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Combining design research with microbiology to tackle drug-resistant infections in different home environments in Ghana: Challenging the boundaries of design thinking

Emmanuel Tsekleves[a*], Andy Darby[a], Collins Ahorlu[b], Dziedzom De Souza[b], Roger Pickup[c], Daniel Boakye[b]

[a]ImaginationLancaster, LICA, Lancaster University, United Kingdom
[b]Noguchi Memorial Institute for Medical Research - University of Ghana, Ghana
[c]Biomedical and Life Sciences, Lancaster University, United Kingdom
*Corresponding author e-mail: e.tsekleves@lancaster.ac.uk

Abstract: The aim of this paper is twofold. Firstly, to present design research work that crosses into specialist medical areas, in this instance that of antimicrobial resistance (AMR); and secondly, to contribute to the debate on the need for design-driven research to explore alternative ways of delivering healthcare by focusing on preventive design responses. These points are addressed in the exploration of an international design-led research project, Dust Bunny. The project uniquely combines design research and microbiology to provide an informed assessment of societal practices in domestic cleanliness and to co-create novel solutions that reduce infections in the home. The findings and experiences from this unique transdisciplinary collaboration (design, microbiology, epidemiology and social science) reveal several insights on the challenges and opportunities on challenging the boundaries of design thinking.

Keywords: Design for health, antimicrobial resistance, preventive design, global health, design thinking

1. Introduction

Although predominantly medical, global challenges, such as AMR, are hugely complex problems with diverse influences, driven by human activity as much as by biological mechanisms. Biomedical, clinical and medical expertise alone cannot tackle AMR and collaborative and innovative interdisciplinary approaches are needed to tackle the challenge.

Bacteria found in the natural and built environment (e.g., homes, schools, hospitals, etc.) are building their resistance to drugs. They are changing to protect themselves against antibiotics. This means that in the not-too-distant future, something as simple as a minor cut or infection could become life-threatening (O'Neill, 2014). The issue is such a concern that AMR is now considered a global health crisis. The situation is even more critical in developing countries in Africa, such as Ghana, where there are a great number of deaths from infectious diseases (Feigin et al., 2010).

Despite there being clear evidence for microbial exposure and infection transmission within the home (Rintala et al., 2012), there has been less research effort invested in understanding the home environment, due to the difficulty of conducting detailed studies (Curtis et al, 2003). Although the transmission routes of dust in the home environment are well known (Rintala et al., 2012), what has not been studied is how to prevent bacterial infection in home environments and thereby reduce resistance.

Furthermore, the hygiene guidelines available for preventing infection in the home environment, are targeted at hygiene professionals (Beumer, 2002) and do not reach the everyday household in Ghana. There is, therefore, a much-required and unmet need to identify, understand and develop domestic hygiene practices that are relevant to different home environments, and educational and cultural backgrounds in developing countries, such as in Ghana. These new practices must reduce exposure to bacterial pathogens and, thereby, limit the development of AMR.

Within this context, the Dust Bunny project aims at developing an understanding of the home as a source of infection by antibiotic resistant bacteria, found and carried by dust. This is done by exploring hygiene practices across different home environments in Ghana, to define the bacterial microbiome, to consider whether this antibiotic resistance is driven by household practices with the ultimate aim to reduce bacterial infection in the home environment thereby reducing AMR.

Following an introduction of the related work and research methodology, we present the initial findings from the Dust Bunny project and discuss the challenges and opportunities in design research being applied in such a specialist medical area

2. Related Work

2.1 Design Research in Preventive Health

Developing strategies for promoting health or preventing 'illbeing' of the population forms one of the most complex global challenges. Traditionally designers have paid attention predominantly to acute and chronic care, through new medical products, prostheses, hospital, clinic and care home design (Jones, 2013; Tosi et al, 2016; Mawson et al., 2014; Ludon et al., 2014). More recently the complex picture of maintaining population wellbeing and health prevention has begun to emerge, and thus the role of designers indirectly in supporting the promotion of healthy lifestyle or in their contribution to illbeing. Works such as (Ulrich et al., 2008; Chamberlain et al., 2015; Tsekleves and Cooper, 2017) have demonstrated the propensity of design to contribute significantly in health and wellbeing.

