Using Living Labs to engage communities and stakeholders in the development and knowledge exchange of urban health and sanitation solutions in the Global South

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Abstract: Engaging communities and stakeholders in developing user-centred urban health solutions, whilst linking the research to their own development, pose major challenges for design researchers working in the Global South. In a number of circular sanitation projects in a community school in Ghana, we co-designed and installed an anaerobic digester delivering electricity and sanitation improvements. To enhance impact we developed and pilot-tested a Living and physical Lab design approach. One project focussed on hand hygiene. We introduced students to 'making the invisible visible' by visualising microbes from their hands and assessing handwashing effects. Our findings suggest that visualisation of microbes not normally apparent to school children raised their awareness and prompted communication to peers and family. Building change agent capacity through community engagement like Living Labs can promote sustainable development in the community. Design researchers should further explore schoolchildren's potential as home and community change agents.

Keywords: Living labs, community engagement, urban health, participatory design

1. Introduction

Transitioning urban sanitation systems toward circular models that regenerate resources offers immense potential for improving public health in urban informal settlements. However, adopting circular innovations requires navigating social, cultural, economic and regulatory complexities. A growing body of work argues that lasting change necessitates engaging communities themselves in co-creating context-specific solutions tailored to local priorities and constraints (Tindana et al., 2007; Jagosh et a;., 2015; Wallerstein et al., 2018).

This participatory design orientation calls for new methodological approaches that catalyze grassroots innovation through “making, telling, enacting and empowering” (Manzini, 2015).

One emerging methodology, living labs, shows promise for enabling participatory design within communities. Living labs facilitate active user engagement and real-world experimentation to develop solutions addressing complex problems (Burbridge et al., 2022). Rather than limiting users to providing feedback on predefined designs, living labs involve community members as collaborators in framing challenges, generating ideas, prototyping interventions, interpreting results and disseminating information. This democratisation of the design process grounds innovations in lived realities while empowering users (Steen & van Bueren, 2017).

Urban health represents one domain where living labs are gaining traction as platforms for contextualised innovation. For instance, Tjörnhammar et al. (2021) established a living lab engaging youth to tackle childhood obesity through co-design sessions and pilot interventions. Others have leveraged living labs to explore e-health solutions for African informal settlements, noting benefits of embedded community participation (Hossain et al., 2022). Across applications, core goals include bidirectional learning, building capability and capacity, and ensuring community benefit beyond the project timescale (Burbridge et al., 2022).

While living labs show promise, further inquiry is needed into their application for sanitation improvements in underserved urban areas. In particular, the use of school-based living labs to promote youth-led innovation warrants exploration given students’ natural capacity as change agents. This research helps address these gaps by investigating a living lab model focused on hand hygiene in a Ghanian school community.

The living lab engaged students in visualizing microbial hand contamination to spur behavior change and knowledge diffusion. Activities sought to make the “invisible visible” regarding sanitation, integrating science learning with public health impact. The study evaluated outcomes across students, parents, teachers and researchers to elucidate multi-level influences. Analysis suggests the approach increased handwashing while empowering youth and building community capabilities.

This paper details the living lab methodology, results and lessons for design researchers aiming to advance participatory sanitation improvements in underserved urban settlements. First, background explores challenges around sustainable community engagement along with roles of children as change agents. Next, the living lab co-design process, hand hygiene focus and data gathering are outlined. Findings are then discussed regarding handwashing impacts, local dissemination, teacher strengthening, and researcher learnings. Finally, conclusions summarize contributions and considerations for future community-centered living labs seeking systemic public health impacts.

2. Related Work

Creating a legacy after the project ends is a challenge for any research project, but it is one that poses a greater challenge for Global North researchers working in the Global South. With more design researchers engaging in international projects addressing global challenges in the Global South, this becomes a major consideration. How do we ensure that as design researchers operating in the Global South, we embed legacy and sustainability in our research project? How do we ensure that we 'come back' after the project and funding have finished?

Dissemination oriented towards international journals and conferences rather than local knowledge translation not only diminishes local communities' trust in Global North–led/funded projects but also impedes local dissemination and impact (Godoy-Ruiz et al., 2016; Franzen et al, 2017). Indeed, our academic delivery of results is often unusable for the research participants. A larger and more difficult challenge is to involve the communities themselves in the research questions and to link the research to their own development (Bhutta, 2002).

We are in need of a new knowledge-transfer paradigm to make change that is sustainable and that reaches beyond adults. Preliminary evidence from projects in several developing countries suggests that working through schools has a double advantage: children take in what they are taught and also take these messages home, where they influence their families; the teachers themselves are also influenced (Onyango-Ouma et al., 2005; Wang and Stewart, 2013; Tyndale-Biscoe, Crawford and Bailey, 2020;). Building capacity of potential change agents forms a key education practice that can address sustainability development within the community. In selecting research participants, projects should therefore also consider the potential of actors in engaging in future actions and experiments, and the process should provide them with opportunities to learn, build capacities, and access resources (Silvestri et al., 2018). The model of change agents can also be applied in the school environment. Particularly in contexts in which there are no effective government/ state change agents, community-level change agents—such as community leaders and school teachers—are critical to sustainable development services in communities, and thus resources should be made available to support them (Tyndale-Biscoe, Crawford and Bailey, 2020). Hence, should design research explore children's potency as agents of change in the home and the community? And how can we best be actively empowering schoolchildren as agents of change?

