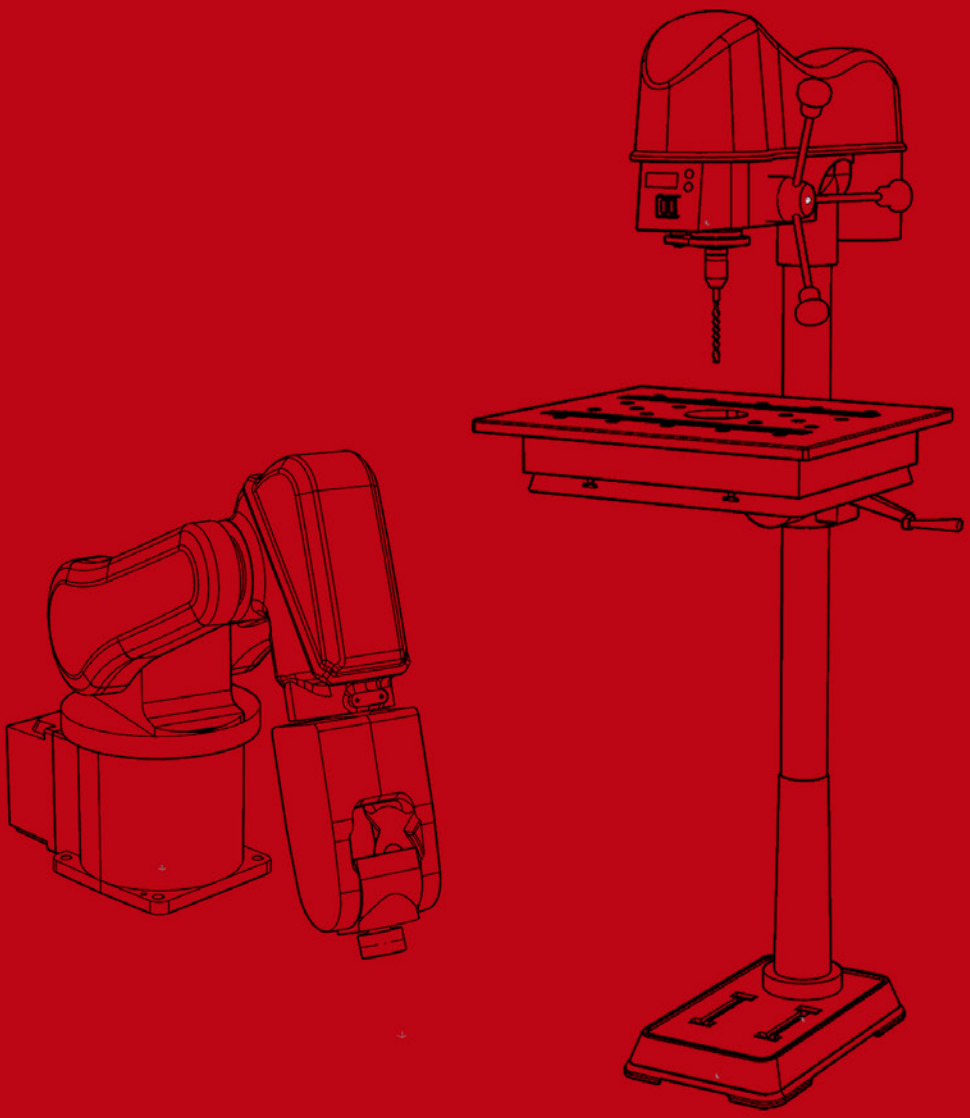
FABRICATION LAB: *DISPOSITIF*

A New Model for Knowledge Generation and Exchange



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FRANCOIS GIRARDIN

UNIVERSITY OF WESTMINSTER
DESIGN RESEARCH FOLIO 2021

FABRICATION LAB: *DISPOSITIF*

A New Model for Knowledge Generation and Exchange

DAVID SCOTT
FRANCOIS GIRARDIN

Project: *Digital Fabrication Workshop '14-'19*
Location: *University of Westminster, London*
Project Lead: *David Scott*
Collaborators: *School of Architecture + Cities*
Cost: *N/A*
Dates: *January 2014-19*

Project: *FAB FEST '16, '17 & '18*
Location: *Ambika P3, London*
Project Lead: *David Scott*
Client/Funder: *Quintin Hogg Trust*
Collaborators: *25 Universities, 20 Architecture Practices, DS Smith, Hawthorns*
Construction: *Recyclable Cardboard*
Cost: *£233,000*
Dates: *July 2016, 2017, 2018*

Project: *Material and Building Systems Research Centre (MBSRC)*
Principal Investigators: *François Girardin, David Scott*
Client/Funder: *Quintin Hogg Trust*
Collaborators: *Material Driven*
Cost: *£115,000*
Dates: *January 2018-2020*

Project: *Helsinki Tea House*
Location: *Helsinki, Finland*
Architects: *Sami Rintala, David Scott, Ransu Helenius, Pekka Heikenenn*
Client/Funder: *The Finnish Institute in London; Design Museum Helsinki*
Collaborators: *Rintala Eggertsson Architects, Aalto University*
Construction: *Timber*
Cost: *£30,000*
Dates: *July 2019*

Project: *Fabrication Lab Remodel 1*
Location: *University of Westminster, London*
Architects: *David Scott, François Girardin, with Parsons Brinckerhoff*
Client/Funder: *University of Westminster*
Collaborators: *Parsons Brinckerhoff, Parkeray, WT Partnership*
Construction: *Mixed*
Cost: *£1,250,000*
Dates: *2014-15*

Project: *Architectural Robotics Theatre (ART)*
Location: *UoW, London*
Principal Investigator: *David Scott*
Client/Funder: *Quintin Hogg Trust*
Collaborators: *Numerous*
Construction: *Mixed*
Cost: *£120,000*
Dates: *May 2016-2018*

Project: *DMA Keep+*
Location: *UoW, London*
Architects: *David Miller, Das da Silva, David Scott*
Client/Funder: *Keep+*
Collaborators: *David Miller Architects*
Grant: *£30,000*
Dates: *January-September 2019*

Project: *Kinetic Climate, '19*
Location: *UoW, London*
Project Lead: *David Scott*
Client/Funder: *JISC*
Collaborators: *Information Systems, UoW*
Grant: *£8,000*
Dates: *July 2019*

Project: *Fabrication Lab Remodel 2*
Location: *University of Westminster, London*
Architects: *David Scott, François Girardin, with Capital*
Client/Funder: *University of Westminster*
Collaborators: *Capital, Overbury, WT Partnership*
Construction: *Mixed*
Cost: *£3,250,000*
Dates: *2016-17*

Project: *Realising Sustainability*
Location: *UoW, London*
Principal Investigators: *Rosa Schiano-Phan, David Scott*
Client/Funder: *Quintin Hogg Trust*
Collaborators: *Trend, Hewlett-Packard*
Construction: *IoT*
Cost: *£97,900*
Dates: *January 2018-2019*

Project: *XR Lab*
Location: *Internet*
Principal Investigators: *David Scott, Jeff Ferguson*
Client/Funder: *Quintin Hogg Trust*
Collaborators: *School of Computer Science and Engineering*
Construction: *Digital*
Cost: *£270,490*
Dates: *July, 2020*

Fig. 1
Winning Model from the Digital Fabrication Workshop, 2019

Fig. 2
The Fabrication Lab Project Space, for Architectural Media Workshop Exhibition, 2020

ABSTRACT

The Fabrication Lab is a major, institutionally-based research project aimed at investigating new models for a specialist lab for architecture and the built environment, and at testing, developing and disseminating new ways of using the Lab as an innovative platform for the generation and exchange of knowledge. The research project addresses and offers a response to the opportunities and threats posed by the rapidly advancing, potentially disruptive digital ecosystem of design and construction technologies taking hold of professional and industry practice. The project includes the innovative architecture, technology, structures and systems designed by the authors for the Lab, as well as the novel pedagogical, research and institutional practices and projects created using the Lab as a platform.

Its principle working tool, as well as its largest output, is the Fabrication Lab itself, understood through the thought of Foucault as a *dispositif*, or 'apparatus'. The research is based on an understanding of a lab that looks beyond its role as an institutional facility to focus on the multiple, heterogeneous elements through which the Lab, its staff, users, and technologies are constructed. The Fabrication Lab thus becomes an experimental vehicle to investigate how the system of relations between diverse institutional elements and situated practices might be re-thought and re-configured to generate the new technological objects, subjectivities, practices and pedagogic and research outputs required to keep pace with today's rapidly advancing developments.

As well as the Fabrication Lab itself, as a platform for an experimental centre it has produced numerous significant outputs including: FAB FEST, a series of three major international fabrication and dissemination events attended by academics and practitioners from around the world; live projects in London, Helsinki and South Korea; numerous workshops, outreach projects and public events; academic conference papers and new knowledge exchange partnerships; as well as the thousands of experimental outputs produced in the Lab by academic staff, students and researchers from the allied School of Architecture + Cities and School of Applied Management at the University of Westminster.