A key challenge that emerges within this context is how should we shape our built environments and infrastructure to support healthier behaviours? What is abundantly clear, here, is that as we shape our environment it is shaping us, our psychological, physiological and physical status as well as our interactions with other people and with the natural environment too (Frank & Engelke, 2005; Wood

et al., 2010; Dempsey et al., 2012). The environment is closely linked to the lifestyles we adopt and again it is clear from the wealth of research in this area (Frank et al, 2003; Smith & Cummins, 2009; Robertson-Wilson & Giles-Corti, 2016) that the current state of our environment plays a significant role in the predominantly sedentary lifestyles adopted today but also in terms of microbial exposure and infection (viral/bacterial) transmission (McMichael, 2000; Weiss & McMichael, 2004; Kembel et al, 2012; Prussin & Marr, 2015).

2.2 Design Research in Specialist Medical Areas

The use of participatory design and codesign within health is relatively common in the design literature (Donetto et al, 2014; Minkler & Wallerstein, 2011) with positive outcomes reported in the areas of community-based health (Israel et al, 2001; Greenhalgh et al, 2016) though there has been limited exploration of these approaches within African and developing countries contexts (De la Harpe et al, 2012; Cepiku & Giordano, 2014).

Design research has, also, previously engaged in specialised areas, such as Motor Neurone Disease, to codesign and develop patient-acceptable neck-support products (Craig and Chamberlain, 2017); cerebral palsy and rheumatoid arthritis for the development of anatomically personalised foot orthoses (Paterson, et al., 2017); stroke and biomechanics for the codesign of motion visualisation of complex interventions (MacDonald, 2017). However, combining microbiology with design research within a developing country context goes beyond the traditional boundaries of design research in the areas of health and medicine.

Part of the rationale behind the marriage of design research with microbiology in the Dust Bunny project, lies in the difficulty of conducting detailed studies within the home, in comparison with data available from other environments such as hospitals (Stanwell-Smith and Bloomfield, 2004) and due to the private and morally bound nature of the subject of hygiene (Curtis et al., 2003). Furthermore, the work proposed in this paper argues that there is a need to shift the healthcare model of disease infections from treatment to prevention. It therefore proposes that by studying household hygiene practices, with the aim of reducing bacterial infection in the home environment, the resultant preventative interventions will in turn reduce exposure to bacterial pathogens minimizing the growth of AMR.

3. Methodology

3.1 Combining Design with Microbiology Research Methods

Dust Bunny employs and combines qualitative design research methods with quantitative microbiology research methods. These include: hard copy surveys to obtain a broader spectrum of responders and picture of hygiene practices across a range of different households in Ghana and to help recruit a sub-sample of households for a more detailed study; design ethnography methods (observations, etc.) to collect more in-depth information for identifying the current local hygiene practices across different socio-economic urban and rural households in Ghana; cultural probes, to help provide a deeper understanding of household cultural practices and beliefs between ‘dust’ and ‘germs’, and between ‘cleanliness’ and ‘hygiene'; interviews, to elicit rich data to help establish the

impact of household beliefs (explored by the cultural probes) on domestic hygiene practices; codesign workshops with the community of households involved in the research and experts in order to consider how to best make safe hygiene practices parts of daily routine that are sustained by social norms (see Figure 1).