2.1 Hygiene

Of the 2.3 million deaths attributed each year to infectious diseases (ID), such as diarrheal diseases and lower respiratory infections, in Low, Middle-Income Countries (LMIC), 1.6 million deaths occur in Africa. Unsafe water, poor sanitation and hygiene accounts for half of these deaths each year (1.4 million), which accounts for over 30,418 deaths in Ghana (WHO, 2023). In Ghana over 15,000 people (4,135 children under 5) die each year from poor hygiene alone (WHO, 2023).

Up to 80% of ID are preventable through hygiene education and clean water supplies (Prüss-Üstün et al., 2016). However, it is improved hygiene that breaks the chain of infection and reduces the ID burden within and between communities. Hence, if the burden of hygiene-related disease is to be reduced, in an economically sustainable manner, the responsibility has to be shared by the public (Bloomfield et al., 2009).

Evidence from other Low Middle Income Countries suggests that working through schools might have a double advantage: children take up what they are taught and also take these messages home, to influence their families (Curtis et al., 2003); also educators themselves are influenced. Hence, children's potency as agents of change (Waterkeyn & Cairncross, 2005) in the home should be further explored within the Ghanaian context.

2.2 Community engagement in WASH

A range of tools and methods, which have been shown to raise greater awareness of sanitation and hygiene issues, are being proposed in the literature, including media, planning workshops, training sessions and house-to-house visits by village authorities and health officials, and co-created learning processes with engaged stakeholders (Kariuki et al., 2012; Kema et al., 2012; Bisung et al., 2015; Hetherington et al., 2017; Silvestri et al., 2018). The key in all these approaches is, on one hand, the simplification of the scientific language used and, on the other hand, using human-centred storytelling approaches that can increase public engagement on environmental health and WASH issues (Appiah et al., 2020). Also, integrating tools such as 'photo voice', community theatre, can enable the expression of issues difficult to express with words (Silvestri et al., 2018).

Involving schoolteachers in sanitation- and hygiene-related programmes has shown to increase promotion at the community level (Crocker et al., 2016; Manjang et al., 2021) often leading to the implementation of novel school-based education and training (Person et al., 2016). Working with community leaders and volunteers and establishing a peer education programme for societal gatekeepers have shown that it can enable them to, on one hand, become advocates for young people and other community members (Kema et al., 2012) and, on the other hand, provide more regular and sustained health information that will ensure more accurate information is accessible to people (Aduro & Ebenso 2019). The key to community engagement and continued participation, especially once the project has ended, is the establishment of change agents, people who have ongoing responsibility for the delivery of WASH services in communities.

Unequal access to education forms another challenge in the urban WASH context (Silvestri et al., 2018). Building the capacity of potential change agents forms a key education practice that can address sustainability in urban health and WASH awareness and services within the community. In selecting research participants, projects should therefore also consider the potential of actors in engaging in future actions and experiments, and the process should provide them with opportunities to learn, build capacities and access resources (Silvestri et al., 2018). The model of change agents can also be applied in the school environment. Especially, in contexts where there are no effective government/state change agents, community-level change agents, such as community leaders and schoolteachers, are critical to sustainable health and WASH services in communities, and thus resources should be made available to support these change agents (Tyndale-Biscoe et al., 2020). A project by Person et al. (2016) has demonstrated that the training of a small group of schoolteachers enabled training a larger group of teachers in their school, leading to more children being engaged in WASH prevention and control activities. Parents were also encouraged to attend in order to learn about the impact of WASH practices on health and how to prevent this in their children (Person et al., 2016).

Community engagement and participatory approaches can be valuable methods to achieving this

2.3 Leveraging Living Labs for Community-Engaged Urban Health Research

Engaging communities in developing user-centered urban health solutions poses challenges for design researchers, especially when working in the Global South (Hossain et al., 2022). Living labs, as a participatory design approach, provide opportunities to involve local stakeholders while embedding research legacy via knowledge dissemination.

Living labs facilitate active user engagement in real-life settings to prototype solutions addressing complex problems (Burbridge et al., 2022). In urban health, living labs have been

leveraged as platforms for participatory design and grassroots innovation. For instance, Kleinsmann and Valkenburg (2008) established a healthcare living lab where patients, designers and providers co-designed hospital waiting experiences. Others have created community-centered living labs tackling challenges like preventing childhood obesity (Tjörnhammar et al., 2021).

Key benefits of living labs include democratising research through community inclusion and reciprocal learning. Hossain et al. (2022) note living labs "give voice" to users while embedding research locally, citing examples of participatory e-health projects in informal settlements. Similarly, Malmberg et al. (2022) found that involving youth in living labs aided idea generation and empowerment. Blum-Ross et al. (2022) advocate participatory design in living labs to influence urban policies.

To disseminate research locally, living labs can include communication strategies like demonstrations, technology trainings, workshops, and pilot implementations accessible to the community (Hossain et al., 2022; Følstad et al., 2022). Burbridge et al. (2022) argue living labs should ensure community benefit through skills building, capacity development, and transferable solutions.