The project has been supported and funded through 17 successful bids for competitive internal and external funding, grants and sponsorships, multiplying over the seven and half years' of the project initial funding of £250,000 to a total investment of over £5.7m, and the size of the Lab from 80m^2 to 1400m^2, with a staff that has grown from one to over 30.

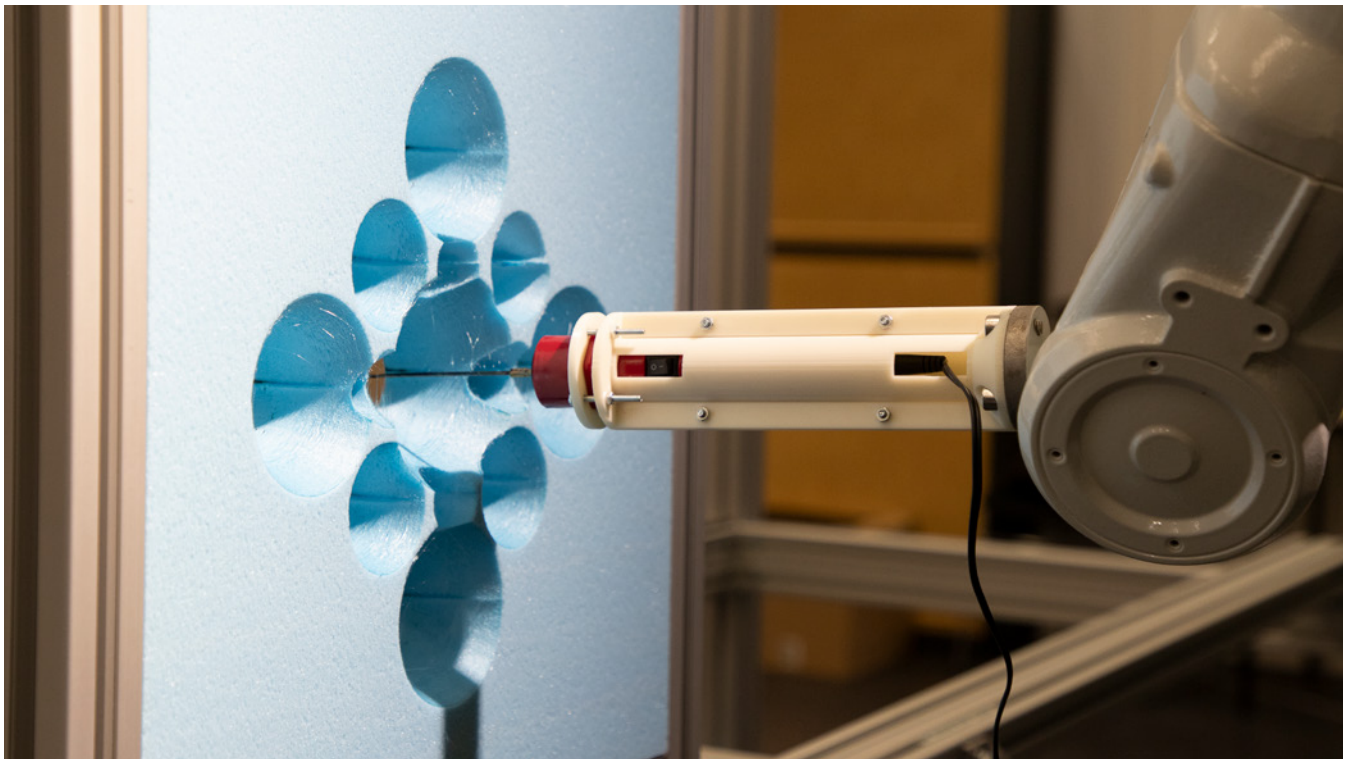


Fig. 3
Robotic hot wire carving, 2018

Fig. 4
Fabrication short-burst teaching workshop in Ambika P3, 2017

Fig. 5
CNC Lab, ready for the Architectural Media Workshop Exhibition, 2020

RESEARCH QUESTIONS

- How might we conceptualise design and construction technologies more effectively to provide an inclusive, dynamic platform for teaching, research and knowledge exchange, better suited to the diverse and rapidly evolving technologies emerging today?
- What spaces, resources, systems and strategies are needed to implement a new model for a specialist lab for investigating fast developing digital design and construction technologies, and how might it function as a vehicle for constructing new subjectivities and understandings of technologies as accessible tools and research objects?
- How might such a new form of specialist Lab be used as a novel platform for designing, implementing, testing and innovating new models for knowledge generation and exchange for architecture and the built environment? And how might it be evolved through ongoing iterative practice?
- How may a substantial, institutionally-based live project in a fast-emerging research context challenge traditional ideas separating academic from professional practice, and research from teaching, and how may new pedagogical practices of generating and disseminating knowledge be developed to optimise this?

GENERAL DESCRIPTION

The Fabrication Lab is a major, institutionally-based, specialist lab equipped with a diverse array of new digital as well as traditional technologies for architecture and the built environment. Although the research project in this folio informed and generated the Fabrication Lab, it is not the physical Lab itself that is the main subject of the research, but the original model it embodies that was developed and tested through the project and which underlies the design. This includes its architecture, unique organisational structures, experimental systems and practices, as well as the significant body of projects produced using the Lab as an innovative experimental platform for investigating new forms of knowledge generation and exchange.

The project started in October 2013, and it has grown and transformed many times, from 85m^2 and three digital tools, to 1400m^2 and more than 100 diverse digital and many analogue technologies. Likewise it has grown from a single technical member of staff, to a heterogeneous group of more than 30 academics, researchers, software developers and trained student Lab Assistants. This evolution has entailed very many small and large experiments, live projects and innovations, a small proportion of which are presented here. Only key projects are reported in the folio, and only those created and led by the authors, not the thousands of smaller projects produced in the Lab by students and other academics. For a more complete account and a view into the Lab, see the Lab portal: www.FabricationLab.London.

Fig. 6
FAB FEST 2017, Ambika P3

Fig. 7
Strategic Design for the Lab Remodelling Project, Phase 2

Digital Fabrication Workshop '14-'19

The Digital Fabrication Workshop (DFW) was the first experimental project introduced by Scott to test the model proposed for the Lab, as well as initiating its use as a new platform for its innovative pedagogic approach. It introduced and tested many key ideas that would be developed throughout the Fabrication Lab project, including the centrality of the event, new ways of students engaging with technology, a new use of short-burst teaching in the academic curriculum, the introduction of teaching from other areas of architecture, and the start of the iterative practice approach. The project ran annually for seven years, each iteration testing, refining and re-presenting the original model.

Fabrication Lab Remodel Phases 1 & 2

A major part of the development of the project was the expansion of its spaces and technology, from the small 80m^2 space it once occupied to a new location within the University campus. Two disused spaces were identified, a postgraduate study room and a redundant bar, and through adaptive reuse a major remodelling project was undertaken led by Scott to create new spaces to accommodate the new digital tools, designed using the principles outlined in the research project, as well as procuring the essential new digital tools for the new Lab. The first remodelling project brought £1.25m investment from the University, introduced 350m^2 of new space, as well as a diverse range of digital technologies from 3-axis mills to 7-axis robots.

Funding was won from the University to transform an additional 800m^2 of space to bring it within the remit and leadership of the Fabrication Lab, and to greatly expand the scope and application of the research project and its associated institutional innovations. The second remodelling project introduced traditional wood and metal workshops as well as a host of other innovative new places within the Lab including a light Lab, Materials Lab, a materials shop, and a series of new, permanent galleries.

FAB FEST '16, '17, '18

FAB FEST built on the success of the remodelling project, and was created to demonstrate the value of the significant investment by the University, as well as being an important opportunity to develop the research agenda on a much bigger scale. FAB FEST was a major international design and fabrication competition and public event, made possible through further funding won from the Quintin Hogg Trust and from commercial sponsorship. After a very successful first event, it won further financial support to be developed through two further cycles. The project strategically blended agendas including a novel mode of pedagogy, with research into design for manufacturing and assembly, and knowledge exchange through dissemination through the culminating festival and the inclusion of professional practices at the heart of the project. FAB FEST won funding of £233,000, and involved 31 universities from 19 countries, and 18 architecture offices.