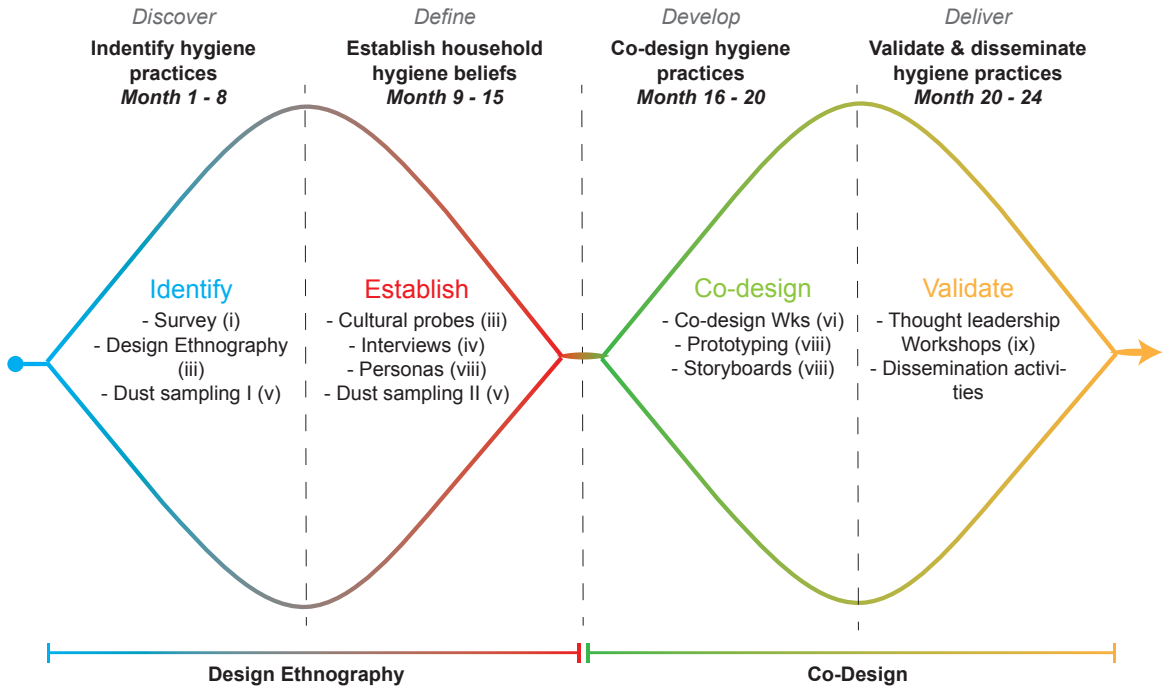

Figure 1. Dust Bunny research framework and plan.

The design of all research methods and material are led by researchers in the UK in consultation with researchers in Ghana. Most field research is conducted in Ghana by researchers at our partner research institution. We have designed and recently ran a survey (n=251) across different domestic environments (i.e. urban vs rural, private vs communal dwellings) and a range of social scales (i.e. low, low-middle, middle, upper) within Accra, Ghana. Through the face-to-face survey process we have recruited 12 households for our design ethnographic study (across urban and rural domestic environments, private and communal house environments, low, low-middle, middle and upper social scales).

We are also currently collecting dust samples from each study household to assess bacterial diversity, including the presence of infectious bacteria and to assess the degree of AMR in those bacteria. The dust will be subjected to DNA extraction and diversity assessed by deep sequencing using the latest technologies and bioinformatic analysis to describe the comparative diversity of bacteria in the households. Furthermore, polymerase chain reaction (PCR) amplification of DNA from the samples will be used to identify 5 specific antibiotic resistance genes representing established and emerging resistances. Microbiological Culture will be performed using selective antibiotic growth media to link AMR to bacterial species.

The design ethnography, which has already commenced, will be followed by cultural probes being deployed in participating households (n=12). After the cultural probes are completed a second dust sampling will be taken and subjected to DNA analysis as described above to assess the comparative stability and robustness of the results obtained in the first bacterial survey.

The qualitative and quantitative data will be analysed using thematic analysis (Braun and Clarke, 2006) and data triangulation (Denzin, 2012) and synthesized to produce personas and storyboards of

hygiene practices for different communities and home environments. These will be further enriched by a series of codesign workshops. The hygiene practices and ideas of how to best disseminate them to communities will be explored by the research team through prototyping and the co-creation of visual material. These materials and hygiene practices will be presented at local champions workshop in Ghana for feedback and validation.

Lastly, following the morally bound nature of the research subject, ethical procedures have been embedded in the methodology design. These include adhering to the ethics policy both at Lancaster University and at Noguchi Memorial Institute for Medical Research in Ghana, by submitting ethics application to both Ethics Committees. Ethics review was also incorporated that monitors study ethics assessment twice a year and an annual ethics study report.

4. Findings

4.1 Survey

The survey data is currently being analysed by a Ghanaian data scientist, however some simple analysis has been shared below to demonstrate the breadth of the survey and aspects of our approach.