Overall, living labs show promise for contextualising urban health research through participatory methods while enabling local engagement. Key considerations include facilitating ongoing partnerships, co-ownership and community education to translate outcomes into impact. Further work is needed to evaluate long-term change catalysed by health-focused living labs.

2.4 Overview

The related work highlights the need for sustainable, community-engaged approaches to improving public health and WASH (water, sanitation and hygiene) in low- and middle-income countries. A key strategy is leveraging schools and youth as change agents, as children can influence families while teachers spread knowledge broadly. To further catalyse change, community participation, co-design and capacity building are critical for contextualising and disseminating research. Living labs provide a platform to bring these strategies together, facilitating participatory design with youth and community partners to prototype context-specific solutions. Key considerations include ongoing partnerships, co-ownership, skills development, and accessible knowledge translation to embed research locally. More work is needed to evaluate the long-term, sustainable impact of youth- and community-engaged living labs on improving health and hygiene.

3. Methodology

We employed a cobination of participatory design and living lab methods for the study.

3.1 Scope

The exercise focused on two groups of students from Umar Bun Hatab Islamic School at Madina in Greater Accra, Ghana and community youth forerunners at Gbegbeyisee (see Figure 1). A total of 22 students, ten (10) from Umar Bun Hatab Islamic School and twelve (12) students from Madina.

Figure 1: Living Lab setting at School with students and teachers

A visualisation exercise was carried out for all the students in the science laboratory at at Umar Bun Hatab Islamic School. This exercise involve a general talk on microbiology (bacteria) and the fact that they can be found in the environment including the room they were in and on their hands. Video footage of how culture media are prepared from the initial stage of weighing of dehydrated media, heating on stirrer hotplate after addition of distilled water through to autoclaving and pouring of media into patri dishes (culture plates). Also laboratory equipment were displayed on the screen with detailed explanation of theirs uses and applications in the microbiology laboratory.

The presentation was followed by questions and answers. Additional engagement through lectures, seminars and a webinar took place over a period of three months.

3.2 Study Design

Co-Designing the Living Lab Study Experiments

To co-develop the research design, initial engagement included lectures, seminars, and a webinar over four months to immerse stakeholders and collaboratively define the scope (see Figure 2).

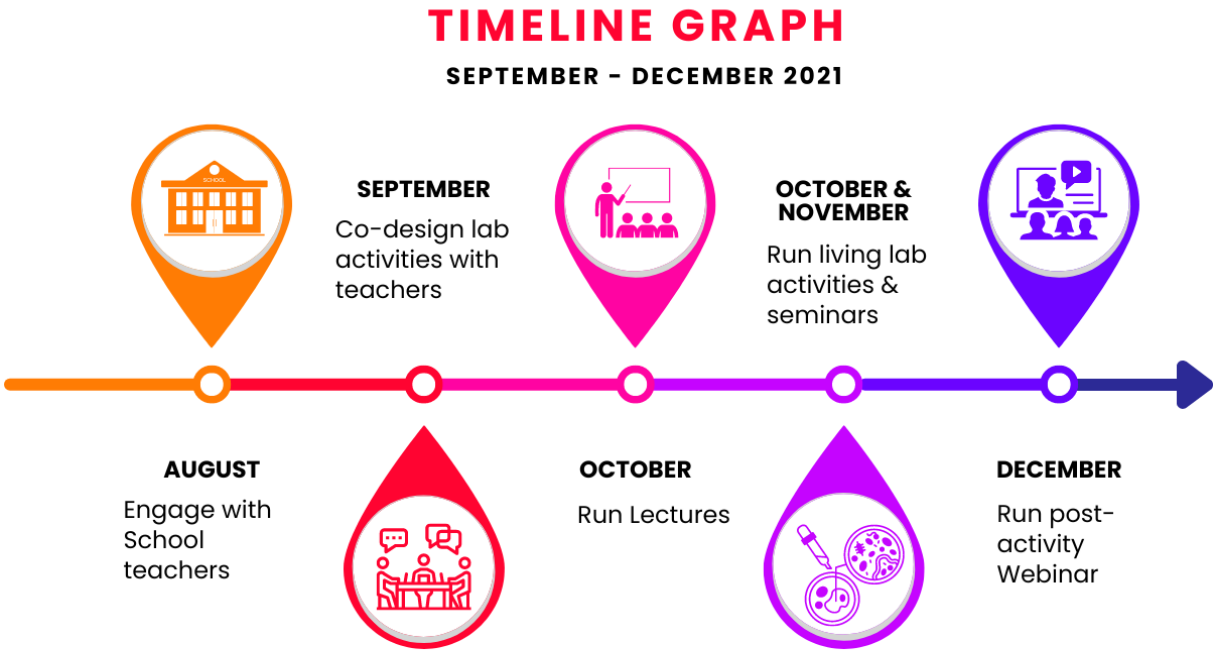

Figure 2: Living Lab timeline

Teachers helped frame key questions on how different handwashing actions might impact microbial presence. Students brainstormed fun experimental ideas based on their science lessons. Local researchers suggested supplemented swab sampling with wider community surveys to gauge handwashing knowledge and attitudes.

