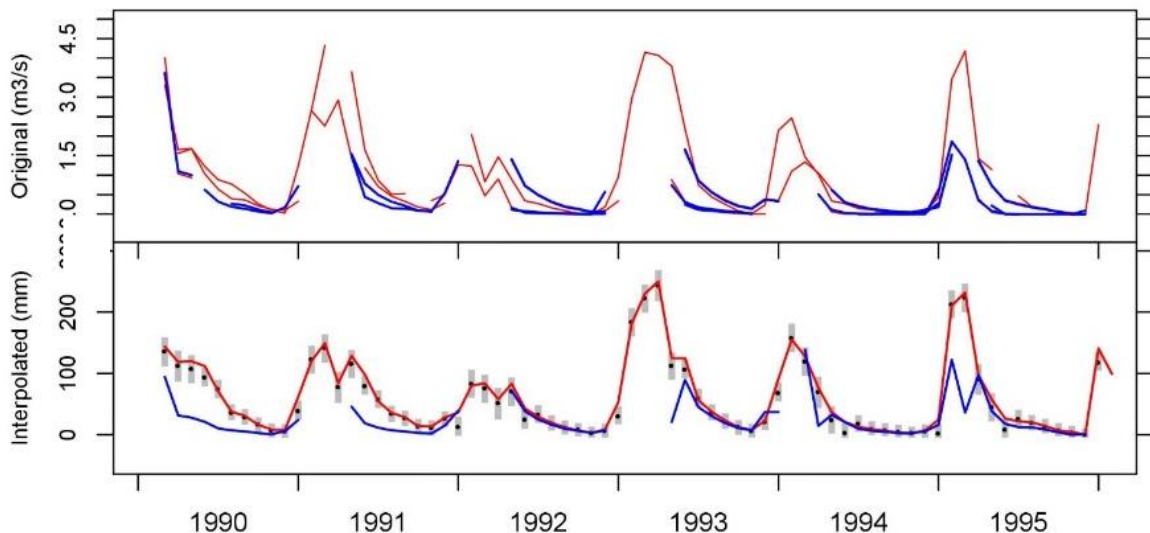
(1) University of Michigan, Ann Arbor, MI, United States, (2) Malawi Ministry of Agriculture, Department of Fisheries, Monkey Bay, Malawi, (3) The Malawi Polytechnic, Department of Civil Engineering, Blantyre, Malawi, (4) University of Malawi, Department of Geography and Earth Sciences, Blantyre, Malawi

**Introduction:** Lake Chilwa is the second-largest lake in Malawi, and serves as a critical resource to the region for drinking water supply, the fishing industry, and agricultural production. However, Lake Chilwa has recently experienced episodic extreme drops in water level, and has been noted to be highly vulnerable to the El Niño and Southern Oscillation (ENSO) phenomena as well as climate change, raising concerns about its ability to continue supporting the needs highlighted above. There are multiple historical studies of Lake Chilwa, however they tend to focus on fish productivity and ecosystem habitat.

**Materials and Methods:** Here, we provide one of the first comprehensive assessments of the Lake Chilwa water balance using a combination of historical, sparse, *in-situ* data records, and a novel statistical model that has previously been applied to the Laurentian Great Lakes (in North America). More specifically, we employ this statistical model to develop historical estimates of Lake Chilwa precipitation, evaporation, and tributary inflow that close the water balance over consecutive historical periods. Results from this new water balance model are expected to lead to an improved understanding of lake water level fluctuations, and could potentially benefit the fishing industry, as well as water resource management planning in general.

### Results and Discussion:

#### Lake Chilwa Runoff Time Series



Our study has led to a new, first-of-its-kind set of historical water balance estimates for Lake Chilwa. In the above figure, for example, original conventional runoff estimates (top panel) are highly variable and uncertain, making it difficult to differentiate drivers of water level change across the lake (red and blue lines represent different data sets). Our approach to aggregating multiple historically disparate data sets, and processing them in our water balance model, leads to a single set of runoff estimates that express a degree of uncertainty, while also helping provide an explanation of short and long-term water level variability.

**Conclusions:** This new data record not only helps citizens and practitioners understand drivers of Lake Chilwa water level variability over time, but it also provides a platform for a new seasonal water balance and water level forecasting system that can help practitioners better plan for upcoming water level variability. The method we developed can also help us identify gaps in monitoring infrastructure, which we could use to make recommendations regarding future strategic investments to improve that infrastructure.

## Requirements Elicitation Interviews with Prototypes in Low-Resource Clinical Settings

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<sup>1</sup>Design Science, <sup>2</sup>Biomedical Engineering, <sup>3</sup>Mechanical Engineering, University of Michigan.

**Introduction:** The discovery, development, analysis, and management of requirements (i.e., needs that a design, product or process aim to meet) are activities performed during the front-end phases of medical device design. Requirements that capture real stakeholder needs are essential to the success of a design project. Stakeholder interviews are the primary method of eliciting stakeholder-driven requirements. Access to stakeholders in clinical settings is often limited, especially when designers and stakeholders are not co-located. The elicitation of robust requirements from stakeholders within a global health design context is, therefore, of particular interest. Further, methods for stakeholder engagement used in high-resource settings might not be appropriate in low-resource settings. The use of prototypes during requirements elicitation interviews with stakeholders may increase the quality and quantity of information elicited. However, many questions persist about how to best leverage prototypes, including how many to present to interviewees. This study aimed to elicit requirements for the design of contraceptive implant removal devices from stakeholders in a clinical setting in Ghana through interviews while presenting three, one, or no prototypes.