Architectural Robotics Theatre

The Architectural Robotics Theatre project (ART) was designed to activate the Lab's industrial robots by supporting the research necessary to develop new applications, as well as to engage and share findings and applications with our students, professional and industry partners, and the community around the Lab. The project made use of the unique, seven-axis robot arm mounted on a five metre rail. ART produced a series of projects generating research for new applications for robotics

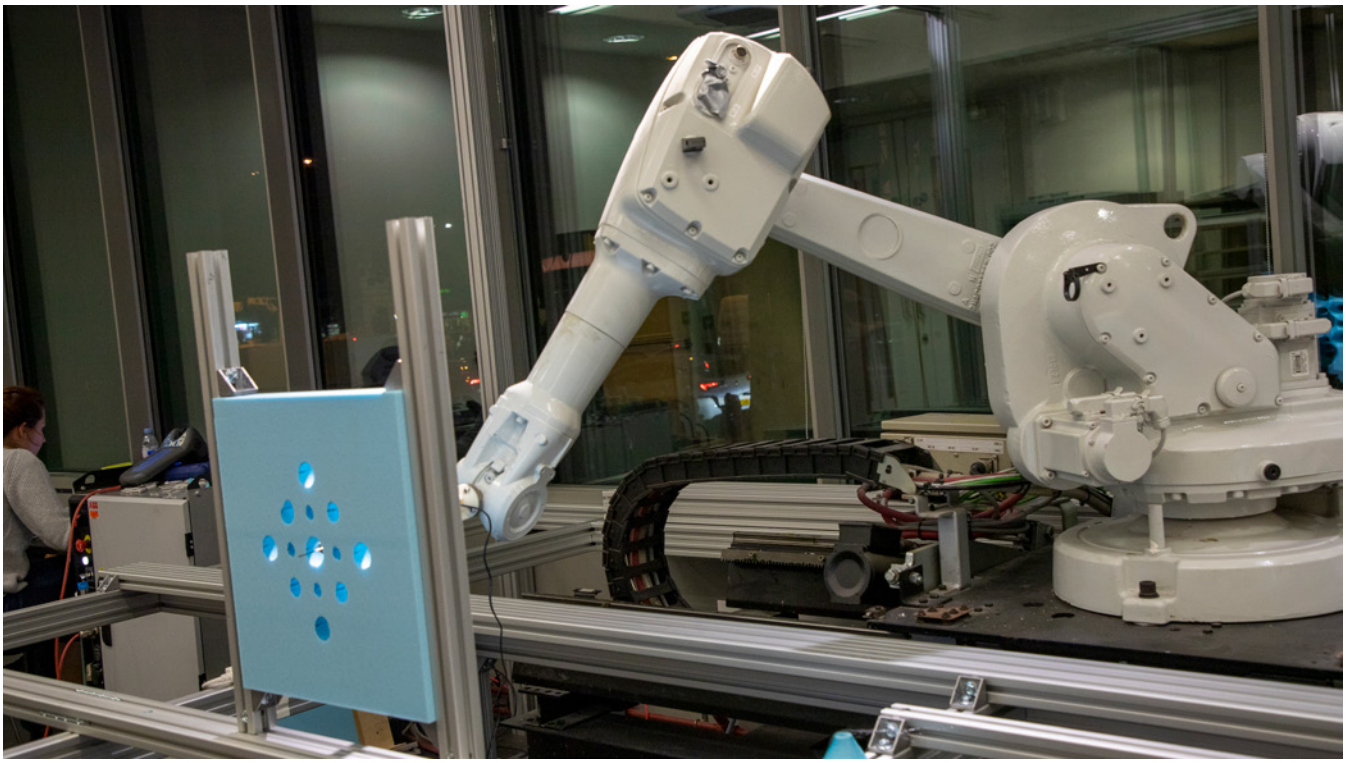


Fig. 8
Robotic Carving in the Architectural Robotics Theatre, 2017

Fig. 9
Helsinki Tea House, 2018

and creating new opportunities for knowledge exchange. It won a grant through two consecutive bids for a total of £120,000, and included the a partnership with Affan Innovative Structures LLC, one of the world's leading advanced composites companies for the construction industry. Affan, based in Dubai, produced a 1-2 pavilion presented by Scott at the UIA 2017 Seoul World Architects Congress in Korea.

Realising Sustainability

After establishing the technologies and physical spaces of the Lab, and beginning the task of creating its associated organisational structures and systems, Scott and Girardin began partnering with other academics from the University to apply for further, more diverse Grants. Realising Sustainability in partnership with Dr Rosa Schiano-Phan, won £97,000 for a project that used the technical infrastructure and network of IP addressable displays in the Lab as the basis for an internet of things (IoT) experiment making environmental data visible to building occupants, with the aim of influencing behaviour and helping to make a more sustainable built environment.

Materials and Building Systems Research Centre

The Materials and Building Systems Research Centre (MBSRC) aimed at creating an innovative materials and details library in the Fabrication Lab that could form the foundation for research into new materials as well as a library of scale samples of modern methods of construction and new building systems. The project built on the core principle of the Lab of providing a seamless transition between diverse technologies – previously siloed into independently managed workshops. The project added to the more usual offer of materials libraries the possibility of testing and documenting material properties using the Labs industrial testing tools, as well as combining materials with other fabrication processes now available in the Lab. Funding was won for £115,000.

DMA Keep+

In partnership with David Miller Architects the Lab won a Keep+ grant for £30,000, providing an opportunity for an applied research project, as well as expanding the model for resourcing the Lab and providing new opportunities for our architecture graduates and growing team of graduate architect staff. The research explored the use of digital fabrication tools, and specifically those offered in the Lab, in conjunction with a purely digital, BIM-based workflow. It provided an opportunity to combine research with practical office experience for one of our Architectural Research Assistants.

Helsinki Tea House

The Helsinki Tea House continued the Lab's investigation of the application of digital fabrication tools for traditional modes of construction, as well as its practice of international collaboration between academic institutions and professional practice. It was designed and built through a series of workshop collaborations between the Fabrication Lab and the School of Architecture and Cities, Aalto University in Finland, and Rintala-Eggertson Architects. The timber pavilion, prefabricated using 5-axis milling of bespoke joinery, was built in a prominent location in Helsinki in front of the Design Museum, and became a widely visited Summer attraction.

Fig. 10
XR Lab Augmented reality mapping

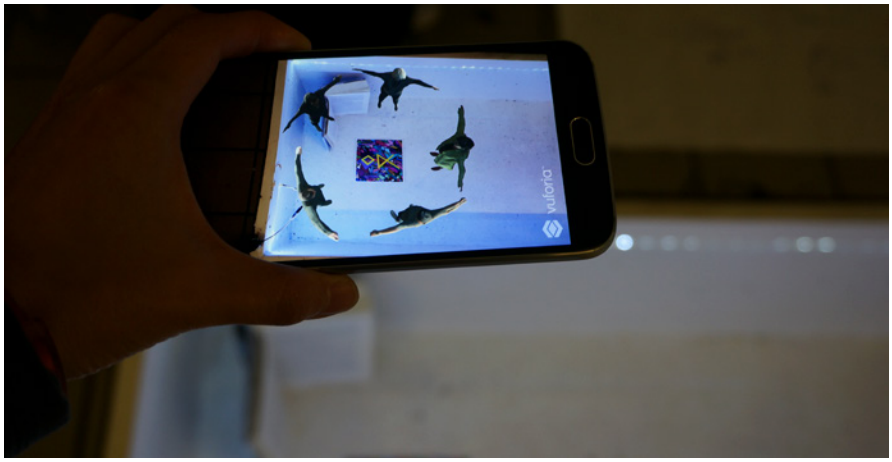


Fig. 11
XR Lab visualisation

Kinetic Climate

Kinetic Climate made possible through an £8,000 grant from JISC, and £3,000 from the National Saturday Club. It was designed to initiate research into the Internet of Things (IoT) and especially the new technology of LoRaWAN. The project built on the Realising Sustainability project, as well as the short-burst teaching workshop and exhibition format investigated in numerous Lab projects. Having completed the research and development required to build working prototypes, a one-week workshop was offered for young people to learn about these technologies and create an artistic, spatial installation. Inspired by the kinetic art of Jean Tinguely and Alexander Calder, participants built kinetic sculptures that responded to environmental data processed using AI in the cloud, linking concerns around climate change to local conditions and people's behaviour, and making these visible through engaging art installations. Another iteration of the project is planned for 2022.

XR Lab

The XR Lab was a joint venture with Jeff Ferguson from the School of Computer Science and Engineering to build a new, innovation and research-focused Lab specialising in VR and Augmented Reality technologies. The project built on the record of success already established in the Fabrication Lab and expanded its scope considerably beyond the digital fabrication tools that had been the previous focus. This development matched changes in professional practice and industry, where new digital representation tools were becoming increasingly prominent. The project won funding of £270,000, to create a new dual-centre, XR Lab.

Fig. 12
The University of Westminster main campus on London's Regent Street, featuring a Festive Window display by the Fabrication Lab, 2018

Fig. 13
The 'Digital Workshop', 2013

Fig. 14
CNC Machines in the Fabrication Lab after the first remodelling project, 2015

CONTEXT

University Context

The Fabrication Lab is part of the University of Westminster, and is based in the University's Marylebone Campus in Central London. It was originally part of the Faculty for Architecture and the Built Environment, which included both architecture and construction management disciplines, and it was designed to bring these heterogeneous disciplines together in one place. It retains its specific and distinctive focus on architecture and the built environment, though it now forms part of a new College of Design, Creative and Digital Industries. As the Lab has grown it also works increasingly with researchers and students from across the College and University, as well as collaborating with numerous partners beyond academia, from industry, professional practice and the local community.

The Lab grew out of an originally modest project to update the University's 'Digital Workshop', a limited and ageing digital fabrication facility which comprised a 3D printer, three laser cutters and 80m^2 of workshop space, run by a single technician. In 2013, Professor David Dernie, then Dean of the Faculty of Architecture and the Built Environment, won funding from the University for £250k to invest in new technologies to bring the workshop up-to-date. Scott, a Visiting Lecturer in Architecture at the time, had the necessary expertise and volunteered to lead the project to oversee the new investment and re-invent the facility. He was joined later by Girardin in 2017.