Integrating these diverse perspectives, the experiments were co-designed to blend scientific rigor with experiential learning for maximal student engagement and knowledge acquisition.

The study involved visualized hand swab microbial sampling before and after different handwashing techniques.

Sterile culture plates containing autoclaved nutrient media agar were transported from the Microbiology laboratory of the CSIR- Water Research Institute to the school's science laboratory at Madina.

Each student was allocated 2 plates containing the agar and were marked 1 and 2 with the student's initials.

Figure 3: Students partcipating in the living lab, taking a hand swab microbial sampling on the agar plate.

Exercise 1

A control agar plate was kept open for duration of the exercise and one control plate was kept closed and not opened . This was closed after the exercise and added to the handprint plate (see Figure 3).

Each of the 22 students were allowed to walk around and touch a few objects (door handles, desks and chairs). They then were instructed to place one full handprint on the agar (they were made to press the hand firmly on the agar but not too firm to breaks the agar) in the Plate labelled 1 that also bears their initials immediately after the plates were opened. The lids were then replaced and sealed with tape

The 22 students were then split into three groups (2a, 2b and 3)

Exercise 2

Group 2A consist of 11 students who washed their hands with soap and water before drying hands with paper towels and disposing towels into an autoclave bag for safe disposal. They were then instructed to place their full handprint on the agar of the agar plate bearing their initials, following the same procedure as exercise 1

Group 2B consist of 11 students who were instructed to wash their hands with only water without soap and dry hands with paper towel before placing their full handprint on the agar of the agar culture plate bearing their initials.

Group 3 consist the same students in group 2b who washed their hands with only water and later washed their hands with soap before placing their full handprint on the agar on the agar plate bearing their initials. This group had additional plates as Plate 3 bearing their initial.

The students, after the exercise washed their hands with water and soap, and wiped their hands with paper towel.

All the culture plates (hand print and control agar plates) were wrapped in an aluminum foil and placed in an ice chest. All culture plates (both handprint and control plate) were transported to CSIR-Water Research Institute for incubation at a temperature of 37^{o}C for 48 hours. In the laboratory, control plates containing the agar (unexposed plates) were incubated under the same condition to represent negative control plate (Fig 2).

Lectures, Seminars and Webinar

Extensive preparatory engagement took place through lectures, seminars, and a webinar over a three-month period to immerse stakeholders in the concepts and collaboratively define the study scope.

Interactive lectures were held at each school led by the research team's microbiologists and public health experts. Students learned fundamentals about hand hygiene, disease transmission, and the invisible world of microbes that surround us. To reinforce learning, students observed videos on lab processes like agar preparation prior to the experiments. The visualisation allowed them to better understand the unseen microbial world and scientific methods. They asked thoughtful questions about hygiene habits, demonstrating their interest.

Following up, seminars provided a forum for students to help shape the research focus based on their new knowledge foundation (see Figure 4). In small groups, they reflected on handwashing practices they observed in their communities, discussing barriers like water access and knowledge gaps. They then suggested ideas for an experiment that could illuminate how better handwashing could reduce sickness. This input helped form initial hypotheses.

A webinar allowed connecting internationally with hand hygiene researchers to incorporate broader expertise. Students were inspired hearing about global efforts to improve hand hygiene, and realizing their local project formed part of a worldwide movement. Students also helped examine the photographic results showing microbial growth before and after handwashing. Many expressed pride in contributing to original health research and eagerness to share findings with their communities to promote behavior change.

Teachers also gave input on aligning the project with educational curricula to maximise learning. Public health officials suggested supplementing lab trials with a community survey on handwashing access and attitudes. Engaging these diverse voices in the preparatory phase allowed aligning research objectives, public health priorities, and student learning goals.

Figure 4: Interaction with students at the show lab

3.3 Data Analysis

Both qualitative and quantitative data were gathered during the living lab hand hygiene study, requiring a mixed methods analytical approach (Creswell, 2014). Key data sources analysed included audio recordings from the preparatory lectures, seminars and webinars, photographic data from the microbial hand swab experiments.

The audio recordings from the preparatory sessions were transcribed and subjected to thematic analysis using an inductive, data-driven approach (Braun & Clarke, 2006). Two researchers independently coded the transcripts, manually identifying emergent themes related to student perspectives, motivations, and learning outcomes. Coders then compared

notes and agreed on primary themes and sub-themes. These provided insights into student mindsets, knowledge acquisition, and overall engagement.

Quantitative analysis methods were applied to the microbial hand swab experiments. The research team visually examined the photographed nutrient agar plates, manually counting colony-forming units (CFUs) on each plate representing microbial growth. CFUs were compared before and after different handwashing techniques to quantify reduction efficacy. Statistical analysis like t-tests calculated significance of CFU declines by washing method. This enabled empirical conclusions about optimal hand hygiene procedures.

Thematic analysis captured nuanced perspectives from students and teachers, while microbial sampling and surveys allowed for empirical assessment of hand hygiene behaviors and impacts on health. Together, these techniques enabled rich multidimensional insights to inform handwashing promotion initiatives.