**Materials and Methods:** Structured interviews were conducted in English with 36 medical professionals in Ghana. Depending on background and previous experience, participants were interviewed about one of three potential needs related to subdermal contraceptive implant removal aids; contraceptive implants are small plastic rods inserted in the upper arm that release progestin in a woman's body, preventing pregnancy for 3 to 5 years. Participants were presented with three prototypes, one prototype, or were not presented with any prototypes of preliminary concept solution(s). The assignment of the number of prototypes followed a minimization protocol to ensure the equal frequency of all combinations of removal aid need and prototype number. Interviews were audio-recorded and transcribed, a codebook was generated using an inductive process to characterize categories of requirements, and the data were coded.

**Results and Discussion:** Regardless of whether a prototype was used during the interview or not, the following requirement categories were elicited: safe; effective; low-cost for the healthcare system; low-cost for the patient; easy to clean; easy to store; easy to repair with local tools and available spare parts; contextually appropriate (i.e., the device should be adapted to the socio-cultural context by accounting for literacy level, religious and cultural beliefs, and local work culture); and compliant with local infrastructure and resources of healthcare facilities (e.g., appropriate power source). Other requirements elicited were specific to the particular type of removal aid need or related to the device's primary operating characteristics, characteristics that supplement a product's basic functions, or aspects of usability. A subset of requirements related to aspects of usability and training were only elicited when a prototype was presented (three or one).

**Conclusions:** Requirements elicitation interviews revealed a diverse set of removal aid requirements, that varied slightly as a function of the specific removal aid need discussed. Preliminary results suggest that the presence of one or three prototypes during requirement elicitation interviews with healthcare providers in Ghana led to the elicitation of additional tacit requirements related to usability and training.

**Acknowledgments:** This work was supported by a University of Michigan Rackham-funded grant to the Department of Mechanical Engineering for the Global Engagement of Doctoral Education and the University of Michigan Global Health Design Initiative. We thank participants from the Komfo Anokye Teaching Hospital in Kumasi, Ghana, and Korle-Bu Teaching Hospital in Accra, Ghana.

## **Mapping Memories of District Six: An Interdisciplinary Approach**

Authors: Jessica Yelk, Architecture & Urban Planning; Valyn Dall, Information; Vincent Qiu, Design Science & Information; Vaness Cox, Developmental Psychology

**Introduction:** The District Six Museum in Cape Town, South Africa wanted to publish an interactive map on their website representing the memories and history of residents who were forcibly removed from the District Six area as part of the apartheid system during the mid-to-late 1900s. This map would be designed by our team as part of the 2019 iteration of the University of Michigan's Global Information Engagement Program (GIEP), and it would build upon work previously established by the 2018 GIEP cohort in conjunction with St. Mark's Anglican Church (St. Mark's) and upon contributions from the Cape Peninsula University of Technology (CPUT). The primary concern of our client was to integrate all of this information in a way that could be accessible to the general public via their website. We also strove to be accurate to historical geography, respectfully present cultural history, and increase engagement and empathy.

**Materials and Methods:** In 2018, interns from the University of Michigan were able to partner with St. Mark's Anglican Church, one of the few remaining buildings from District Six, to digitize baptismal records of its parishioners. These records were digitized using an Excel spreadsheet. Furthermore, they also interviewed 6 former residents whose baptismal records were recorded. The digitized baptismal records were filtered through a program which extracted street names and addresses. These street names and addresses were then plotted in GIS software (QGIS) along with historical building footprints collected by lecturers and students at Cape Peninsula University of Technology. This foundational work provided us the geographic information we needed to include on the map, and it also provided us with storytellers whose memories could be captured. In order to develop the webpage, we used QGIS2web, OpenLayers, GitHub, and Wordpress. These materials aided in exporting, hosting, and developing the map online.

**Results and Discussion:** At the close of our partnership with the District Six Museum, we were able to achieve four primary tasks. First, in addition to re-interviewing 5 of the 6 previous storytellers, we were able to interview 2 additional storytellers, whose stories were geolocated in historical District Six. Second, we were able to locate information on and pictures of prominent landmarks, which were then plotted. Third, we were able to create a map of historical District Six that included street names, building names, and prominent community sites such as the Seven Steps. Fourth, we were able to implement the interactive map on the museum's website. This final web map accessible from a desktop computer web browser features the 7 storytellers and landmarks pertinent to their lives, in addition to buttons that highlight schools, places of worship, community spaces, and other prominent landmarks. (see website here: <https://www.districtsix.co.za/project/st-marks-memory-mapping-project/>)

**Conclusions:** Overall, we were able to successfully capture the stories of seven former District Six residents and display these stories digitally in an interactive map on the District Six Museum's website. In addition to having the stories of these former residents, we were also able to include landmarks and descriptions of these landmarks on the map. The map also includes all the buildings from historical District Six, allowing users to click on any building and see what it was. Because of this interactive map, more users of the museum's website will be exposed to and informed of the injustices done to those in District Six during apartheid. This could potentially inspire change and move restitution cases forward. We recommend that the next steps for the web page include adding a search bar to the map as an alternative way for users to navigate the map. We also recommend adding more storytellers or possibly exchanging storytellers periodically. QGIS is a free software available to everyone that can be used to update and maintain the mapping.

