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Bottle house: A case study of transdisciplinary research for tackling global challenges

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ABSTRACT

Globalisation has brought a number of challenges to the fore, particularly those problems which require collaboration, innovation and capability development between nations. There are some complex issues piquing the attention of researchers with respect to sustainable development, such as, waste management, climate change, and access to amenities, housing or education. Non-Governmental Organisations, Institutions, governments and others working in the field of international development have been grappling with these difficulties for decades. However, it is becoming apparent that many of these difficulties require multifaceted solutions, particularly in Low and Middle Income countries (LMIC) where it is difficult to consolidate gains and fund schemes. Development work can sometimes be disjointed and inefficient, impairing the capability of local communities and inhibiting sustainable and innovative approaches. Transdisciplinary collaboration is reliably a more efficient way of tackling some of the most pertinacious challenges. This paper presents findings from a transdisciplinary research project focussed on developing resources and capacity for the construction of affordable homes in a low income community in Nigeria. The project explored the suitability of using upcycled materials such as plastic bottles and agricultural waste in construction. Using a user-centred, co-creation methodology, a team of experts from the UK and Nigeria worked with local entrepreneurs to build a prototype home. The study explores the functionality of the home and the sustainability of project. The findings demonstrate the benefits of tackling global challenges from a transdisciplinary perspective. This has implications for researchers focused on developing technical solutions for low-income communities.

1. Introduction

The right to adequate housing is embedded in the Universal Declaration of Human Rights (UN, 1948). Housing is an "economic, social and cultural right" which protects families from many vulnerable circumstances including natural disasters, civil conflict and social stigmatisation (Rolnik, 2010). Furthermore, Kenna (2008) argues that too many people around the world are living in dwellings that are inadequate because the shelter they have is temporary, unaffordable, inhabitable, insecure, inaccessible, culturally inappropriate or unsafe. By these standards, approximately 1.6 Billion people lack adequate housing (Habitat, 2017). In addition, the World Health Organisation estimates that nearly 2 million deaths occur in Low and Middle Income Countries (LMIC) annually due to health issues linked to inadequate housing (WHO, 2010). People who live in poor housing are often forced to live in unsanitary conditions with little or no provision for waste

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disposal, creating environmental problems, which aggravate their housing, health and economic circumstances (Darkey, Visagie, 2013). As such, it is generally accepted that contending with the housing crisis invariably deals with many of the global challenges (Heslop, 2017).

Spiegel (2017) notes how disjointed and inefficient development work can be, impairing the capability of local communities and inhibiting sustainability. A scientific approach to the complicated web of problems around international development projects is needed; for example, around housing, a solution, which employs suitable, locally sourced material and resources, should be adopted. This should also tackle the health, environmental and education concerns related to housing and ensure the resulting accommodation is cost-effective, sustainable, socially acceptable and functional. In response, many researchers (Harriss, 2002; Hasnain, 2013) have proposed interdisciplinary approaches to solve these sorts of complicated problems. Tackling low income housing from an interdisciplinary perspective can enhance innovation and collaboration, empowering indigenous communities to meet their housing needs by delivering pragmatic solutions which are sustainable and meet the aesthetic and culturally requirements of the local population (Lyall, Bruce, Tait, & Meagher, 2015). Similarly, it has been suggested that significant impact can be achieved when there is collaboration (formal and informal channels) between academia, industry partners and end users (Azagra-Caro, Barberá-Tomás, Edwards-Schachter, & Tur, 2017; Hanieh, AbdElall et al., 2015). This suggests that an interdisciplinary approach, in collaboration with industrial partners and end users could potentially yield significant positive impacts. Research of this nature, which transcends the boundaries of scientific disciplines, stretching into the domains of civil society and entrepreneurship in the real world context, can be termed transdisciplinary (Lawrence, 2010).