4. Findings and Discussion

Bacteria load on plates 1 (a,b,c) (see Figure 5-6) were observed to be significantly higher than those observed on plates representing handwashing (Plate 2a, 2b and 3) (see Figure 5, 7). Also, other bacteria growth were also observed on the plates, aside where the hand print was done. These were ones landing on the plate from air or dropping off unwashed parts of the arm or clothes.

Figure 5: bacterial load on agar plates bearing the initials of student with unwashed handprint (Plate 1) and handprint after washing with water and soap (Plate 2A).

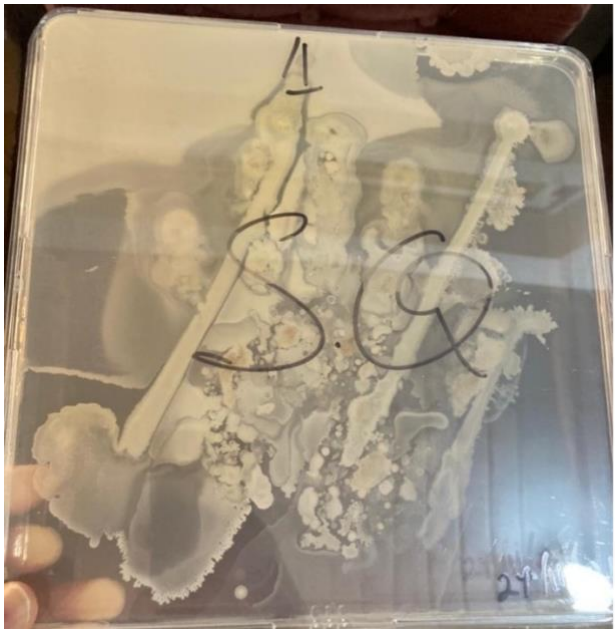

Figure 6: bacterial load on agar plates bearing the initials of student with unwashed handprint (Plate 1)

Figure 7: handprint after washing with only water (Plate 2B).

This research demonstrates the value of community-engaged living labs for generating localised impact in the context of hand hygiene promotion within urban schools in Ghana. Both quantitative microbial data and qualitative feedback from students, parents, teachers, and researchers highlight the effectiveness of the living lab approach in driving behavior change, knowledge acquisition, and research translation.

4.1 Visualising the Impact of Handwashing

A predominant theme across respondents was the power of making the invisible visible by visualising microbes to reshape handwashing perceptions and habits. As a student described:

> "I was so surprised to see how many little bugs came from my hands when I did not wash with soap. But then when I washed them properly with soap, so many disappeared. This made me realise I must wash my hands every time."

Previous studies similarly found interactive demonstrations greatly increased student knowledge retention and engagement compared to traditional teaching methods (Abdulwahed & Nagy, 2009). Enabling students to directly see swab results and the bacteria reduction after handwashing appeared pivotal in compelling both students and parents to improve hygiene habits. As a parent explained:

> "Seeing the pictures of the dirty hands made me insist my children wash when coming from outside. This small experiment had big result for our home."

Another student reflected:

> "I taught my little sister how to rub the soap and count to 30 seconds. Now she washes hands before eating her food."

These statements showcase how visualisation led to cascading hygiene improvements beyond the lab environment itself, as students adopted the role of change agents. The experiential learning was particularly impactful given that the microbial threats are invisible to the naked eye (World Bank, 2005). Making contamination visible stimulated both disgust and interest among students, consistent with theories around leveraging emotions in hygiene promotion (Curtis et al., 2009).

4.2 Knowledge Dissemination and Local Dissemination Impact

A major impact pathway identified was students' eagerness to disseminate their learnings by educating peers and family. One teacher observed:

> "The students were so excited to show their parents the pictures of the microbes. This helped the parents understand better and reinforced the lessons at home."

This demonstrates the potential of school-based living labs to catalyse broader attitude and behaviour change within households and the wider community. As change agents, the students helped multiply the intervention's reach far beyond the lab environment. A parent also noted:

> "Children are very effective teachers! My son reminded me about proper handwashing every day after doing the experiment. His new knowledge has helped our family."

This aligns with prior evidence that schoolchildren-led health education can positively shape parental knowledge and practices, creating a beneficial cascade effect (Ayele et al., 2020).

Children's natural inquisitiveness and openness to new ideas are assets for promoting household behavior change (Dreibelbis et al., 2016). Moreover, the public nature of handwashing lent itself well to being encouraged and monitored by children.

4.3 Teachers as Champions and Influencers

Teachers also reported observable hygiene improvements among students following the living lab, along with new ideas for experiential learning they could incorporate into their ongoing pedagogy. As one explained:

> "I have started using more active demonstrations in my lessons after seeing how engaged the students were. This experiment gave me many ideas to try and teach in fun ways that stick."

Another noted:

> "Students often teach me new things too! This lab allowed two-way learning."

The living lab thus provided professional development benefits in addition to student impacts. As argued by Tjörnhammar et al. (2021), embedding capacity building within living labs can enable sustained impact through empowering local champions. Ongoing hygiene discourse and enthusiasm six months later further indicates the impact of the lab's influence. Equipping teachers with creative pedagogical techniques amplified the project's longevity and integration into school culture (Axelsson et al., 2022).