**Acknowledgements:** We would like to acknowledge the seven parishioners of St. Mark's Anglican Church who volunteered their stories; the baptismal registry of St. Mark's, and Fathers Austen Jackson and Clifford Jones; CPUT Departments of Town & Regional Planning and Civil Engineering & Surveying, lecturers Siddique Motala and Nicholas Pinfeld; University of Michigan's GIEP instructors: David Wallace, Kelly Kowatch, and Jill Coughlin, and students Michelle Rubin, Jackson Huang, and Madel Leal.



# Title: The Use of Pharmaceutical Technology and Local Excipients to Improve Drug Delivery in Pharmaceutical Manufacturing

Authors: Frederick William Akuffo Owusu<sup>1</sup>, Mariam El Boakye-Gyasi\*<sup>1</sup>, Jacob Agbenohervi<sup>1</sup>, Ben Banful<sup>1</sup>, Marcel T. Bayor<sup>1</sup>

<sup>1</sup>Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

**Introduction:** The International Pharmaceutical Excipients Council defines excipients as substances, other than the active drug substances of finished dosage form, which have been appropriately evaluated for safety and are included in a drug delivery system to either aid the processing of the drug delivery system during its manufacture; protect, support or enhance stability, bioavailability, or patient acceptability; assist in product identification; or enhance any other attributes of the overall safety and effectiveness of the drug delivery system during storage or when in use. Pectins from various sources have been developed as biopolymers. Extracts from fresh okra (*Abelmoschus esculentus* L.) pod, are naturally available, relatively inexpensive, non-toxic biopolymers and an attractive resource for industrial applications. Polysaccharides within okra extracts are predominately pectin. Controlled release of drugs has many benefits including; improved patient compliance due to reduction of frequency of drug administration and targeted drug delivery. The objectives of the study were to achieve controlled release of metformin hydrochloride in matrix tablets using okra pectin extracted from six different varieties (genotypes) of okra grown in Ghana, to characterize the extracted pectin and assess their potential pharmaceutical use as control releasing polymers for optimized controlled drug delivery.

**Materials and Methods:** Pectin was extracted from six genotypes of okra grown in Ghana, freeze-dried and the physicochemical characteristics; moisture content, swelling and water holding capacities, pH, and solubility, determined. Fourier transform infrared spectroscopy was used to characterize the pectin. Matrix tablets were formulated by wet granulation and compressed with a single punch tablet machine. Hardness, friability, disintegration, drug content estimation using High Performance Liquid Chromatography and *in vitro* dissolution studies were performed on matrix tablets, to evaluate the okra pectin polymer extracted.

## Results and Discussion:

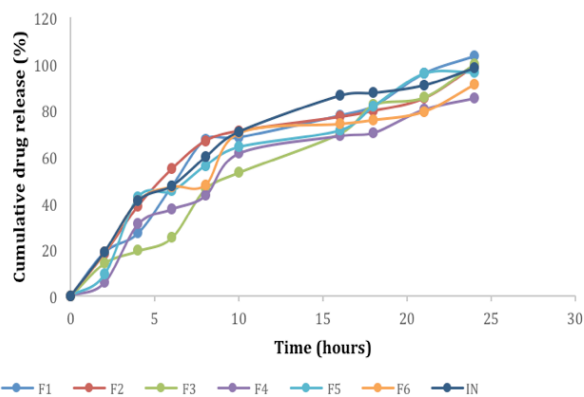


Fig. 1. Drug release profiles of matrix tablets formulated using pectin from 6 different genotypes of okra

All pectin samples analyzed had suitable physicochemical properties. Fourier transform infrared spectra of confirmed that pectin from all the genotypes showed the characteristic features. The bands were similar to those previously reported. Mathematical kinetic modeling of release of metformin from the matrix tablets showed; fickian diffusion (PC1, PC5 and PC6), super case II transport (PC2), zero (PC3) or first order (PC4) respectively for the different samples. The okra pectin polymer exhibited good physicochemical and drug release qualities. They can potentially be used as drug release-controlling agents, as pectin from different genotypes of okra was found to control drug release via different mechanisms.

**Conclusions:** Controlled release of metformin from matrix tablets was achieved using okra pectin from 6 different genotypes of okra grown locally in Ghana as polymers.