The survey was conducted by four female data collectors in the Accra Greater Region's Adenta Municipal Assembly, Ga East Municipal Assembly, and the La Nkwantanang Municipal Assembly. It focused on respondents who had either held responsibility for directing household cleaning 99.60% (n=250) or who had identified themselves as the primary cleaner of the household for a period over three years 90.44% (n=227). The householders visited were across the socio-economic spectrum, with housing breaking down as follows; 16.33% detached houses, 11.55% semi-detached houses, 31.47% flats or apartments and 38.25% rooms in compound houses. The respondents (n=251) ranged from 18 to 83 years old and were 85.66% (n=215) female and 13.94% (n=35) male, with one undeclared (0.40%).

The survey engaged with an ethnically, religiously and educationally diverse set of respondents across the socio-economic spectrum. The ethnic groupings were reported, as follows; Akan 41.04%, Ewe 27.09%, Ga/Dangme 11.95% (the indigenous ethnic grouping of the region), Mole-Dagbani 5.18%, and Other 14.34%. The religious affiliations were reported, as follows; Pentecostal or Charismatic 32.67%, Presbyterian 17.93%, Islam 12.75%, Catholic 7.57%, Methodist 4.78%, Protestant 1.59%, and Other Christian 15.54%. Educational attendance was broadly spread with respondents reporting attendance as follows; Primary 7.97%, Middle 7.97%, JSS/JHS 13.55%, Secondary 14.34%, SSS/SHS 17.13%, and Higher 34.26%.

While 85.26% of respondents recognise dust in their rooms as a cause for concern a lesser number, 74.10%, believe there is a connection between dust and germs. Additionally, a significant number of respondents, 64.54%, consider the presence of dust in the home to be normal. This is an issue that will need to be unpacked further as we consider potential interventions later in the project.

Recognising the need for the project to disseminate its findings the survey instrument included a set of questions covering the leasing or ownership of a number of services or items so that we could further gauge the economic status of respondents and to inform potential communication strategies. This knowledge immediately begins to shape the project's outputs and dissemination plans as we

found that 60.56% of respondents have a radio and 66.14% have a colour TV, while Internet access is more limited at only 20.32% despite 65.34% of respondents having a mobile telephone and 27.89% have a computer or tablet.

The concepts embedded in the survey and the relationships between them are currently being visualised, as are the data arising from it, in order to better inform the participants of the codesign workshops to be run later in the process.

4.2 Rapid Ethnography

In this section we present initial findings from one household, focusing on the ethnographic account of the observation and participant observation. The rapid ethnography includes data from 12 households, we have, however, selected here to present one of these twelve, as the paper focus is not on the ethnographic data findings, but the on the nature and challenges arising from the collaboration across disciplines and geographical regions.

The observation took place on a single day in September for a period of two hours and 25 minutes. The participant observation took place on a single day in October for a period of one hour. The accounts focus on the cleaning practices that the household conduct. The participant, a 37 year old trader, lived in a compound house that opened onto an unsurfaced compound with an unsurfaced road running alongside. The description of cleaning practices from the observation revealed the possibility that disease transmission may present as an issue as the same traditional broom was used to sweep floors from the bed and throughout the house and the ground outside and in the toilet. Aspects of this practice were confirmed in the participant observation session, despite the session being cut short by the participant's work commitments.

Compound houses tend to share cleaning responsibilities between multiple tenants. For example, in this instance, most tenants sweep in front of the entrance to their own room and not the whole compound (see Figure 2). This practice may indicate a need to codesign both individual cleaning practices and communal cleaning processes.

Figure 2. Compound house example in Ghana.

These insights are drawn from an initial summary, and currently the team is writing up detailed ethnographic accounts and triangulating the data between the observation and participant observation sessions.

5. Discussion

Despite useful insights arising from the findings, as these are preliminary and given the conference track theme, we select to focus the discussion on how Dust Bunny is challenging the boundaries of design thinking, instead.

Design, like microbiology, has the ability to shift through enormous amounts of information and provide clarity that allows you to see something differently that either pre-exists or you reinvent. Nevertheless, challenges and opportunities arise independently in both the design and the microbiological strategies and when combining the two.

The following sections are based on reflections from the non-design researchers involved in the project, shared in response to a short questionnaire distributed amongst the team.