This paper reports on the Bottle House project; a transdisciplinary, international, research collaboration between academia, industry and end-users in rural Nigeria. The project explored designing and building an affordable, self – sufficient prototype home from waste Polyethylene Terephthalate (PET) bottles (or plastic bottles). This idea was developed because researchers observed that the plastic bottles were causing severe environmental damage in the area. A transdisciplinary team was formed to tackle different aspects of the housing crisis and develop accommodation that was user friendly, sustainable and affordable in the community. There have been a few constructions in Nigeria (and other parts of the world) that have used plastic bottles as construction material over the past decade. However, there is no study to characterise their acceptability, suitability and efficiency as viable building materials. This seems to be the first study by transdisciplinary team to examine the efficacy of PET bottles as construction material in terms of its economic, social and cultural viability. As of the time of publication, the authors are not aware of any transdisciplinary studies which examine the efficacy of using plastic bottles as building components for economic, cultural, social and environmental purposes. This study therefore aims to fill this gap in knowledge and further demonstrate the benefits of tackling global changes from a transdisciplinary perspective. Insights from this study have implications for researchers focused on developing sustainable, technical solutions for low-income communities.

The rest of the paper will present some background literature relating to the efficacy and use of waste materials in low cost construction; the third section will discuss the methodology and expertise of the transdisciplinary team. Following this, a fourth section will describe the research and development, which underpinned the use of plastic bottles. Other sections will present the construction, the social acceptance of the prototype, and user appeal. A penultimate section will explore the challenges faced by the team followed by a conclusion.

2. Background

2.1. Upcycling materials

The concept of using waste plastic bottles as building blocks has been studied by a few researchers. Taaffe, O'Sullivan, Rahman, and Pakrashi (2014) reported on experiments performed to characterise the compression, acoustic and light transmission properties of Eco bricks (plastic bags packed in Plastic bottles). They concluded that Eco-brick was a viable resource for construction purposes with a number of possible applications. Similarly, Muyen, Barna, and Hoque (2016) studied the structural and thermal properties of plastic bottles filled with different materials (dry sand, saturated sand, or air). They found that although the strength of the plastic bottle wall was about 6 times less than traditional blocks, they could still be used as a suitable building material. They also observed that air filled bottles showed better thermal insulation than traditional blocks. Other studies involving the use of plastic bottles for construction include Shoubi, Shoubi, and Barough (2013), Rawat and Kansal (2014), Mansour and Ali (2015), Patela, Shahb, and Patelc (2016) and Revathi, Kumar, Raman, Umanath, and Student (2017). Most of these studies have focussed on the technical aspects of using plastic bottle walls. Upcycling materials, such as plastic bottles, could be a driver for the development of circular economy (Ilić, Nikolić, 2016).

2.2. Agricultural waste in construction

Several researchers have undertaken studies to explore the suitability of using Agricultural waste in low cost construction. Some of these include Quintana, Velásquez, Betancourt, and Gañán (2009) who used bananas for fibre boards and Korjenic, Petránek, Zach, and Hroudová (2011) who used jute, flax and hemp to develop an insulating material, comparable to conventional ones. Similarly, Demir (2006) investigated the performance of clay bricks optimised with processed waste tea. Sales and Lima (2010) found that replacing sand with sugarcane bagasse ash (SCBA) mortars and concretes, had no effect on the physical properties. Ghavami (1995) suggested that the mechanical properties of bamboo make it an attractive alternative to steel in tensile loading applications. A comprehensive review of the use of various agro-waste materials in construction was done by Madurwar (2013). The case for using agricultural waste in rural areas is further strengthened by availability, most residents engage in some form of Agriculture. Typically, such waste is recycled to feed animals or incinerated.

2.3. Designing sustainable products for low income communities

The need to design sustainable products is key in transitioning to a more sustainable world (Bhamra, Lofthouse, 2007). This can be especially challenging to achieve in low income communities because infrastructure is weak, individuals are generally unaware of the urgency and complexity of global challenges or feel they are not as responsible as wealthy individuals for environmental degradation. As such, many people in LMIC are non-responsive to unconventional building materials (Gan, Zuo, Ye, Skitmore, & Xiong, 2015). Two main areas that significantly increase the environmental footprint of products in low-income communities are transportation and waste disposal (Henry, Yongsheng, & Jun, 2006; Tansel, 2017). Poor planning, weak research systems and weak civic participation exacerbate both these features. From a strategic perspective, design challenges in LMIC seek to eliminate the huge costs related to features like transportation and waste management. Consequently, optimising resources for upcycling provides an opportunity for communities to use locally engineered materials, showcase ingenuity and develop adaptable designs suitable to the needs and ethos of local communities.

3. Methods

The aim of the project was to develop a low cost self-sufficient home that can be easily replicated by local capacity using local materials. The specific objectives of the project were to