**Institution: University College London**

**Unit of Assessment: 16 – Architecture, Built Environment and Planning**

**Title of case study:**

***Interactive architectural innovation in practice, products and business formation***

## 1. Summary of the impact

Gage's research in interactive architecture since the 1990s has influenced the working methods of a sizeable community of SME architectural and environmental design practices, mainly in London, and in some cases significantly extended the scope of their services. The research has established and strengthened innovative exchange between academia, professions and creative industries and led to the creation of a number of new specialist and award-winning design companies with international profiles. One of these developed intellectual property sold in 2011 for over $15m, while another won a RIBA National Award for design excellence in collaboration with Bartlett staff.

## 2. Underpinning research

Stephen Gage, Professor of Innovative Technology – who joined the UCL Bartlett School of Architecture in 1990 and was Director of Technology from 1990–2009 – established the Bartlett Interactive Architecture Workshop (BIAW) in 1995. The BIAW focuses on interactive technologies as subjects of investigation in their own right and their use for creating innovative architecture. Taking its cues from systems theory, cybernetics, behavioural analysis and performative design, Gage's research has elucidated a continuous design feedback between digital and physical iterations. This has informed the work of commercial design studios such as Wilkinson Eyre (Matthew Potter), Flanagan Lawrence (Paul Bavister), Haque Design and Research (Usman Haque), Jason Bruges Studios (Jason Bruges, Dave DiDuca, Richard Roberts), Sixteen Makers* (Chris Leung); and led to collaborations with researchers now at the Arhus School of Architecture (Phil Ayres was employed until 2001 as a researcher in the BIAW team), McLean and Silver Westminster (Will McLean and Peter Silver, also previously at the Architectural Association), and Ruairi Glynn. There are two strands to the research that underpins the impacts described here:

**(i) Responsive behaviour, interactivity and performance**. BIAW's work is predicated on the notion of architecture as time-based, thus changing its form and behaviour rather than being static and fixed. As such, the people and objects in the built environment can be regarded as performers, especially where the behaviour of those objects is also subject to change over time. Against this backdrop, BIAW research has explored and demonstrated the importance of analysing responsive behaviour, particularly in order to understand the differences between simulated virtual systems and the lived behaviour of occupants whose engagement with their environment is largely haptic. This is treated as vital to conceptualising the immediate, localised responses of dynamic architectural elements or systems to their external environment or patterns of internal occupation.

These innovative theoretical ideas were applied in Gage's 2006 exploration of human observers' appreciation of two responsive and interactive installations, 'The Wonder of Trivial Machines' and 'Edge Monkeys' **[a]**. The theme of performance was developed further in a 2009 paper by Gage exploring notions of the temporary and permanent in interactive design **[b]**. The research also considers the ways in which constructed environments can 'observe' and respond to users' needs, in turn catalysing performativity contingent on those observed needs and responses.

**(ii) Innovative design practice**. Understanding differences between simulated and actual behaviour is especially relevant in design, where the observer's engagement is haptic and the virtual observer's descriptions are inevitably partial and incomplete. Work on interactive technologies and innovative design practice is founded particularly on research led by Gage between 1998 and 2001, funded by the Department of Trade and Industry, which examined the innovative use of micro-controllers and internal environmental monitoring in the design and control of 'top down' ventilation in urban areas **[c]**. Gage's second approach during this period investigated the transitory and experiential possibilities of interactive architecture. Conducted in collaboration with Pete Silver, this research extended Silver's earlier work with John Fraser and Gordon Pask at the Architectural Association on cybernetic and performative interests; the resulting 'aesthetically potent environments' (Pask) showed how occupants' delight informs our experience of buildings.

In combination, these ideas put forward by Gage and BIAW colleagues have underpinned the exploration of the capacity for accessible, low-cost digital equipment for sensing, computation and actuation to produce beneficial short circuits in the design process **[d]**. The research has demonstrated that working directly with new responsive technologies allows architects and designers not only to create projects with time-based features, but also to produce innovative software with significant marketing potential. Gage's most recent research focuses on the relationship between active facades and interior occupancy, and the possibilities for delivering innovative, interactive, indeterminate architecture in the context of environmental sustainability.

Both of the two main research strands came together in papers presented at the Digital Creativity Conference (2000) which examined human delight in, and recognition of, physical and logical patterns in designed environments. They have also informed the research conducted and published by Phil Ayres (2001–2003) **[e]**, and, in the case of Usman Haque, supporting the production of his spectacular installations *Scents of Space* (2002) and *Sky Ear* (2005).