5.1 Insights, Challenges and Opportunities for Design

For microbiologists going in to the project they recognised that limiting the sample size to a small number would exacerbate the problem of linking "the microbiology data to possible health impacts" (Researcher One: microbiology researcher). As the sample size was dictated in part by the financial scale of the funder's call, one challenge for design may be in convincing humanities research funding bodies that the higher financial costs of scientific processes, such as the microbiology methods used in the pilot, should be accounted for to allow (design-led transdisciplinary) projects to be more expansive and so they might become more than feasibility studies.

The researchers involved held several understandings of the role and function of design in the project. While one researcher noted the benefit brought about by how the design-led approach altered the nature of how the project might understand context.

> "Combining microbiology with design is complimentary as differences in microbiological/AMR profiles may reflect differences socio-economic status, cultural practices and location. Microbiological methods aren't affected but the strength lies in the questions that can be asked and the targeting of the sampling regime" (Researcher One).

Another researcher, expanding on the point, recognised the opportunity for design research to have positive value from an "epidemiology, public health perspective" as it could potentially provide "the best opportunity to adequately address public health concerns" (Researcher Two: epidemiology/microbiology researcher).

However, another researcher felt that the approach had created an inflexible construct that did not allow for interesting questions to be followed up on, they particularly wanted to grapple with participant's resistance to engaging with particular methods, asking,

> "Why some people will like to participate in the questionnaire survey but not in the observational study including participant observations and the cultural probes? While others will participate in the survey and the observation but resist the cultural probes? Convincing people to open their home for observation was difficult" (Researcher Three: social epidemiology researcher).

The issue of fixedness had not been articulated as a problem in project meetings, and hopefully more can be done to address these questions, particularly as they point back to previously acknowledged difficulties in conducting detailed household studies around this topic area. That the point was not raised previously also demonstrates a need to better manage our "north-south collaborations to the make them mutually beneficial" (Researcher Three) and to ensure that critical voices are able to shape the project's development in a timely manner.

> "Both the challenges and the opportunities for design arise from the discipline being well-placed to lead transdisciplinary mixed method action-orientated evidence-based research programmes",

as Researcher Four (design researcher) observes, in line with Gibson and Owens (2014) reflections. Advancing their reflection, they speculate that building a body of design-led transdisciplinary will build disciplinary and non-disciplinary trust, noting that

> "...as collaborations of this kind continue both the research methods of design and other disciplines and the resulting data may be increasingly understood and articulated as the materials of a design research process. This will hopefully lead to greater confidence, from all parties, in research that crosses science and design."

5.2 Insights, Challenges and Opportunities for Microbiology

Coupling microbiology with design has allowed a complementary design approach to include the needs of a socio-economic framework on top of microbiology that may define microbial distribution and exposure in domestic dwellings. This means that the ethnography and cultural probe activities can be used to direct and focus the sampling required for the microbiology. Therefore the microbiology can be targeted at answering questions that arise from the 'design'. Ordinarily the sampling would choose houses at random and sample. However through 'design' one can target dwellings that are linked or offer different 'practices' thereby the data generated can reveal more about the people than the dwelling per se.

From an epidemiology and public health perspective, combining knowledge from multiple sources presents the best opportunity to adequately address public health concerns, such as in the case of this project. The use of a design research approach to address antimicrobial resistance management at the household level will provide insights into the behavioural challenges, and promote best practices for public health implementation. This is a practice that adds more value to the microbiology aspects of the project, which would typically not engage further with households after sampling has been completed.

It should be noted, that although microbiological methods are not directly affected by pairing them with design research methods, they are strengthened. This is because more specific and relevant questions that can be asked regarding AMR and the targeting of the sampling regime at a household level.

Moreover, as already mentioned above, a key challenge is linking the microbiology data to possible health impacts. The limitation here is due to the small sample size. However, as this a feasibility study and what we learn will help us formulate a larger more impactful study proposal.

5.3 Combined Views

Combining design and microbiology contributes to the strengths of both disciplines, but also helps in alleviating some of the weaknesses found in each. More precisely, design research is predominantly quantitative, typically lacking quantitative data. Data provide the sought after evidence-based characterising policy and decision making in healthcare. Although there is an emerging approach to healthcare design research (Ulrich et al., 2008; Abraham and Kools, 2012), this is not widely adopted and it is mainly applied in areas related to the design of healthcare facilities and environments (McCullough, 2010).