4.4 Researcher Learnings from Community Immersion

Finally, researchers gained invaluable community insights that had eluded traditional data collection methods. The participatory, embedded nature of the living lab yielded crucial cultural and contextual understandings while facilitating trust with the school. A researcher explained:

> "The students were so open sharing details about hygiene habits at home and in their community we never could have gathered through surveys or interviews."

Another researcher described:

> "Being there in person created a connection that helped us understand barriers like water access that quantitative data alone missed."

This underscores the value of situated co-learning for advancing public health research in underserved communities, consistent with arguments made by Hossain et al. (2022). The relationships formed enabled researchers to identify behavioral motivators, address misconceptions, and design appropriately framed interventions (Mosavel et al., 2022).

4.5 Considerations for Living Lab Implementation and Sustainability

While results were highly promising, findings also highlighted considerations for implementing successful school-based living labs with lasting impact.

First, ensuring adequate resources is crucial for maintaining benefits over time. As a teacher recommended:

> "Having a budget for supplies allowed us to reinforce the lessons after the lab. We need tools to build on the momentum."

Consistent with conclusions by Gardner et al. (2020), ongoing financing for follow-up activities, infrastructure improvements, and capacity building is vital for long-term sustainability.

Second, providing continuous mentorship and building teacher capabilities promotes enduring impact and self-sufficiency. A researcher emphasised:

> "Following up with continued training helps educators amplify the benefits over time. This is key for permanence."

Equipping local staff and administrators to champion hygiene allows the vision to take root within the institutional culture (Hetherington et al., 2021).

Finally, fostering community agency and leadership from the start enables communities to own solutions. As a parent advised:

> "Involve us as partners from the beginning so we learn how to keep guiding our children's health."

Enabling participatory mechanisms and platforms where various actors can contribute ensures contextual fit and priorities remain aligned with local needs over time (Walters & Roe, 2021).

4.6 Considerations for Design Researchers

While this demonstration provides evidence of living labs' potential to advance participatory public health innovations in urban environments, key considerations remain regarding their use by design researchers.

First, truly embed reciprocal, equitable partnerships from the inception of living labs, rather than limiting community involvement to feedback on predefined agendas (Hossain et al., 2022). Co-defining research questions and methodologies fosters relevance, drives motivation and enables collective ownership (Tunstall, 2013). However, this requires relinquishing some design authority - are researchers prepared to share power?

Second, develop participatory mechanisms spanning the project lifecycle to ensure priorities stay aligned with local needs over time (Walters & Roe, 2021). Sustained engagement and platforms for contribution build capacity and prevent research drifting from community goals. But this demands intensive relationship building and likely extends typical timelines.

Third, allocate adequate budget for ongoing activities, resources and capacity building post-project to enable self-sufficiency (Gardner et al., 2020). While grant funding commonly covers initial engagements, ensuring local champions can sustain impacts requires forethought and investment. Creative financing models could help seed continuity.

Fourth, proactively assess potential burdens on communities from engagement, and implement appropriate consent procedures and incentives for participation (Mosavel et al., 2022). Living labs provide invaluable contextual insights, but researchers must weigh benefits and costs to partners.

Fifth, develop dissemination strategies beyond academic outputs to maximize local benefit through demonstrations, trainings and pilot implementations (Følstad et al., 2022). Creative communications can increase uptake and empowerment.

Finally, apply a critical lens to living labs' democratising claims to ensure inclusive participation and equitable distribution of benefits (Blum-Ross et al., 2022). Despite aims to "give voice", power imbalances risk replicating exclusion. A justice-oriented perspective remains vital.

In summary, while living labs enable rich co-creation, design researchers must thoughtfully facilitate participation, navigate power dynamics, and center community priorities. This method shows immense potential to contextualise solutions when done collaboratively. But realizing lasting, empowering outcomes requires ongoing critical reflection on researchers' roles. By embracing community leadership and persisting beyond typical timeframes, living labs can fulfill their promise of participatory transformation. With careful facilitation, this approach provides a constructive mechanism for design researchers to ally with communities as agents of change.

4. Conclusion

This real-world demonstration provides multifaceted evidence that living labs can be leveraged as platforms to promote user-driven health solutions grounded in community priorities and values. The interrelated outcomes across students, parents, teachers and researchers showcase the value of embedded co-creation through hands-on visualisation, peer-to-peer diffusion, educator strengthening, researcher learnings, and relationship building. While further evaluation is still warranted, these initial insights contribute promising indications of the potential for school-based living labs to catalyse localized hygiene improvements through active engagement.

Key elements fostering success included the preparatory immersion helping align diverse priorities, the co-design integrating scientific, educational and community goals, and the

focus on empowering youth as change agents. Making the 'invisible visible' appeared pivotal in compelling behaviour change. Enabling students to take ownership as partners generated energy rippling into families and neighbourhoods.

However, findings also reveal key considerations for design researchers in facilitating such living labs. Sustaining participatory mechanisms, navigating power dynamics, and allocating adequate resources remain vital but challenging. This methodology shows immense promise for contextualising solutions, but realizing lasting transformation requires commitment to community leadership.