**Acknowledgements: (Optional)** This study was supported by a grant from the KNUST Research Fund (KReF).



## Title: The Use of Pharmaceutical Technology to Improve Drug Delivery and Patient Compliance

Authors: Frederick William Akuffo Owusu<sup>1</sup>, Mariam El Boakye-Gyasi\*<sup>1</sup>, Priscilla Kolibea Mante<sup>1</sup>, Edmund Ekuadzi<sup>1</sup>, Kwabena Ofori-Kwakye<sup>1</sup>, Eric Woode<sup>1</sup>

<sup>1</sup>Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

**Introduction:** The quest to ensure that patients comply with their medications and are effectively cured or managed of their disease condition has led to the advent of controlled drug delivery systems. Introduction of matrix tablet as sustained release has given a new breakthrough for novel drug delivery system in the field of Pharmaceutical Technology. Folklorically, *Capparis erythrocarpos* is used in the management of arthritis in Ghana and some other African countries. In Ghana, the powdered form of *Capparis erythrocarpos* prescribed and dispensed to patients for the management of arthritis. However, powdered root of *Capparis erythrocarpos* has been processed and used for the management of arthritis for several years at the Center for Scientific Research into Plant Medicine (CSRPM), Mampong, Akuapem, Ghana without any standardized dosage form (Martey et al., 2013). Its chronic use in the management of arthritis makes it a good candidate for formulation into a controlled release tablet. This study aimed to produce controlled release tablets of *Capparis erythrocarpos* roots extract in order to improve patient compliance.

**Materials and Methods:** The protocol employed by Centre for Plant Medicine Research (CPMR), Akuapim-Mampong, Eastern Region of Ghana was used for the extraction process. Hydroxypropyl methyl cellulose and Xanthan gum were used as drug release modifying polymers in varying ratios of (1;1), (1;2) and (1;3) respectively. The drug and excipients compatibility was studied using Fourier Transform Infrared Spectroscopy. Matrix tablets were formulated by wet granulation and compressed with a single punch tablet machine. Hardness, friability, disintegration, drug content estimation using UV spectrophotometer at a wavelength of 210 nm and *in vitro* dissolution studies were performed on matrix tablets.

### Results and Discussion:

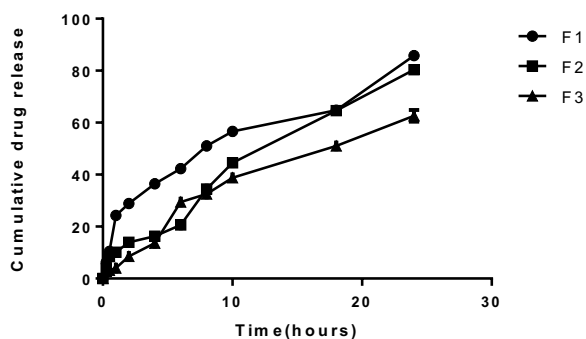


Fig.1. *In vitro* dissolution profile of formulated *Capparis erythrocarpos* tablets

Control release tablet of *Capparis erythrocarpos* has been successfully formulated using HPMC and Xanthan gum as control releasing agents. Ratios of 1:1 and 1:2 combinations of HPMC and Xanthan gum respectively is able to provide the desired drug release over a twenty four (24) hour period. Higher proportions of Xanthan gum in combination with HPMC (3:1) retarded the release of *Capparis erythrocarpos* and did not provide the desired drug release after 24 hours.

**Conclusions:** In the present study, *Capparis erythrocarpos* controlled release tablets were successfully prepared by wet granulation method.

**Acknowledgements:** This study was supported by a grant from the KNUST Research Fund (KReF).

**Title:** Feasibility, acceptability and perceived relevance of a web-based self-management program for HIV-infected adolescents and young adults in Uganda

**Authors:** Anudeeta Gautam, Sophia Jacobs, Anjali Vaishnav, Massy Mutumba (faculty mentor)

**Background:** There are approximately 300,000 adolescents and young adults living with HIV (AYLHIV) in Uganda. AYLHIV face many psychosocial challenges e.g. psychological distress, medication adherence and stigma. However, access to developmentally appropriate psychosocial support for ALHIV remains limited. AYLHIV have reported provider mistrust, lack of privacy and geographical factors as factors that limit accessibility to psychosocial support, while healthcare providers highlight high caseloads, limited resources, and lack of skills are barriers to providing adequate psychosocial support.

**Methods:** We have developed a web-based HIV self-management program to provide tailored psychosocial information to individualized needs of AYLHIV in Uganda. The web-page was created using Python, CSS, HTML, Javascript and a dynamic Flask framework. This pilot program focused on five salient barriers to medication adherence: school, psychological distress, medication, social support, and religious misperceptions. Information presented was tailored to each adolescent's self-reported challenges on baseline program entry assessment. To address the developmental needs of participants and enhance message relevance, information was tailored for age and gender. We conducted in depth interviews with 32 AYLHIV (ages 12 - 24) at three pediatric HIV treatments centers in Kampala. Participants were interviewed during clinics visits and through invitations with local community partners. Once participants were identified, and were briefed about the program and iPad navigation, they completed a baseline entry survey. They were then automatically redirected to complete a module based on their self-reported barrier. If the participant did not classify for an adherence barrier, they were automatically redirected to complete a module on general wellbeing. A research associate stayed with the participant throughout the testing, observing how they navigated the program and answering participant questions. After completing the modules, participants completed a debriefing interview, exploring their experience using the program.

**Results and Discussion:** After the conclusion of pilot testing, we are optimistic that our app will be accessible to the population we are targeting and received positively in the community. Majority of adolescents had access to an iPad (75%) or smartphone (56.25%), and 75% said that the website would be easy to access. Participants who owned or has used a smartphone or tablet before and participants who were unfamiliar with smart devices demonstrated remarkable ease in navigating the website after a brief tutorial - suggesting that the program was user-friendly. Program content was regarded as relevant and educational. Suggestions for improvement included adding more male figures to video content and the addition of an online community platform to facilitate user-interactions.