Having re-cast the apparently straightforward procurement and refurbishment task as a much more ambitious and thorough-going action research project, Scott systematically applied for and won numerous internal and external grants, boosting funding from the original £250k to £5.7m. Joined by Girardin, they introduced a host of new technologies, from industrial robots to expanded reality (XR), and grew the size of the Lab from 80 to 1400m^2. The Fabrication Lab now employs a team of 30 academic, research, software developer, and trained-student staff.

More importantly Scott and Girardin transformed through iterative experimental practice, the nature and scope of what was a simple, technician-led workshop into a sophisticated specialist laboratory, led by academics and researchers, and operating as a innovative experimental centre for teaching, research and knowledge exchange. It is the knowledge and outcomes generated in this radical transformation, and the complex research project underlying it that is reported in the present folio.

Technology Context

The driving force for the initial investment was the recognition of the ever-quickening rate of development of new technologies becoming available for architectural design and construction of the built environment, and acknowledgement of the huge potential impact it might have for academia, professional practice and industry. The evolution and impact of new technologies remains the specific focus for the Lab. The Architecture, Engineering and Construction (AEC) sector has lagged behind other more technologically advanced industries, like automotive and aerospace, in the adoption of new technologies. Nonetheless the use of digital technology has been a major factor in the design and construction of buildings for many years. Drawing boards long ago made way for Computer Aided Drafting (CAD), and in the past 20 years CAD has been overtaken by Building Information Modelling (BIM).

BIM, offering complex and data-rich models that are shared across design teams and contractors, affords the convergence of drawing and modelling with parallel

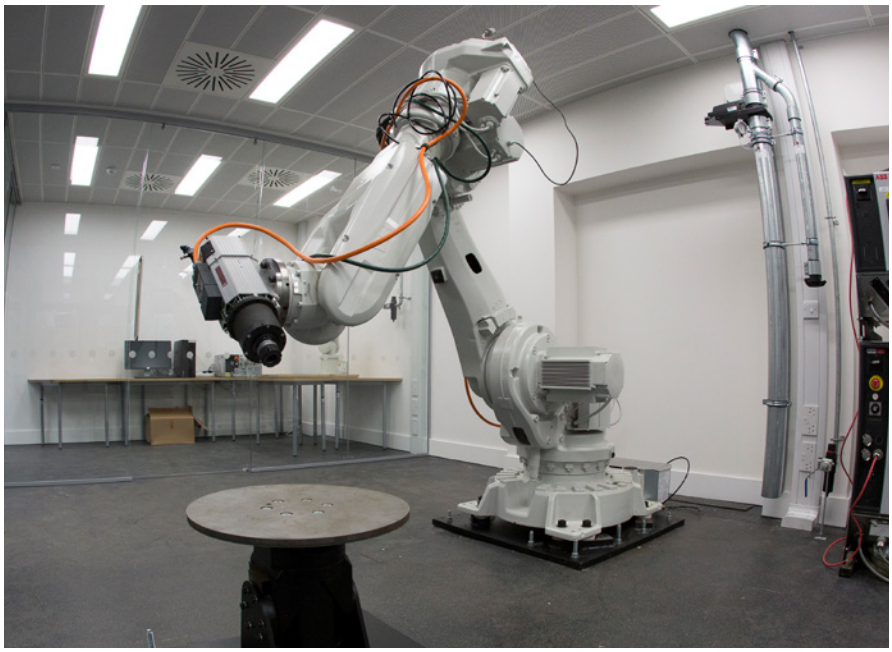


Fig. 15
Industrial Robot arm, after first phase of the remodel project, 2015

Fig. 16
Fabrication Lab in use, 2019

advances in digital fabrication technologies, and increasingly with all manner of other digital representation and simulation tools. As these digital tools mature, the interconnections between them are becoming more accessible and useful making individual technological developments all the more significant. There is now a burgeoning ecosystem of digital technologies which together have the potential for dramatic, disruptive changes to the way we design and construct buildings. The so-called Fourth Industrial Revolution (Schwab, 2017), though slower to impact the Construction Sector perhaps than other more technologically-advanced industries, is beginning to have a potentially radical impact on the way that we design and construct the built environment, creating both great opportunities for innovation, as well as a serious challenge for those attempting to keep up. It was the desire to keep pace with these changes that led to the investment that began the present project.

The Research Problem

It soon became clear, however, that addressing these fundamental, technology-driven changes in our sector would involve more than simply the procurement of the latest digital tools and the provision of suitable accommodation for them within the University. It was not just that the new tools require a new level of sophistication of associated services, and that their procurement and installation was itself a significant architectural and technical design project. More importantly, it became apparent that the technologies of interest were both so new, and were evolving to quickly, that there was in some cases little awareness of them amongst colleagues, and no consensus amongst those who were aware of which were, or would become important. Likewise, beyond the initial enthusiasm for the remarkable technological achievements possible with these new tools, it was not clear in many cases how the new tools might be used effectively, or how they might be introduced into long-established practices of teaching and research. There was a realisation that not only our existing tools were out-dated, but so might be the practices through which they were used in the University. Moreover, these problems were not unique to the situation in Westminster, but were common across academia, as well as in professional practice and the construction industry.

Investigator Context

The unique approach adopted for the Fabrication Lab project was made possible by the unusual background of its authors. Scott's career spans two academic disciplines. Scott trained and worked as a Social Psychologist, both as a lecturer in the Department of Psychology UCL, and in industry as an R&D project leader for Unilever PLC. He subsequently trained as an architect, returning briefly as a tutor at the Bartlett School of Architecture, UCL, before joining full-time as lecturer in the Department of Architecture at the University of Westminster.

Girardin also has a long and varied career as an architect, with experience from the offices of several critically acclaimed designers, and extensive experience as an academic architect working in numerous Universities across the UK and Europe. Aside from the specific focus on the Lab on architecture and the built environment, the investigators were thus able to bring to bear on the project both architectural design skills and an intellectual tradition, sensibility, and methods drawn from the social sciences, as well as practical experience having worked at a managerial level in Research and Development for a blue chip corporation.

Fig. 17
The original Wood Workshop, 2016

Fig. 18
Wood Workshop transformed into
Fabrication Lab Project Space, 2017

AIMS AND OBJECTIVES

- To articulate, test and investigate the potential for a more powerful conceptual framework for understanding and engaging with the rapidly advancing digital technologies now becoming increasingly important for architectural practice and the construction industry.
- To design, build, and refine new models for a specialist lab for architecture and the built environment, including the creation and testing of the necessary purpose-built spaces, organisational structures, systems and practices appropriate for the new breed of design and construction technologies. To produce as an outcome an effective vehicle for constructing new roles and subjectivities that might involve and empower a wider group of people to engage with technology, and foster more helpful understandings of the technologies themselves both as practical instruments and objects for research.
- To investigate and test the subsequent efficacy of the specialist Lab generated through the research as an experimental platform opening new opportunities for knowledge generation and exchange, and to develop the platform through iterative practice, critical reflection and continual evolution to create both an effective new institutional centre and innovative new models for pedagogy, research and knowledge exchange.

METHODOLOGY

The Lab has served throughout the project simultaneously as a fully-functional resource for the University and its students and researchers, as well as being a constantly updated, experimental test-bed for investigating models of what a specialist Fabrication Lab for architecture and the built environment might be. Both the physical spaces with their technologies and materials, as well as all of its organisational structures, systems and practices have been subjected to a continuous cycle of design, implementation, observation and revision, producing a on-going series of live experiments and iterative developments. Its viability as a novel platform has simultaneously been tested through the planning and execution of numerous speculative, hybrid projects that themselves test new models for academic practice, combining and fostering new synergies between pedagogy, research and knowledge exchange. The research approach therefore combines numerous small to major live projects, with a form of action research, aiming at making a transformative change within the institution through simultaneously taking action and doing research (Altrichter, Posch, and Somekh, 2007). This action is framed within an intellectual tradition drawn from the specific background of the authors.

Research Approach

The project is guided by a 25-year interest in the investigation and application of ideas from continental philosophy and in particular the work of Michel Foucault. Scott's PhD responded to the rapid growth in popularity of discourse-based approaches to psychology with a reading of Foucault which engaged with rather than dismissing traditional psychological methods. It offered a novel application of Foucault's thought, as well as an original contribution to the Psychology of Human Values. The research also highlighted the limits of interrogating academic discourse,

Fig. 19
Fabrication Lab Project Space in Use for making 2019

divorced from applied practice, and prompted Scott's move first into R&D for Unilever PLC, and then into the inherently applied discipline of architecture. The Fabrication Lab project offers another novel application of Foucault's thought, in this case intrinsically applied and investigated within an operational institutional context.