This research contributes both insights and practical strategies for leveraging living labs as platforms to advance participatory design for public health in underserved urban settlements. While many open questions persist, the approach provides an actionable model to ally design with communities as co-creators of sustainable change. By making health threats visible and empowering local voices, embedded participation provides a pathway to tackle complex challenges grounded in lived realities. Living labs offer a mechanism to "make, tell, enact and empower" grassroots innovation, and further exploration of their role in sustainable community development holds much potential.

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5. References

Abdulwahed, M., & Nagy, Z. K. (2009). Applying Kolb's experiential learning cycle for laboratory education. Journal of engineering education, 98(3), 283-294.

Aduro, A., & Ebenso, B. (2019). Qualitative exploration of local knowledge, attitudes and use of Moringa oleifera seeds for home-based water purification and diarrhoea prevention in Niger State, Nigeria. Journal of water, Sanitation and hygiene for development, 9(2), 300-308.

Appiah B., Poudyal A., Anum D., Appiah G., Wesuta A. C., Akodwaa-Boadi K., Ogodo O., Nakkazi E., Mulogo E. M. & Odai S. N. 2020 Challenges and facilitators of public engagement with water, sanitation, hygiene and other environmental health issues in Ghana and Uganda: perspectives of scientists, journalists and the public. Journal of Water, Sanitation and Hygiene for Development 10 (1), 16–26.

Axelsson, L., Lindgren, E. C., Westman, A., Haglund, L., Kindeberg, T., & Holmström, I. K. (2022). Health promotion at school from the perspective of teachers and principals-A concept analysis. Health promotion international, 37(2), 383-393.

Ayele, F. A., Tesfa, B., Abebe, L., Tilahun, T., & Girma, E. (2020). Impact of school community based health education program on hygiene and sanitation related practices of school children living in a rural setting, Ethiopia. BMC public health, 20(1), 1-10.

Bhutta, Z. A. (2002). Ethics in international health research: a perspective from the developing world. Bulletin of the World Health Organization , 80 , 114-120.

Bisung E., Elliott J., Abudho B., Karanja M. & Schuster-Wallace J. 2015 Using photovoice as a community based participatory research tool for changing water, sanitation, and hygiene behaviours in Usoma, Kenya. BioMed Research International 2015, 1–10.

Bloomfield, S. F., Exner, M., Fara, G. M., Nath, K. J., Scott, E. A., & Van der Voorden, C. (2009). The global burden of hygiene-related diseases in relation to the home and community. In International Scientific Forum on Home Hygiene (Vol. 24). London: International Scientific Forum on Home Hygiene.

Blum-Ross, A., Kumpulainen, K., & Marsh, J. (2022). Enhancing urban communities through participatory design with children: Theory, practice and implications for policy. Journal of Urban Design, 1-18.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101.

Burbridge, A., Morrison, G. M., & Abreu, L. (2022). Living Labs for Health: A Scoping Review of Their Application and Value. International Journal of Environmental Research and Public Health, 19(3), 1173.

Creswell, J. W. (2014). A concise introduction to mixed methods research. SAGE publications.

Crocker J., Shields K. F., Venkataramanan V., Saywell D. & Bartram J. 2016 Building capacity for water, sanitation, and hygiene programming: training evaluation theory applied to CLTS management training in Kenya. Social Science & Medicine 166, 66–76.

Curtis, V., Biran, A., Deverell, K., Hughes, C., Bellamy, K., & Drasar, B. (2003). Hygiene in the home: relating bugs and behaviour. Social science & medicine , 57 (4), 657-672.

Curtis, V., Schmidt, W., Luby, S., Florez, R., Touré, O., & Biran, A. (2011). Hygiene: new hopes, new horizons. The Lancet infectious diseases, 11(4), 312-321.

Dreibelbis, R., Kroeger, A., Hossain, K., Venkatesh, M., & Ram, P. K. (2016). Behavior change without behavior change communication: Nudging handwashing among primary school students in Bangladesh. International journal of environmental research and public health, 13(1), 129.

Franzen, S. R., Chandler, C., Siribaddana, S., Atashili, J., Angus, B., & Lang, T. (2017). Strategies for developing sustainable health research capacity in low and middle-income countries: a prospective, qualitative study investigating the barriers and enablers to locally led clinical trial conduct in Ethiopia, Cameroon and Sri Lanka. BMJ open, 7(10), e017246.

Følstad, A., Lagesen, V. A., & Knutzen, H. (2022). Engaging with children: The practicalities of using living labs in research with children. Behaviour & Information Technology, 1-15.

Gardner, E. A., Doherty, A., Geraghty, S., & Mullen, A. (2020). Sustainability of community-based health promotion interventions–a scoping review. Health Promotion International, 36(2), 398-415.

Godoy-Ruiz, P., Cole, D. C., Lenters, L., & McKenzie, K. (2016). Developing collaborative approaches to international research: Perspectives of new global health researchers. Global Public Health, 11(3), 253-275.

Hetherington E., Eggers M., Wamoyi J., Hatfield J., Manyama M., Kutz S. & Bastien S. (2017) Participatory science and innovation for improved sanitation and hygiene: process and outcome evaluation of project SHINE, a school-based intervention in Rural Tanzania. BMC Public Health 17 (1), 1–15.