**Conclusions:** Preliminary findings indicate that the iCARE program is a feasible strategy for providing ALHIV with psychosocial support. Future work will focus on expanding program content and features, as well as measuring its impact on health outcomes such as medication adherence, mental health, HIV disclosure.

## **A Study of Low-Cost Epidural Simulators: Designing for Low-Resource Settings**

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**Introduction:** Epidurals are a form of regional anesthesia commonly used as continual pain management for women during labor and delivery. The anesthesia is given by an anesthesiologist through inserting a small catheter into the lower back and delivering the medicine into a region called the “epidural space,” which is a small region just outside the membrane of the spinal cord. However, during a field immersion in Ghana, it was observed that epidurals were rarely given to women, leading to immense pain during labor and an increase in anxiety surrounding the birthing process. A large reason for this is that the anesthesiology residents do not have a structured epidural administration training, causing a lack of confidence in their ability to administer the drug safely. Because incorrect epidural administration has been shown to cause paralysis or even death, correct techniques are of the utmost importance.<sup>1</sup> Based on this information, we propose to design a low-cost epidural simulator specifically for low-resource settings as a way to increase the number of anesthesiologists able to provide epidural administration to laboring women in Ghana.

**Materials and Methods:** During a two-month immersion in Kumasi and Accra, Ghana, a need was identified for the development of a low-cost epidural simulator that could be effectively used in low-resource settings. This need was identified during a three-week long needs assessment phase in which 50 need statements were generated through clinical observations performed at Komfo Anokye Teaching Hospital (KATH). The need statement was selected through needs filtering procedures, including priority rankings performed internally by team members and externally by stakeholders at KATH, Korle Bu Teaching Hospital (KBTH), and the University of Michigan. The need was then validated through literature review, benchmarking analysis, and additional interviews with stakeholders. International stakeholders such as obstetrics and gynecology (ob/gyn) physicians, anesthesiologist physicians, residents, house-officers, ob/gyn department heads, medical professors, simulation center staff, midwives, nurses, and purchasing directors were asked to participate in semi-structured interviews during the field immersion in order to elicit relevant requirements to be used to develop a target product profile for the device. Following the clinical immersion experience, the user requirements and specifications were further iterated upon based on observations and semi-structured interviews performed with clinical professionals in the US and University of Michigan faculty. The target product profile developed will be used as prototyping guidelines during development phases in the upcoming semester as part of the ME450 class.

**Results and Discussion:** Based on clinical observations, literature review, benchmarking analysis, and interviews with international and domestic stakeholders, a set of user requirements and engineering specifications was developed over the remaining 5 weeks in Ghana. This set of requirements and specifications was used to create a target product profile for the design and implementation of an epidural simulator specifically tailored for use in low-resource settings. The user requirements developed cover function of the device, accessibility, trainability, usability, safety, tech management, availability, durability, aesthetics, and infrastructure requirements of the device. The current plan is now to continue concept generation with these requirements in mind and eventually select a concept to put through an engineering analysis and validate.

**Conclusions:** Through ethnographic studies and literature review, it was determined that a low-fidelity, low-cost epidural simulator would allow anesthesiology residents to practice epidural insertions without risk of harming patients. An increase of technically proficient residents would increase the number of available staff to administer the epidural and consequently reduce the labor costs associated with insertion of the epidural.

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## **Bottlenecks in ICT Innovation Ecosystem in Rwanda**

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**Introduction:** Rwanda is an East African country with a population of 11.8 million. Rwanda has chosen a unique strategy for economic development because of its geographical disadvantage; it is a landlocked location and has limited natural resources. They have made Information Communication Technology (ICT) one of the pillars of their national strategy. With the strong leadership of the government, Rwanda ranks 2nd in Africa in both the ease of doing business (World Bank) and lack of government corruption (Transparency International).

However, there are challenges to overall socio-economic development and ICT readiness in Rwanda. According to UNDP's Human Development Index, Rwanda is ranked 159th in both general development and educational achievement. ITU's ICT Readiness scale, which assesses access, use, and skills of ICT, also ranks Rwanda 150th. Both indicators rank Rwanda in the lowest 15% in the world.

Therefore, in order to understand existing challenges and propose policy interventions for future industry development, I raise the following research question: *What are the bottlenecks in ICT and innovation capacity development in Rwanda?*

**Materials and Methods:** Thirty-one face to face semi-structured interviews were conducted in 2017 to systematically explore the views of all stakeholders regarding ICT sector development in Rwanda. Participants were found by snowball sampling, with the goal to include participants in the following categories: government policy-makers, entrepreneurial leaders, university students, university professors, software engineers, and international development donors. Ultimately, I interviewed 23 Rwandans and 8 non-Rwandans. The interviews consisted of a series of open questions regarding perceptions of the ICT sector, policy, education, and aspiration/motivation.