## 3. References to the research

**[a]** Gage S. (2006) 'The Wonder of Trivial Machines', *Systems Research and Behavioural Science*, 23 (6): 771–778. [DOI: 10.1002/sres.763]

**[b]** Gage, S. (2009) 'Constructing the User', Invited paper for the 2009 ACADIA Conference, Association for Computer Aided Design in Architecture, Chicago, published in *Conference Proceedings*, pp. 44–51. [Available on request]

**[c]** Gage, S.A., Hunt, G.R. & Linden, P.F. (2001) 'Top Down Ventilation and Cooling', *Journal of Architectural and Planning Research*, 18 (4): 286–300. [Available on request]

**[d]** Gage, S. & Leung, C. (2008) 'The Mechanical Homunculus', in Trappl, R. (ed.), *Cybernetics and Systems,* Vol. 1, Vienna: Austrian Society for Cybernetic Studies, pp. 103–108. [ISBN. 978-3-85206-175-7; Available on request]

**[e]** Ayres, P. (2007) 'The Origin of Modelling', in Glanville, R. (ed.), *Kybernetes Special Issue: Cybernetics and Design*, 36 (9/10):1225–1237. [DO1: 10.1108/03684920710827256]

Outputs [a, c, d, e] appeared in world-leading, peer-reviewed journals or books within the fields of cybernetics and interactive design. The ACADIA conference [b] is widely accepted as among the most important globally in its area.

Research leading to the publication of [a] was supported by a £200,000 DTI Partners in Technology Grant, awarded to Gage, titled 'Enhanced Stack Ventilation and Cooling for Urban Sites' (1997–2000), which investigated how to naturally top ventilate urban buildings to avoid low level air intake from polluted streets and car parks.

## 4. Details of the impact

The UCL research has underpinned the development of original artistic and cultural artefacts that are valued highly by both the public and private sectors, and which are making an important contribution to the global profile of British innovation in architecture and design. Although impossible to quantify, it has nonetheless delivered significant financial impacts via its influence on major projects by leading architectural practices, as well as on the formation of innovative young design studios. The following examples illustrative some of the ways in which the research has underpinned these important outcomes:

**(i) Contributions to major architectural projects:** The research has supported the delivery of major architectural projects run by some of the UK's best known architectural and design practitioners, including globally renowned London practice, Wilkinson Eyre Architects, which has twice won the RIBA Stirling Prize (2001, 2002). Several of the company's 110 staff (including former BIAW researcher Matthew Potter, now an Associate Director) identify Gage's research as an important influence, and core elements of that research are evident in some of the company's biggest projects. Thus its environmentally responsive conservatories for 'Gardens by the Bay' (Singapore's iconic park) deployed a tiered approach to energy-use by using shades responsive to their local climate conditions to regulate the building's internal thermal levels. This use of solar responsive technologies reflects the insights published in **[c]**, and Wilkinson Eyre acknowledges

the direct influence of Gage's research legacy upon projects such as these **[1]**.

Flanagan Lawrence (formerly BFLS Architects) likewise cites the influence of the research on work such as their [text removed for publication] Soundforms project in Cardiff, completed in 2011. The work done here on sound and performance by the Associate Director of Flanagan Lawrence, a former BIAW researcher, fed directly into the Cardiff scheme, wherein *'adaptive technologies and digital prototyping were used for the development of the acoustic panels'* and *'generative software was used to optimise the layout and position of the panels to meet the acoustic requirements'* **[2]**.

**(ii) Formation of innovative design studios producing original artistic and cultural artefacts:** Gage's work has catalysed the institution of numerous commercially and artistically successful design firms. The influence of BIAW research on interactive, responsive and performative architectural design is much in evidence in the work of the these companies, with most of them specialising in the development of responsive architectural elements such as interactive facades, modulated lighting and motion-sensing components, and in the provision of immersive and large-scale landscape installations for public and private clients. The resultant designs are finding favour among consumers in both the public and private sectors, and in doing so are contributing directly to the global profile of British innovation in architectural design.

Jason Bruges Studio was established in 2001 partly to commercialise BIAW research techniques, especially vision systems, low-cost actuation and control hardware/software, and digital prototype fabrication. The company, which now employs more than 20 staff, has deployed these techniques in international projects and installations [text removed for publication] between 2008–13, including the development of the changing lighting facade on the W Hotel in Leicester Square (2010) and an installation for San Diego International Airport, USA (2012). The influence of the research is explicitly acknowledged by the firm, who state: *'The research environment, both in the Bartlett Interactive Architecture Workshop and the Bartlett Digital Fabrication Workshop, has had a considerable impact on the success of the Jason Bruges Studio'* [3]. The extent of this influence on Bruges, who worked for many years alongside Gage, is evident in *Ariel Dynamics*, an interactive sound-and-light 'bubble', fully immersive installation developed for the 2012 Olympics Park. Commissioned by Coca-Cola, *Ariel Dynamics* used people-tracking LED sensors in 180 polypropylene 'bubbles' responding to the 'chink' of glasses. Its design was underpinned by Gage's research on social cybernetics and agent-based responsivity, and was described by the firm as *'a practical substantiation of the arguments put forward by Prof Gage in his paper, "The Wonder of Trivial Machines"'* **[3]**.

It likewise underpinned the establishment in 2003 of Haque Design + Research Ltd by another former BIAW member, Usman Haque. The practice has since developed cutting-edge, experimental interactive architectural designs incorporating responsive environments, interactive components, digital interface devices, and mass-participation initiatives. Expertise developed within the BIAW allows Haque to employ technologies including wearable computing, mobile connectivity, people-centred design, and ubiquitous 'cloud' computing. The company's director acknowledges *'the considerable contribution that the research environment of … the Bartlett Interactive Architecture Workshop has had in the development and success of my design practice … In cultivating a forum for radically new, but explicitly practical, approaches in architecture* [it] *has particularly influenced my work on 'open source architecture'* **[4]**.