Conceptual Framework

Foucault is best known for his ideas about power and its relationship to knowledge, as well as his frequent involvement with public protests in the 1970s. But Foucault's work spans many fields of enquiry and numerous complex strands of thought, several of which are explored in the Fabrication Lab project. Common to his thinking is the central idea that the objects we encounter in the world and the subjectivities through which we encounter them are not pre-existing, but are constituted through discourse, institutions and historically-contingent social practices. Though extensive and detailed historical analyses Foucault consistently unearthed and revealed these historical contingencies, challenging status quos commonly accepted today, revealing them as the product of games of truth and power, and subject to radical change – hence, the idea of Foucault's histories as histories of the present.

The present research does not offer an historical analysis of the present, but draws on Foucault's intellectual tradition and perspective on the present, and especially the possibility of transformation that his work implies. Framed through the thought of Foucault, the Lab is hence understood as a form of *dispositif* or 'apparatus', described by Foucault as 'a thoroughly heterogeneous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions' (Foucault, 1977). It is the relationship between these heterogeneous elements that gives rise to the subject positions available in institutional organisations like the University and its 'workshops', as well as being the elements that constitute our understanding of the objects found in such places.

The notion of the Lab as *dispositif* is useful in many ways, providing a novel and rigorous way of conceptualising what might otherwise be understood in more conventional and restrictive terms. Foucault offers a broader, historically-situated understanding from which to interrogate the contemporary field of design and construction technologies, and to analyse and work with the ways they become assimilated into practice. His thought draws our attention to the multiple elements – architectural, institutional, regulatory, and discursive – through which we apprehend the Lab and engage with it and its technological objects as social agents. If offers a place from which to re-appraise and challenge traditional roles available for the key actors operating in this field, as well as providing new freedom to actively re-construct its technological objects.

Research Methods

The broad scope of the project necessarily entails the use of a wide range of research methods, drawing on every part of the diverse experience of its authors. The research uses research by design methods commonly used in architecture – precedent studies, sketching, diagrams, drawing, model-making – combined with theories and methods from social science including critical reflection and empirical testing for specific projects using interviews, focus groups and online surveys.

Fabrication Lab: *Dispositif*

Fig. 20
Initial Set of Design Elements proposed for the Fabrication Lab Project, 2013

Fig. 21
Initial Set of Design Principles proposed for the Fabrication Lab Project, 2013

Precedent Review

The project began by reviewing existing designs and practices used in equivalent labs elsewhere, both in the UK and abroad. The review aimed at identifying both examples of best practice that might be incorporated into the project, as well as assessing the general state of readiness and willingness to adopt new digital technologies. The review of practice also allowed the authors later in the project to understand the potential applicability of the model developed in the project to other contexts. In all, visits and exchanges were made with 38 different Labs and workshops around the world.

Of particular note was the emergence of the Fab Lab network started by Neil Gershenfeld from MIT. This rapidly expanding network embraced fully the technological developments brought about by cheaper computational power and actuator electronics that were fuelling the growth of consumer-level digital fabrication tools. The accessibility that Fab Labs offered and the consequent empowerment of non-technical makers was an inspiration and key precedent for the present project, though the approach that developed subsequently was specific to the academic context and differed radically from that embodied in the Fab Lab charter. The name Fabrication Lab was chosen both to recognise the similarity in ethos to Fab Labs, while being careful to distinguish the Westminster Lab as something different.

Design Elements

Approaching the design for the Lab understood as a *dispositif*, inevitably leads to an extremely wide ranging set of concerns for the project. With a view to engaging with the heterogeneous elements through which a *dispositif* constitutes its subject and object domains, the project began by identifying what these key elements might be. The simple grid of factors involved in the formation of an institutional body like the Lab, was derived from the authors' experience and review of other Labs, and was intended as a working hypothesis to be tested through practice, rather than a theory *per se*. Each of these elements is considered in the course of the research, as a variable to be systematically analysed, and open to intervention and experimentation. This understanding guides the design of the architecture for the project, to steer the increasingly wide selection of technologies, to develop the systems through which these technologies are presented and used, as well as informing the design of the many institutional and operational factors underlying the enterprise, and the training, teaching and research practices that are its function. These elements are then treated as design problems to be addressed in the research.

Design Principles

To guide design decisions made across very different areas of the project, a set of guiding principles was established at the start. These were understood as both design rules to enable action, as well as hypotheses to be tested through reflection on the subsequent results. The principles were derived from a number of sources including a widespread literature review, from the comparative analysis of other similar attempts to engage with technology, and from the extensive experience of the authors from previous work exploring new digital tools in architecture and construction. The principles also reflect choices made about the research approach, as well as value judgements implicit in the ethos of the host University to which the project subscribed, drawing in particular on the long history of the University of Westminster as a pioneer in the adoption of technology, and the ambition to empower people by making technologies accessible to students from diverse backgrounds. This aspect of the ethos of the University was central to the direction of the project. A set of

Fig. 22
FAB FEST Design Team Meeting for FAB FEST 16, participants with David Miller Architects, 2016

Fig. 23
FAB FEST, Festival Event, 2016

12 principles resulted from this process and were consistently applied and tested through the research.

Funding Strategy

The Fabrication Lab project by its very nature has been heavily dependent on winning funding. The project began with a grant of £250k from the University, which was enough to buy the initial digital tools to establish part of the Lab. But it required very much more funding to create proper accommodation for the growing Lab, and to evolve into the substantial research vehicle and experimental platform it has since become. As a research strategy as well as out of necessity therefore the authors have consciously and systematically applied for numerous grants, from both the University, its related charities, research bodies, as well as from commercial organisations. Many of the staff employed to develop the Lab were funded through grants, and there was the additional pressure to win more funding to keep the team together and loyal people employed. Funding was eventually won for the Lab for more than £5.7m.

Strategic Project Design

A strategic decision was made at the beginning therefore to design projects which overlaid parallel agendas, most projects multi-tasking to deliver teaching, at the same time as developing the underlying research agenda, and in many cases also including a central element of knowledge exchange. The ability to combine these activities, described in detail in relation to specific projects later in the folio, evolved and improved over the course of the research. Initially imposing further challenges, the approach soon became increasingly beneficial as it became more fundamental to the way projects were designed and implemented in the Lab. The research has thus come to offer not only the findings from the research as knowledge for others, but presents a strategic methodology that challenges traditional distinctions between teaching and research, suggesting more fruitful and synergistic ways forward more appropriate for contemporary conditions of funding in academia, and especially in Universities where there are increasing demands for teaching, and a tendency for teaching consequently to take precedence over research.

Dissemination Strategy

A final key strategic element in the methodology of the Lab has been the use of events. Events of all kinds have become a distinctive outcome of many Lab projects, for several important reasons. Events can be key to combining the three areas of activity, teaching, research and knowledge exchange. With the emphasis on creating something new, in a taught curriculum that is already crowded, attempts to implement and test ideas introducing technologies through short-burst teaching workshops have often had to begin in the interstices of established time-tables and practices, key projects being delivered outside of the usual taught semester. Many began as voluntary. Making the culmination of a project an event has been a way of marking out new spaces for the workshops, as well as providing a focus for participants, and a way of adding motivation and energy. Having begun with this in mind, the authors has developed particular expertise in the design and production of events, not least FAB FEST, which was a major international festival attracting participants and an audience from all over the world. In the process events have developed into a key part of the dissemination process for Lab research, and play an important role in knowledge exchange whether with professional practice, industry, outreach or the more local community.

Fig. 24
The first realisation of the Fabrication Lab, 2014

Fig. 25
Busy Project Space in the first Lab, 2014

OUTPUTS AND FINDINGS

The main outputs from the project are of two types. First, the elements designed and tested in the research that collectively form an innovative new model for a specialist lab. These include two significant architectural remodelling projects as well as the design and implementation of a host of diverse systems, resourcing strategies and operational practices, responding to the heterogeneous elements that constitute the Lab. Secondly the extensive series of iterative, strategic projects that have used the Lab as a platform for exploring new ways of teaching and researching emerging digital technologies, as well as exploring new relationships between pedagogy, and knowledge generation and exchange. Synergies between the two types of output have been capitalised upon throughout the project. As the Lab has evolved as an ever more capable vehicle for exploring its research agenda, so it also became more effective as a platform for further targeted research and pedagogic projects. The early outputs and findings are reported in the folio chronologically, to better understand these parallel developments.

From Workshop to Specialist Lab

Soon after the start of the project, the single technician involved with the previous Digital Workshop left the University and no suitable applicants applied to fill the post. As well as leading the new investment project, Scott therefore became *de facto* responsible for all the operational aspects of the then limited spaces and digital fabrication tools that fell under the project remit. As the project has grown, he has remained responsible for all the spaces, tools and staffing of the Lab ever since.

Scott immediately introduced a host of changes testing the principles established in the review and planning phases. The ‘Digital Workshop’ was officially renamed the Fabrication Lab, to highlight the new direction. An innovative short training course was put in place called an Essentials Course that allowed tools that had previously been strictly the domain of technical staff to become accessible to all architecture students and research staff. The private nature of the workshop space was thus opened out and made public. Likewise, the principle of engaging the users of the Lab as co-creators was introduced, with a second programme to train students to oversee the day-to-day running of the machines as trained student Lab Assistants. Having once been excluded from access to the machines, the students were soon then both using and tools overseeing their use by others.