**Results and Discussion:** Preliminary analyses of the interview data suggests the following strengths and weaknesses of Rwanda's current ICT ecosystem:

1. Strengths in ICT and innovation ecosystem development
  - Government initiative for a knowledge-based country: Not only Rwandans but also foreigners, such as development partners and researchers, appreciate the strong initiative of the Rwandan government to foster the ICT sector and entrepreneurship in Rwanda.
  - Strong aspiration of citizens to contribute to Rwanda: Citizens express a strong desire to contribute to national development. Most interviewees put a higher priority on their contribution to the country rather than personal success. This mindset seems to come from the history of tragedy, the genocide in 1994.
2. Weaknesses in ICT and innovation ecosystem development
  - Higher education in Rwanda does not consistently produce industry-ready graduates. Participants cited lack of connection with industry and lack of practical training, such as software development project, team-building, and business model development. Carnegie Mellon University in Rwanda is an exception with a high reputation of both students and industry.
  - Job creation: Since the ICT sector in Rwanda is still small, employment, especially for inexperienced new graduates is difficult. This is one reason for so many single entrepreneurs in Rwanda.

Overall, Rwanda has a clear vision of ICT-based national development, with both leaders and citizens who are highly motivated. On the other hand, there is a gap between vision and reality, primarily between industry and higher education. Although the ICT sector is willing to hire engineers who have experience, most universities provide theory-based learning without practical training. Training programs that focus on business skills, for example, are one recommendation.

**Conclusion:** In spite of strong support from the government of Rwanda for establishing ICT-related businesses, the country faces challenges developing ICT talent and innovation capacity. Ongoing work will further the analysis of interviews and allow a comparison of the findings with existing theories regarding ICT sector development.

# Management generates a landscape of behavioral tradeoffs influencing space use of critically endangered lions in West Africa

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**Introduction:** Spatially varied resources and threats complicate the persistence of African lions across dynamic protected areas. High-quality habitat may mitigate risks from trophy hunting, poaching, and other human encounters that cause differential space use based on management. An important precursor to effective conservation for lions requires assessing socio-ecological tradeoffs between national parks and hunting areas, the dominant land-use classifications across their range. Critically endangered West African lions remain in few protected areas, and face human-induced pressures of hunting (legally and illegally), habitat loss, and prey depredation.

**Materials and Methods:** We conducted the largest camera survey in the national parks and hunting concessions of W-Arly-Pendjari (WAP) protected area complex in West Africa, which spans over 26,500-km<sup>2</sup> in Burkina Faso, Benin, and Niger. We created single-season, single-species occupancy models for lions, their competitors (hyenas and leopards), humans, and livestock to determine space use of each throughout WAP. We combined occupancy model results with structural equation modeling to disentangle the relative effects ( $\delta$ ) of environmental, ecological, and anthropogenic variables influencing space use of critically endangered lions across 21,430 trap-nights from 2016-2018.

**Results:** National parks are intended to serve as refuges from human pressures, and thus we expect higher lion occupancy ( $\psi$ ) in national parks (NPs) compared to neighboring hunting concessions (HCs). But because prey availability drove lion occupancy and was comparable between NPs and HCs, lions exhibited no spatial response to management type ( $\psi_{NP} = 0.56$ , SE 0.02;  $\psi_{HC} = 0.58$ , SE 0.03). Furthermore, water availability and habitat diversity were higher in HCs, possibly outweighing risks from trophy hunting and higher human occupancy ( $\psi_{NP} = 0.49$ , SE 0.04;  $\psi_{HC} = 0.61$ , SE 0.04;  $p$ -value = 0.006). Prey availability ( $\delta = 0.22$ , SE 0.08) was influenced by edge effects and water availability, therefore indirectly influencing the space use of lions in the complex.

**Conclusion:** We provide potential management interventions to indirectly influence lion space use, highlighting the dire need for increased funding for lion conservation in West Africa. Our findings suggest that high-quality habitat coupled with increased human pressures and associated risks of human-lion conflict may cause HCs to function as equal-preference ecological traps for lions. Revenue and habitat disparities between management types could prove detrimental to lions throughout Africa, as well as many other species facing the pressures of trophy hunting and poaching. We expect such dynamics of risks and benefits in space use to occur especially in systems where overall resources and well-protected lands are scarce, a scenario likely to become more common as human pressures increase around the world. Suitable refugia from human-induced mortality is necessary to maintain viable populations of threatened species. Our work improves understanding of coupled risk-benefit dynamics that induce behavioral tradeoffs across heterogeneous management landscapes for African lions.

## **Title:** Antimicrobial Stewardship in Northern Tanzania

**Introduction:** In the developing world, poor health literacy and ease of access to antibiotics lead to irresponsible use of antibiotics. This promotes the development of resistant pathogens.<sup>1-3</sup> In Kilimanjaro, Tanzania, a group at the Kilimanjaro Christian Medical Centre (KCMC) demonstrated that 92.3% of pharmacies dispense antibiotics without a prescription.<sup>2</sup> The group has formed an antimicrobial stewardship committee (ASC) that has pioneered antimicrobial stewardship initiatives within the healthcare system in Northern Tanzania.<sup>4-6</sup> However, to our knowledge, no work has been done educate rural community members about the proper use of antibiotics. In this setting, educating rural community members about antimicrobial stewardship could be impactful.