Sixteen* makers are an experimental architectural practice with a particular interest in 'design through making', where the nature and properties of materials combine with a site's environmental conditions to inform their design process and eventually produce 'responsive architecture'. Phil Ayres drew on the research in producing the experimental sixteen* makers installation called 55/02 in Kielder Forest, Northumbria (2009). Designed and built with Nick Callicott, Chris Leung and Professor Bob Sheil (co-owner of sixteen* makers and Director of Architectural Technology at the Bartlett), 55/02 used environmental sensing to explore principles of site-specificity and adaptive behaviour. The influence of Gage's work on interactive technologies, feedback systems, performative elements and time-based architecture is evident in the use in 55/02 of sophisticated environmental sensory devices to respond to its environment and to weather conditions **[d]**.

**(iii) Impacts on culture, well-being and the economy:** The production of original artistic and cultural artefacts by companies founded on or using UCL research has important benefits to

cultural life, not just in the UK but also in the many countries around the world where those projects are realised. Some of those projects, moreover, deliver significant additional benefits, including supporting improved health and wellbeing. The Nature Trail by Jason Bruges Studio, completed in 2012 for the new Morgan Stanley Clinical Building at Great Ormond Street Hospital (GOSH), London, provides one notable example. This interactive 'wallpaper' installation was designed specifically to support the 'patient journey' from ward to theatre for children aged 6 months to 18 years. The installation drew heavily on Gage's research into the ways in which design can be 'environmentally' responsive to its local conditions, and through which interactive and responsive architectures can enhance the user's well-being **[a, b]**. Synthesised in uniquely accessible, child-centred graphic wallpaper, patients, parents and health-workers are able to find responsive LED image-panels of animals that are 'hidden' in the 'natural canvas' of the wood, allowing young patients to be fascinated and distracted during their stay in hospital **[5]**.

In some cases, projects generated using the research have delivered very significant economic benefits. Recent examples include Pachube, an open-source, real-time environmental data infrastructure and online community designed by Haque Design + Research between 2009 and 2011.The software allows individuals to store, share and discover real-time sensor, energy and environment data from objects, devices and buildings around the world through the internet of things - a globally online network of tools and gadgets. Key characteristics of the software were informed by Gage's work on low-cost local actuated-environmental monitoring, human-to-computer and open-source enabled design **[c, d]**. The Director of the firm specifically acknowledged the influence of this work on the development of Pachube **[6]**. In 2011 the software (now rebranded as Xively) was sold as a $15m spin-off company to LogMeIn to support its cloud services; by July 2013, more than seven million devices have been connected using Pachube technology.

**(iv) Contribution to the global profile of British innovation in architecture and design:** The use of the research by established architectural practices has allowed their delivery since 2008 of some of the best and most innovative design in the world. Wilkinson Eyre's 'Gardens by the Bay' project won the 2012 World Architecture Festival 'World Building of the Year', whilst Flanagan Lawrence's Soundforms took four top architectural awards in 2012: RIBA Design Award, RIBA Welsh Award, Best Welsh Building, and Welsh Client of the Year. In the same year, this project was also mid-listed for the RIBA Stirling Prize and at the World Architecture Festival.

The innovation and quality of the designs produced by new companies founded on or making extensive use of the UCL research has also been widely acknowledged nationally and internationally since 2008 through prestigious awards. Awards to Jason Bruges Studio include the Design Museum's 2012 'Design of the Year' award and the Brit Insurance Design of the Year Award in 2010 and 2011. Haque Design + Research have won prizes including the Design Museum's 2008 Interactive Design of the Year Award; the 2008–09 Wellcome Trust Sci-Art Award; the Swiss Creation Prize; Japan Media Arts Festival Excellence Prize; and Asia Digital Art Award Grand Prize. Sixteen* makers' 55/02 installation also won a 2011 RIBA National Design Award.

**5. Sources to corroborate the impact**

**[1]** Statement corroborating the impacts of Gage's research on the Singapore 'Gardens by the Bay' project as provided by Wilkinson Eyre Architects on 8 March 2013 [Available on request]

**[2]** Statement corroborating the impacts of the research on the Soundforms project as provided by Flanagan Lawrence Architects on 2 September 2013 [Available on request]

**[3]** Statement corroborating the impacts of the research on the formation and work of Jason Bruges Studio as provided by the company on 25 October 2012 [Available on request]

**[4]** Statement corroborating the impacts of the research on the formation and work of Haque Design + Research (including about the development of its successful Pachube technology) as provided by the company on 29 October 2013 [Available on request]

**[5]** For a description of the 'Nature Trail' at Great Ormond Street Hospital (GOSH), and its impacts, see the video at http://bit.ly/HAFvWd, which includes short interviews with patients and staff

**[6]** For the sale of the Pachube technology to LogMeIn and its usage to date, see http://bit.ly/1cylmNT, while the re-branded Xively software may be accessed at https://xively.com/