Hossain, M., Leminen, S., & Westerlund, M. (2022). A systematic review of living labs literature: Innovating healthcare through co-creation. Health Policy and Technology, 11(2), 133-151.

Kariuki G., Magambo J., Njeruh F., Muchiri M., Nzioka M. & Kariuki S. (2012) Changing Mother's hygiene and sanitation practices in resource constrained communities: case study of Turkana District, Kenya. Journal of Community Health 37, 1185–1191.

Kema K. M., Komwihangiro J. & Kimaro S. (2012) Integrated community based child survival, reproductive health and water and sanitation program in Mkuranga district, Tanzania: a replicable model of good practices in community based health care. The Pan African Medical Journal 13 (Suppl 1), 1–7.

Kleinsmann, M., & Valkenburg, R. (2008). Barriers and enablers for creating shared understanding in co-design projects. Design studies, 29(4), 369-386.

Jagosh, J., Bush, P. L., Salsberg, J., Macaulay, A. C., Greenhalgh, T., Wong, G., ... & Pluye, P. (2015). A realist evaluation of community-based participatory research: partnership synergy, trust building and related ripple effects. BMC public health, 15(1), 1-11.

Malmberg, K., Rodrigues, V., Lännerström, L., Wetter-Edman, K., Vink, J., & Holmlid, S. (2022). Experience Labs: Involving Youth in the Public Realm. Design Issues, 38(2), 59-77.

Manjang, B., Ochola, E. A., & Elliott, S. J. (2022). The use of non-pharmaceutical interventions for the prevention and control of schistosomiasis in sub-Saharan Africa: A systematic review. Global Public Health, 17(3), 469-482.

Manzini, E. (2015). Design, when everybody designs: An introduction to design for social innovation. MIT press.

Mosavel, M., Ahmed, R., Daniels, D., & Simon, C. (2012). Community researchers conducting health disparities research: ethical and other insights from fieldwork journaling. Social Science & Medicine, 75(1), 145-152.

Onyango-Ouma, W., Aagaard-Hansen, J. and Jensen, B.B., 2005. The potential of schoolchildren as health change agents in rural western Kenya. Social science & medicine, 61(8), pp.1711-1722

Person, B., Knopp, S., Ali, S. M., A'kadir, F. M., Khamis, A. N., Ali, J. N., ... & Rollinson, D. (2016). Community co-designed schistosomiasis control interventions for school-aged children in Zanzibar. Journal of Biosocial Science, 48(S1), S56-S73.

Prüss-Üstün, A., Wolf, J., Corvalán, C., Bos, R., & Neira, M. (2016). Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks . World Health Organization. https://apps.who.int/iris/handle/10665/204585

Silvestri, G., Wittmayer, J. M., Schipper, K., Kulabako, R., Oduro-Kwarteng, S., Nyenje, P., ... & Van Raak, R. (2018). Transition management for improving the sustainability of WASH services in informal settlements in Sub-Saharan Africa—An exploration. Sustainability , 10 (11), 4052.

Steen, K., & Van Bueren, E. (2017). Urban Living Labs: A living lab way of working. Amsterdam: AMS Institute

Tindana, P. O., Singh, J. A., Tracy, C. S., Upshur, R. E. G., Daar, A. S., Singer, P. A., ... & Lavery, J. V. (2007). Grand challenges in global health: community engagement in research in developing countries. Plos medicine, 4(9), e273.

Tjörnhammar, E., Lange, E., Mansfeldt, G., Vestbro, D. U., & Mårald, G. (2021). Co-creation and learning in landscape laboratories: the Living Lab of Mariestad municipality, Sweden. Sustainability, 13(6), 3360.

Tunstall, R., Bevan, M., Bradshaw, J., Croucher, K., Duffy, S., Hunter, C., ... & Wilcox, S. (2013). The links between housing and poverty: an evidence review. York: Joseph Rowntree Foundation.

Tyndale-Biscoe, P., Crawford, P., & Bailey, B. (2020). Engaging with the WASH enabling environment. Journal of Water, Sanitation and Hygiene for Development , 10 (1), 124-135.

Wallerstein, N., Duran, B., Oetzel, J. G., & Minkler, M. (Eds.). (2017). Community-based participatory research for health: Advancing social and health equity. John Wiley & Sons.

Walters, J. P., & Roe, E. J. (2021). Community engagement for environmental health interventions-a scoping review. International journal of environmental research and public health, 18(3), 1124.

Wang, D., & Stewart, D. (2013). The implementation and effectiveness of school-based nutrition promotion programmes using a health-promoting schools approach: a systematic review. Public health nutrition, 16(6), 1082-1100.

Waterkeyn, J., & Cairncross, S. (2005). Creating demand for sanitation and hygiene through Community Health Clubs: A cost-effective intervention in two districts in Zimbabwe. Social science & medicine , 61 (9), 1958-1970.

WHO (2023) Burden of disease attributable to unsafe drinking-water, sanitation and hygiene, 2019 update. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789240075610

World Bank. (2005). The handwashing handbook: a guide for developing a hygiene promotion program to increase handwashing with soap. World Bank, Water and Sanitation Program. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/681501468141299225/the-handwashing-handbook-a-guide-for-developing-a-hygiene-promotion-program-to-increase-handwashing-with-soap

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