**Materials and Methods:** During January 2020, the medical student will travel to KCMC to collaborate with the ASC. The MS4 will lead a rural community intervention comprised of 10 interactive sessions in Swahili, conveying fundamental concepts of antimicrobial resistance. We predict that participants will demonstrate increased knowledge about antimicrobial resistance and commitment to stopping the spread of resistant pathogens. In addition, the MS4 will contribute to existing antimicrobial stewardship activities, including provider education, community educational campaigns, and data collection for ongoing research.

**Proposed Results and Discussion:** Proposed outcomes of the intervention will be assessed via pre- and post- surveys. If participants demonstrate improved knowledge and attitudes toward antimicrobial stewardship, this intervention could be adapted for other settings in the developing world.

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## **The Physics of Energy: Empowering Nations to Power Their Nation**

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**Introduction:** The slightest increase in electricity can have a significant impact - socially, economically, and industrially - on communities with little to no access to reliable electricity. Energy poverty, or a lack of access to reliable electricity, heavily impacts so-called developing countries, many of which have electrical grids that are at best not reliable, and at worst nonexistent. Locally designed mini grids, defined as electrical grids that provide electricity to neighborhood-sized communities, are one means of fighting energy poverty. However, the physics and engineering curriculum in so-called developing countries typically does not include the practical information needed to design mini grids. The Energy E3 (Engineering, Education and Entrepreneurship) curriculum addresses this challenge through providing communities impacted by energy poverty with resources for designing, building and marketing their own mini grids and associated devices.

**Materials and Methods:** We have developed a public-domain textbook - “The Physics of Energy: Empowering Nations to Power Their Nation” - written to provide engineers and technicians with the practical connections between engineering theory and practice necessary for designing mini grids and devices for powering their communities. This textbook is based off of lecture notes from workshops given by Prof. Moses Musaaazi (of Makerere University) and Prof. Abigail Mechtenberg (of the University of Notre Dame), and covers introductory mechanics and electricity and magnetism; forms of energy and energy conversion; and designing and marketing mini grid devices.

**Results and Discussion:** The textbook was deployed in 2018, and energy teams in Uganda, Rwanda, Nigeria and Haiti currently use “The Physics of Energy” as a resource for their mini grid designs. Each energy team is made up of professors, engineers, and technicians in the target country, and a student in the ESDD Lab. Each team has made substantial progress in designing and producing mini grid devices. For example, the Rwandan team has recently added designs for a table generator (a hand crank on a table to convert mechanical to electrical energy), a hydroelectric generator (designed to be placed in a river to convert the mechanical energy of water flow to electrical energy), and a vertical-axis wind turbine.

**Conclusions:** An increase of 20W generating capability per capita would lead to a 100% increase in power availability for countries where current power production is less than 20W/capita. Many of the devices included in the E3 textbook easily produce this amount of power. In addition, the process of designing and producing the devices takes into account socio-cultural factors, such as the appropriateness of a device for use in the community in question and local availability of materials.

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## **Walking Aid for Children with Cerebral Palsy in Low-Resource Settings**

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**Introduction:** Cerebral palsy (CP) is the leading cause of disability in children worldwide, with an estimated incidence of 1 in 323 children according to a 2014 study performed by the Center for Disease Control and Prevention (Christensen, D, et al., 2014). CP is defined as a related range of neurological disorders resulting from damage to the brain due to developmental abnormalities or traumatic physical head injury (McKee, Ann, et al., 2015). Motor function impairment lasts through adulthood with onset occurring in infancy or early childhood. Common symptoms include lack of muscle coordination, spasticity (muscle tightness), and muscle weakness. Severity and the range of symptoms may vary substantially among patients.

Some patients with moderate symptoms may be able to walk with the use of an assistive device up to Gross Motor Function Classification System Level IV (Paulson, Andrea, et al., 2017). However, in low and middle-income countries with fewer resources, there is a lack of access to appropriate assistive walking devices for pediatric CP patients at affordable costs for families. Walking devices that are currently available in clinics are donated by non-governmental organizations in limited numbers, and many are adult sized with limited support and functionality. One primary limitation identified by local therapists is the lack of proper posture support. Lastly, patients visit a therapist limited times per week and often do not have reliable walking devices at home due to cost inhibitions. Thus, the goal of this project is to develop an affordable pediatric assistive walking device meeting physiotherapy functionality needs for CP pediatric patients from low income families in low-resource settings. This project was identified in collaboration with clinicians at Komfo Anokye Teaching Hospital, Ghana (KATH).

**Materials and Methods:** Approaching the solution for affordable pediatric CP walking devices began with identifying requirements and specifications for the device. Pediatric physical therapist collaborators provided several functionality, accessibility, and versatility requirements to suit the needs of patients visiting their clinic from a design ethnography standpoint—some of which was achieved through observation and interviews with a team member at KATH for six weeks. Additionally, because a long-term goal for the project was to target patients in broader low-resource settings as well, requirements and specifications were developed from sources outside the scope of KATH. These sources include proxy stakeholder interviews with UM physiotherapists and consultation with sourcing and manufacturing engineering in the biomedical industry. Literature search has also provided insight in the design process, with information derived from medical journals, engineering standards, geo-economic data, and patents. Benchmarked assistive devices helped initiate concept generation, and common features will be considered in creating an initial design meeting all requirements and specifications. The next steps include further concept generation and selection, engineering analysis, and validation.