There were many effects of these changes. The capacity of the Lab increased enormously. Allowing users to operate the digital tools for themselves increased bookable slots on the machines from 30 to 200 per week, without any increase in the number of machines. More importantly, these simple changes albeit at this stage at a small scale, created new relationships between the digital technologies, the University and the students. The changes to the Lab created new roles, or subject positions for those working with the technologies, as well as the beginnings of a new understanding of the technologies themselves as readily accessible and usable objects.

Fig. 26
Digital Fabrication Workshop, 2019

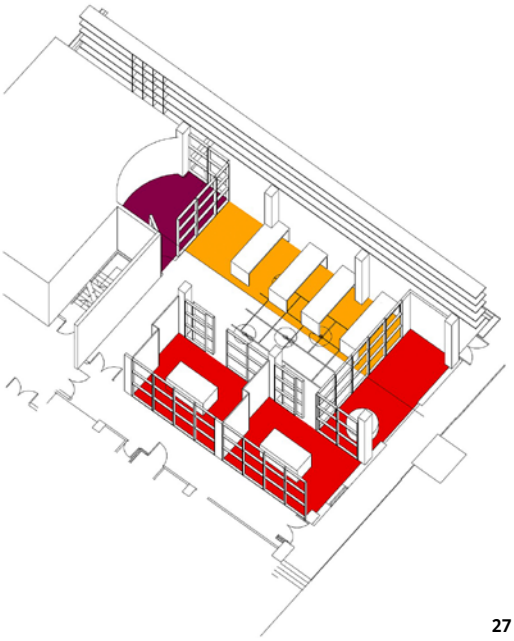
Digital Fabrication Workshop ’14-’19

Having established a new set of practices and working principles for the newly created Fabrication Lab, Scott developed the design for a pivotal new project to build on and test the efficacy of the Lab proposition.

The Digital Fabrication Workshop (DFW) embodied many of the principles identified at the start of the research. With the brief of introducing digital fabrication to a wider audience, the project offered for the first time a short-burst teaching workshop in a making context that would include all 150 of the new first year architecture students. Rather than teaching technology by itself, the opportunity of having an architecturally trained academic running the Lab allowed Scott to teach architecture, simultaneously and on the back of teaching the use of contemporary technologies. The experimental model for a project thus became a highly successful tool for teaching the role of representation in architectural design, as well as a way of teaching and exploring the architectural importance of canonical buildings – a novel way of teaching architectural history.

From the point of view of the Lab as research project, it had other important consequences. It was a crucial proof of principle for the approach being used to develop the Lab, and gave the institutional sponsors of the project some confidence in its direction and leadership.

The project also began an important iterative cycle. DFW ran for another seven years, each time testing new ideas based on the same underlying principles. The results of the project were presented as a conference paper, and the outputs from the collective workshops are now being combined and will soon be available as part of a major online, public catalogue of case studies of significant architecture, explored by participants during the seven digital fabrication workshops.



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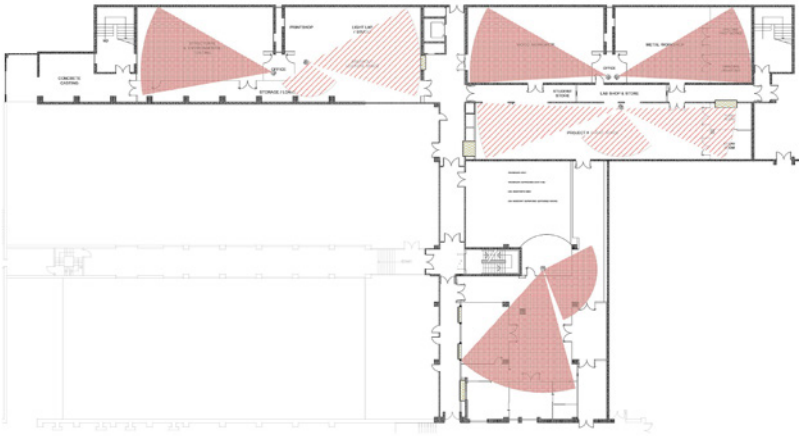

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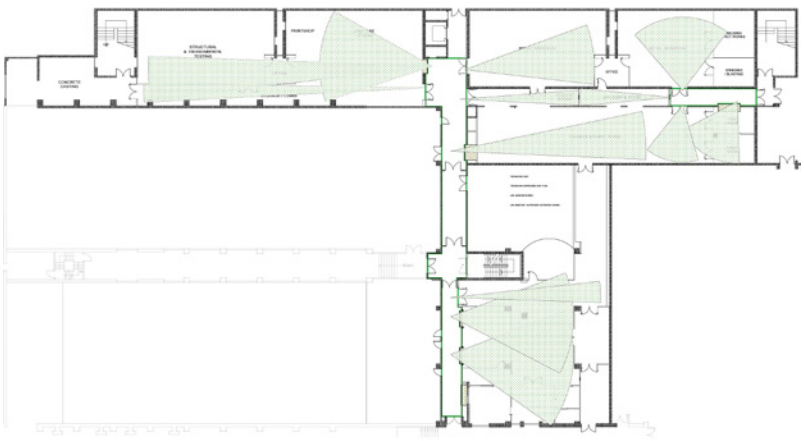

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Fig. 27
Axonometric diagram for the original CNC Lab, Remodelling Project Phase 1, 2014

Fig. 28
Strategic design for a unified Fabrication Lab, Remodelling Project Phase 2, 2016

Fig. 29
Strategic design for supervision by staff in the Fabrication Lab, Remodelling Project Phase 2, 2016. Spaces that can be seen by the full-time staff (red), and Lab Assistants (red striped).

Fig. 30
Strategic design for visibility in the Fabrication Lab by non-Lab Users, Remodelling Project Phase 2, 2016

Remodel Projects 1 and 2: New Lab Places

An essential, and significant output of the research was the design and realisation of the unique, purpose-built spaces in Central London that comprise the Fabrication Lab, and accommodate its tools, staff and users. This involved two major re-modelling projects with contract sums of £1.25m and £3.25m. The authors were intimately involved as architects and researchers, developing the brief and the strategic architectural design, as well as closely overseeing at every stage the construction and delivery of the built projects.

The first remodelling project was designed to accommodate the digital fabrication tools procured with the initial £250k funding. It produced a Laser Lab at ground floor level, including a 7-axis robot mounted on a 5-metre rail, and on the basement level an extensive CNC Lab, with large-scale routers, mills, and a second, more substantial robot. Both parts of the project re-purposed disused spaces, a post-graduate study room and a nightclub that had closed several years before. The first project offered a highly visible example of a contemporary Lab, was highly acclaimed, and very popular with students and staff.

Eighteen months later a second bid was made to the University, this time aimed at incorporating the adjoining, existing workshops and testing Labs to bring them up to the same high standards as the new digital fabrication spaces, as well as unifying the diverse areas together into a single Lab. These areas had been neglected for many years, and were run as individual, siloed workshops by technicians working independently of each other. Their operating methods had similarly remained largely unchanged for many years, and the contrast with both the spaces and practices used in the Fabrication Lab could not be ignored.

Following extensive negotiations with both the University and the academic staff using these spaces, funding was won to remodel the areas and agreements were reached to bring them into the scope and management of the Fabrication Lab. This provided an invaluable opportunity to re-think the design from scratch, to build on the principles explored in the first remodelling project, and to embed the approach being developed in the research in the physical arrangement of the spaces.

Architectural Design

The architectural design included complex technical requirements involved in the spatial arrangement of the diverse technologies and tools, the provision of specialist services, and demands of fire compartmentation. Beyond these more usual concerns, however, the strategic design was able to focus on the approach being developed for the research and could treat the architecture as a key element in an institutional apparatus. Working in conjunction with other institutions, systems and practices, the design could explore the possibility for creating a model that might not just accommodate the new technologies, but which might offer new and more fruitful conceptions of the technologies as objects and create new opportunities for the people that might use them.

The general arrangement of the spaces was radically re-thought to remove any duplication of functions, re-purpose redundant or little-used spaces and, without losing any existing capability, free-up areas to allow the introduction of wholly new and novel parts of the program. These included a shop – now generating a significant income – a new Light Lab, materials library, several permanent galleries, an immersive 3D cinema, 3D Print Farm, and a multi-functional project and event space.

Fig. 31
The CNC Lab, after the Remodelling Project Phase 1, 2016

32

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Figs 32-33
Wood workshop, before (Fig. 32) and after (Fig. 33) the Fabrication Lab Remodel Phase 1, 2016

Given potentially hazardous technologies, and the primary importance of safety for the design, the space was analysed according to the distribution of hazards within it. Building on the Lab Assistant model being developed since the start of the project, the role of the architecture in creating opportunities to further empower Lab Assistants and extend their reach within the Lab was then considered. This led to the redistribution of many of the tools in the spaces so that those that were most hazardous could be placed together in the same space for more experienced staff to supervise, creating lower risk areas and new opportunities for both Lab Assistants, and for students more generally to work unattended.