Microbiology, on the other hand, provides the hard evidence in the form of quantitative data, which are established through rigorous research collection and analysis methods, a view shared by healthcare and medical professionals (Köser et al., 2012; Murray et al., 2015; Kwong et al., 2015). It does not, however, include the required techniques to communicate its findings in a form that is not only plausible but persuasive too. Put it simply, microbiology researchers are powerful analysts but weak storytellers.

Storytelling is the natural language of persuasion (Marris, 1997; Moezzi et al., 2017; Davidson, 2017), since any story has to involve both a sequence of events and the interpretation of their meaning. Design and designers are generally very good storytellers but do not often have the numbers to show. For policy and strategy you need to have the numbers. Thus the coupling of design with microbiology provides opportunities for strengthening both and in developing evidenced insights that make convincing arguments around our need to act.

6. Conclusion

From climate change to global health, we are facing unprecedented challenges that require a more integrated and transdisciplinary approach to finding interventions and solutions. Design's ability to engage real people and communities, understand everyday problems and implement the 'right' solution, not just the 'newest technology', enables it to act as a bridge between other disciplines.

As the design community, along with other research communities, are called upon to tackle the complex global challenge of improving health and wellbeing, our research efforts should focus on developing strategies for promoting health and preventing illbeing of population beyond the Global North into the Global South.

Within this context, the Dust Bunny project, explores the global health crisis of antimicrobial resistance by looking at how to prevent bacterial infection in home environments in Ghana and thereby reduce resistance. This is done by challenging the traditional design thinking boundaries and by combining design-led research and microbiology in an international context. Incorporating design research in microbiology and in public health, in Dust Bunny, has enabled interdisciplinary, multidisciplinary and transdisciplinary research questions to be addressed through collective research approaches.

The approach adopted has the opportunity to provide a platform for understanding complex issues regarding microbiology (microbial resistance) and public health through engaging the community of practice. Doing this from various perspectives (design, social science, epidemiology/public health and microbiological perspectives) presents the best opportunity to adequately address emerging public health concerns, such as antimicrobial resistance in the home setting.

The insights gained from combining design and microbiology suggest that there are still challenges to address in enabling and supporting such transdisciplinary collaborations. Furthermore, there is still work to be done on enhancing other disciplines' understandings of the role and function of design in such specialist medical areas. There are, however, several opportunities arising in embedding design in microbiology research, such as providing insights into the behavioural challenges, promoting best practices for public health implementation and improved targeting of microbiological sampling at the household level. In addition, we posit that coupling design and microbiology enables the strengths of one discipline, counterbalance the weaknesses found in another; namely evidence-base/data in design and storytelling in microbiology.

Lastly, we envisage that the experiences and insights outlined in this paper, will help other design researchers to embark on transdisciplinary research that challenges the boundaries of design in new specialist medical areas.

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About the Authors:

Emmanuel Tsekleves is a Senior Lecturer at ImaginationLancaster. He leads international research in design interactions for health, which lies at the intersection of *global health, design for behaviour change* and *technology*. He is the author of the Routledge Design for Health book.

Andy Darby is a PhD Candidate at HighWire Centre for Doctoral Training and a Research Associate with ImaginationLancaster at Lancaster University, designing research tools for household studies in Ghana**.**

Collins Ahorlu is a Senior Research Fellow in cultural epidemiology, social science approaches and community engagement at the Noguchi Memorial Institute for Medical Research. Collins is a Social Epidemiologist whose research works cover, Epidemiology and Medical Anthropology/Sociology.

Dziedzom De Souza is a Senior Research Fellow at the Parasitology Department at the Noguchi Memorial Institute for Medical Research. His interests are in the molecular biology of disease vectors and parasites, medical entomology, climate change and geographic information systems.

Roger Pickup is a professor of environmental microbiology at the department of Biological and Life Sciences at Lancaster University. His research interests lie in 'Environment and human health' with expertise in molecular microbial ecology/environmental microbiology.

Daniel Boakye is a professor at the Parasitology Department at the Noguchi Memorial Institute for Medical Research.

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