**Results and Discussion:** With needs of the device identified, the focus has shifted towards generating further ideas to incorporate into the design. Common features identified via benchmarking are being evaluated with source information and stakeholder input before being modified to fit requirements and specifications laid forth by the project. High priority requirements identified through literature search and stakeholder interviews include versatility, functionality, and accessibility. In order to be versatile, the device must have an adjustable height for two to six year-olds, as well as support the patient's weight. In terms of functionality, the device must be effective and safe, travel over common Ghanaian terrain, and help the patient develop extremity musculature. In order to be accessible, the device must be low cost, manufactured in the local community, and easy to transport.

**Conclusions:** Due to a lack of sufficient resources in Ghana, there is a need for a versatile, functional, and accessible walking aid for children with cerebral palsy. The device needs to be effective and versatile for various-sized children, assist in correcting improper walking form, and be affordable to the Komfo Anokye Teaching Hospital, Ghana (KATH) community, with an ultimate goal for utilization in other low-resource settings.

## **measHER: Device for Blood Loss Measurement following Vaginal Childbirth in Low-Resource Settings**

Authors: Chun Hei So (College of Engineering), Sanghamithra Kalimi (Ross School of Business), Yvonne Wu (School of Public Health)

**Abstract:** For two months, the measHER team conducted design ethnography research within two partner hospitals in Ghana: Komfo Anokye Teaching Hospital (KATH) and Korle Bu Teaching Hospital (KBTH). In collaboration with the hospitals' Obstetric and Gynecology departments, the team found the need for a device to accurately quantify blood loss up to 4 hours after vaginal delivery to diagnose primary postpartum hemorrhage. Proper management of postpartum hemorrhage cases is heavily reliant on prompt diagnosis and treatment. This diagnosis is dependent on accurate blood loss estimation. The measHER obstetric drape aims to address the gap in a suitable blood loss measurement method for women in low-resource settings. Data from stakeholders allowed the team to elicit a number of user requirements that guided the design of the device. The team's final design, through many iterations, is a plastic drape with two cones. The top cone collects pre-delivery fluids and is perforated to allow for easy removal. After the baby is delivered, the bottom cone collects postpartum blood and is graduated to allow providers to easily quantify blood loss. The cones are attached to a drape which lies under the patient and guides blood flow.

**Introduction:** Primary Postpartum hemorrhage (PPH) a leading cause of maternal death worldwide, accounting for up to 30% of maternal deaths every year, and particularly afflicts low resource settings.<sup>1</sup> Primary PPH is defined as blood loss following vaginal delivery that exceeds 500 mL, or any amount of blood loss that could pose a potential health risk to the patient within 24 hours of delivery.<sup>2</sup> Current methods that are used to assess postpartum blood loss at KATH and KBTH rely heavily on visual estimation. Studies have shown that current visual estimation methods result in underestimation of blood loss by up to 50%.<sup>1</sup> Providers often rely on the presentation of other clinical symptoms, delaying treatment of PPH, causing increased health complications and morbidity to mothers.

**Materials and Methods:** The measHER team approached the issue of PPH diagnosis by conducting design ethnography in two hospitals in Ghana, where they interviewed a variety of stakeholders to elicit user needs and develop engineering specifications. The requirements of the device include: Low-Cost, Accurate, Able to Distinguish Blood from Other Fluids, Easy to Use, Compatible with Setting, Durable, Safe, and Comfortable. "Able to Distinguish Blood from Other Fluids", "Easy to Use", and "Compatible with Setting" were addressed through the concept generation process and design of the device. The team engaged in an iterative process of concept generation, selection, and validation process from Fall 2018-Winter of 2019. Concept selection was primarily conducted by presenting ideas to Ghanaian stakeholders and eliciting feedback in-country. Tests and analysis used include cost analysis, usability tests, drop-testing, empirical testing, and force analysis.

**Results and Discussion:** Three tests were performed to ensure the integrity of the design: two force analyses and volume indication confirmation. Force analyses, cost analyses, usability testing, and drop-testing yielded results that surpassed our engineering specifications. Empirical testing was conducted to confirm the amount of liquid poured into the device was accurately reflected on the device's graduations. The team conducted three trials, each time pouring amounts of liquid 200 mL, 500 mL, and 1000 mL of water into the cone. This testing showed that the device was able to read within 12.5 mL of the the fluid loss. Integral design flaws were identified through qualitative from health providers in KBTH, which was elicited in August of 2019. Currently, challenges exist in implementation of the device in local hospitals, and limited local manufacturing capabilities in Ghana. Future work will be conducted to overcome these limitations and to mitigate design flaws.

### **Conclusions:**

In the future, the team hopes to better address some design critiques, specifically, methods to ensure the bag remains open, to direct fluid into the bags, and manufacturing plans to decrease heat-sealing errors. Furthermore, the team plans to conduct formative and summative usability testing with stakeholders at Michigan Medicine, KBTH, KATH, and laypeople. Future investigation should be conducted to determine the feasibility of salvaging red blood cells from the blood collected to be transfused back into patients with anemia or sickle cell disease.