Through an analysis of the isovists at key points in the Lab, consideration was then given to how the spaces might be most effectively supervised without leaving blind spots for hazardous activities to go unnoticed. In an apparent reversal of Foucault's more general conclusions in Discipline and Punish (1975), it was argued that the function of surveillance in the Lab was empowerment, not social control. The more that trained staff were able to surveil the typically inexperienced Lab users, the lower would be the risk to them of using the Lab, and the greater would be their freedom to do so.

Consideration was also given to how the activities of the Lab might be made more open and transparent to visitors and non-users of the Lab. Extensive use was made of glass in both remodelling projects, and especially where it served a strategic function. The most hazardous and dramatic digital tools were placed close to windows and glass partitions, so that visitors could get close to the cutting tools while staying safe, and leave with a new appreciation and interest in digital fabrication. Restricted by the reinforced concrete fabric of the building, use was made of all existing apertures, and old door openings were converted into gallery exhibition cases, with examples of the best previous work to inspire, and glass backs to allow views straight through into the machining rooms and working spaces behind.

Finally, for two reasons, the strategy left open the completion of the project as far as possible, and attempted to design in at every point the flexibility to continue to adapt and develop the design. First it was clear at this point that the technologies of interest to the Lab were only going to continue to improve and mutate into other more useful items the Lab would want to include. The project was also at its core experimental. The notion of the laboratory was applicable not only to the work completed within it, but to the Fabrication Lab itself. It was designed as a living experiment, and given that it also contained the tools, materials and capabilities to develop and transform itself, the end of the remodelling project became also the start of a new phase of construction, modifying, testing and re-adapting the spaces which has continued ever since.

Careful design of the architecture of the spaces created both a successful and highly functional Lab for the University, but also, understood as a key element of the Lab as an apparatus, produced the inherently safer spaces, vehicle for experimentation, and some of the essential conditions required to construct new ways of apprehending technical objects, and new opportunities for Lab users and staff, discussed in the next sections.

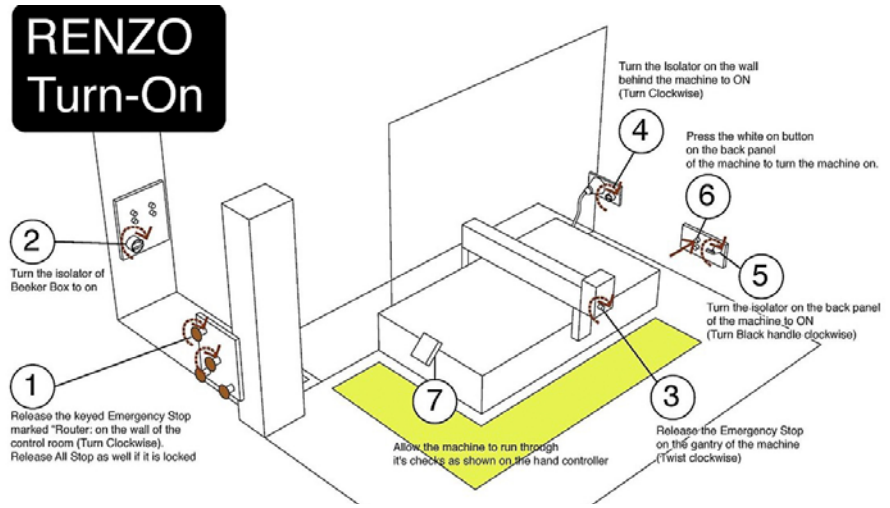

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Fig. 34
Constructing Technologies through Graphic Communication using Posters, 2018

Fig. 35
Constructing Technologies through Graphic Communication using the Machines, 2018

Fig. 36
Metal Essentials, 2018

Lab Technologies and Tools: Toward New Objects

Two factors were found in the research to be especially important in constructing technologies as objects. The first concerned their status as 'technical', and the second the importance of discourses and practices around health and safety. While new technologies are clearly 'technical' by their nature, and in many cases do pose potentially serious hazards for health and/or safety, the project investigated ways of resisting the usual patterns of emphasising these factors, often leaving users disempowered and tools inaccessible.

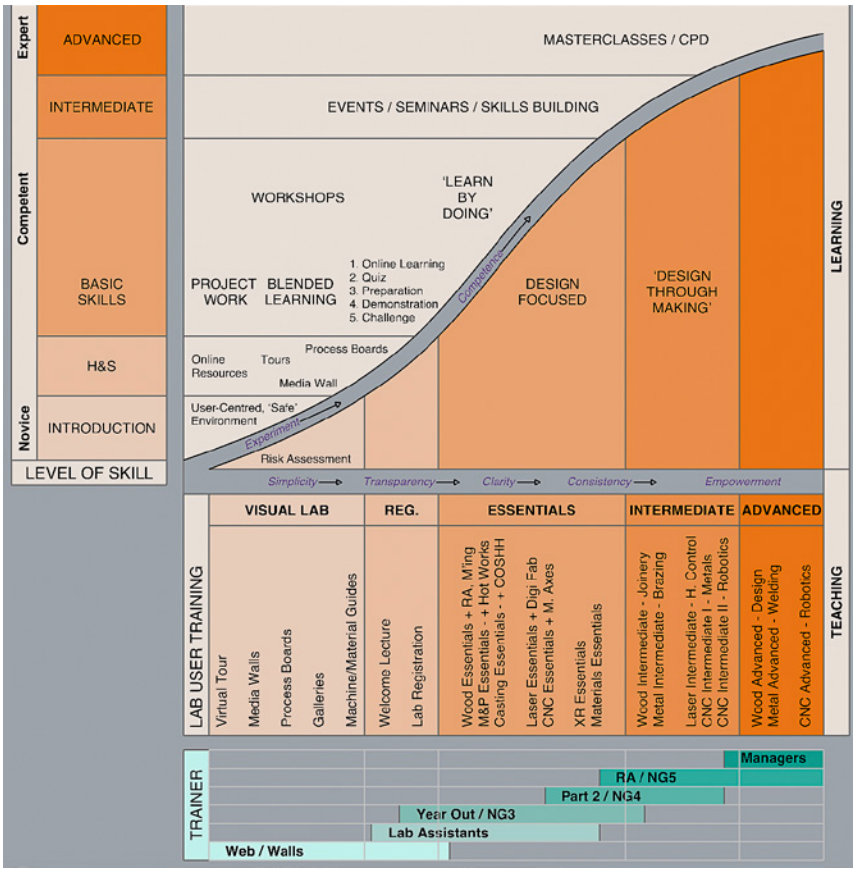
With the aim of proactively designing the conditions for more positive constructions of tools as objects, the project focused on ways of systematically reducing the technicality of tools and technologies, and of rigorously eliminating unnecessary hazards. Making tools simple and safe, empowers new and non-specialist users, as well as those with more experience. The architecture of the Lab was combined with other systems and strategies to investigate and generate these conditions.

The Essentials courses initially developed to train new users on the Lasers was greatly expanded with the growth of the Lab to include courses on working with Wood, Metal, Ceramics, CNC Machining, 3D Printing, XR Technologies and others. The same principle was applied of teaching the central concepts involved and of stripping away unnecessary complexity and technicality to reveal only what was essential for the safe and productive use of the tools and materials, while unlike traditional workshop inductions, teaching enough about the tools to allow people to make something useful with them.

Simultaneously a rigorous programme was put in place to investigate ways of re-constructing the meaning of the machines through graphic design and communication. This involved numerous experiments with stickers, posters, web page designs and instructional leaflets. The posters explored ways of using graphic design, like the Essentials courses, to reveal what was important and what could be safely ignored.

The graphic design approach was similarly applied directly to the tools. Machines were painted the same neutral colour grey, eliminating unnecessary distractions and creating a cleaner, coherent aesthetic for the space, while allowing clear and unified colour coding to be introduced. Hazards are highlighted in red, hazard controls in yellow, and the relevant and safe touch points in green. Principles drawn from the Kaizen approach to strategic management, were also used to translate practices into clear visual symbols so that anyone without specialist knowledge would know how to relate to objects just by looking at them. These experiments evolved into a highly successful set of strategies both testing the thesis of the research at the same time as providing much wider yet safer access to the opportunities of the Lab.

Having established these principles, significant outputs have included the sustained expansion of the number and type of technologies that have incorporated, many embedded within the spaces building on the notion of the living Lab. Having close involvement in the remodelling projects, the seeds could be planted early on for the investigation of embedded technologies for the built environment including IP addressable cameras and monitors, multi-channel audio, DMX lighting, projection mapping, LoRaWAN Networks, BEMS integration and digital dashboards, and biometric controls.



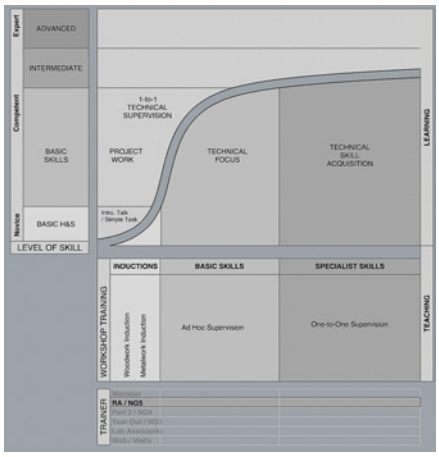
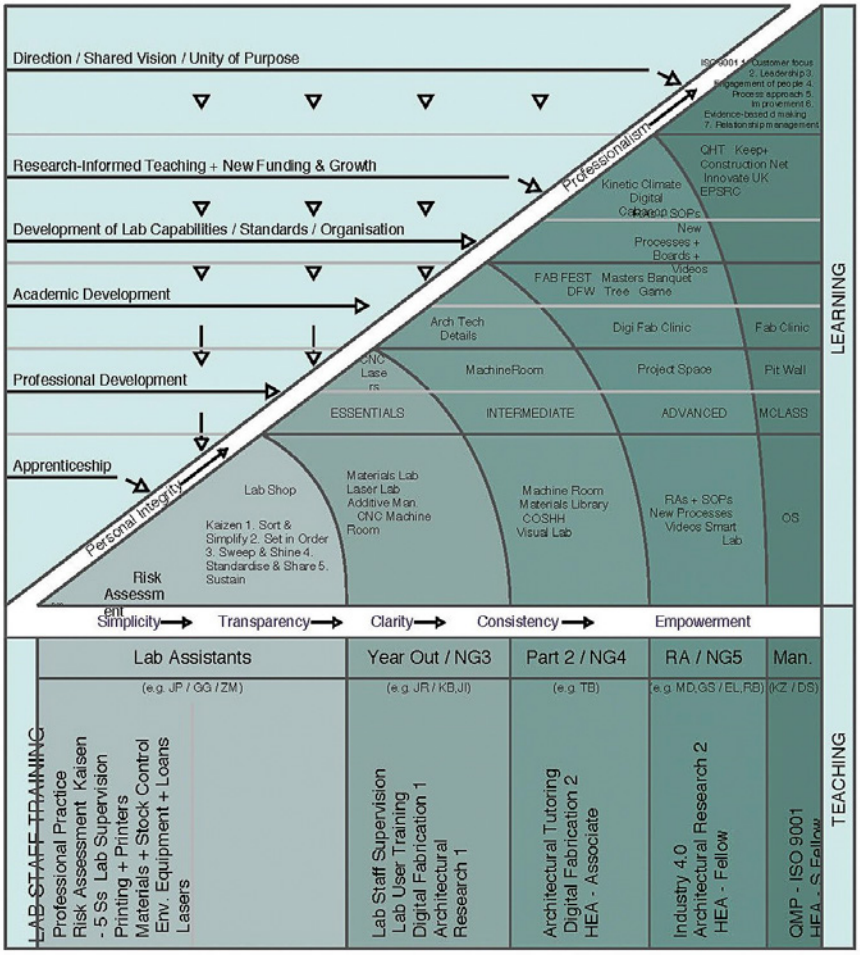


Fig. 37
Strategic Staffing Diagram Illustrating the Inherited Model, 2017

Fig. 38
Strategic Staffing Diagram Illustrating the Proposed Model, 2017



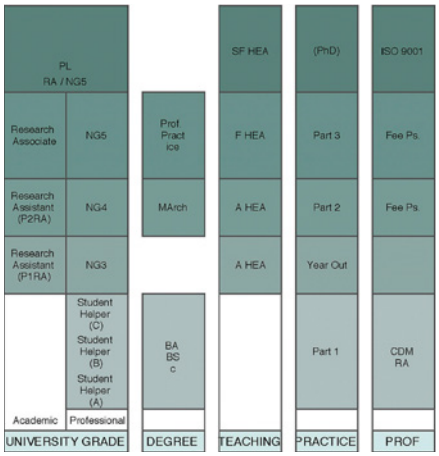


Fig. 39
Strategic Staffing Diagram Illustrating the Proposed Model, 2017

Fig. 40
Strategic Staffing Diagram Illustrating the Proposed Model, 2017

Lab Staff and Users: Toward New Subjectivities

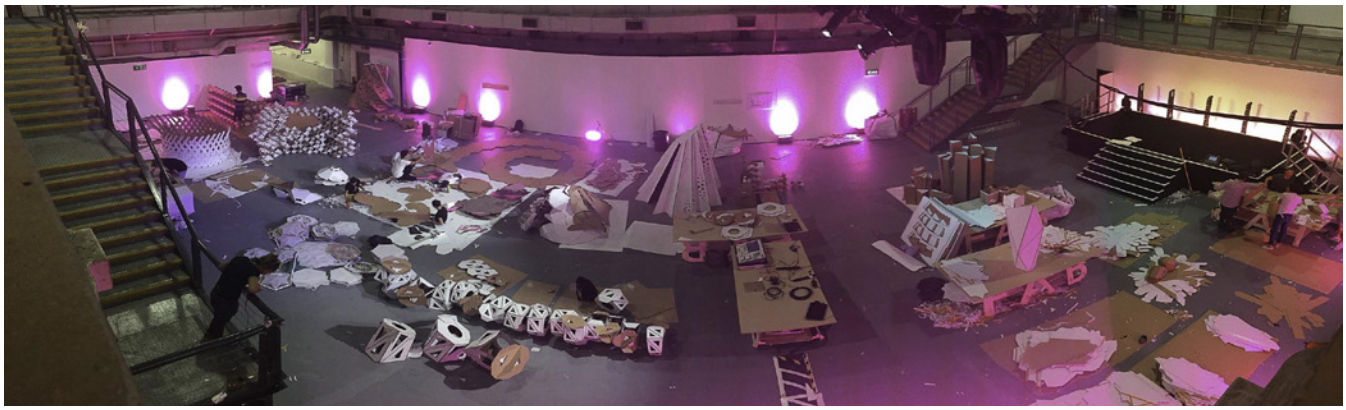
As the project expanded it built on the initial experiments begun in the first few months, and as other, pre-existing workshops were incorporated within the scope of the Lab, the same staffing model was modified, applied and further developed. The initial group of four trained student Lab Assistants (LAs) was expanded to a team that at various points has included more than 30. Systems were implemented through which students were systematically recruited following successful outcomes in first year teaching workshops, and most stayed throughout their degree as working participants in the development of the Lab.

Responsibilities undertaken by LAs have grown enormously from over-seeing laser cutters and large format printers, to managing the shop, working in the analogue wood and metal workshops, assisting with both Lab training courses and teaching workshops, and more recently to more specialised roles including documenting events, curating the Lab galleries, and fabricating Lab development projects. The extension of Lab duties has been accompanied by an associated extension of training courses as the demands have become more technical and sophisticated. The continual widening scope of the Lab has meant that the LA team now includes students from other disciplines, and especially Computer Science.

As the first set of Lab Assistants have grown and graduated with the Lab, so too has the system of staffing to offer new, more senior roles. These have coincided with the development of the other research programmes in the Lab, to offer positions appropriate for architecture and computer science graduates, post-graduates and post-docs. While this seems an apparently simple transition, it represents a radical departure from existing practice, and involved considerable negotiation. Various institutional elements combine to create these positions, including the Unions, which are different for academic and professional staff, the University HR Department, that is bound by agreements with Unions as well as its own policies, and the Royal Institute of British Architects, that requires architecture graduates to undergo a specific type of work between their degree and postgraduate studies.

In this context the authors have created new positions and opportunities in the Lab that go well beyond traditional technician roles, to include posts created specifically for the Lab, including Architectural Research Assistants and Architectural Research Associates. The majority of the technician roles have likewise be reconstructed to reflect the new ethos and working practices of the Lab, and to create new opportunities including Process Developers and Software Developers.

The Lab has thus offered new ways for students to engage with technology, as responsible agents and co-creators within the Lab. It has given them new opportunities to learn, while also paying in part for their studies. The Lab has created this opportunity now for more than 70 of our students. Twelve of these Lab Assistants have taken the opportunity to continue after the degree full-time, and 7 of the 10 current full-time staff began working in the Lab as Lab Assistants.



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Figs 41-43
FAB FEST ’16-’18 pavilion construction and display, Ambika P3, 2016-2018

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FAB FEST 2016, 2017, 2018

FAB FEST was the first major project to build on the success of the first phase of construction of the Lab. It was designed in the first instance to realise and demonstrate the new capabilities introduced by the significant expenditure the University had made in the Lab, and hence to provide some justification for the investment. It also was an opportunity to build on the early success of the DFW project and to further test the hypotheses of the research. FAB FEST in particular was created as a powerful new opportunity to combine in a novel way the three areas of teaching, research and knowledge exchange.

The project was created as a major, international design and fabrication competition and exhibition. Competitive funding was won from the Quintin Hogg Trust for £60,000. The considerable success of the project, visited by the members of the QHT board, was a key factor in securing subsequent funding for other projects, including two more iterations of FAB FEST. Participants were invited from partner Universities around the world, including India, USA, Italy, Spain and Turkey to enter teams of five participants to engage in a remote design and fabrication workshop, leading to a week's installation project in the Fabrication Lab and a public festival held in Ambika P3. International teams were accompanied by 30 teams from the University of Westminster, who Scott partnered with 18 leading architectural offices, with practicing architects volunteering to work as mentors for the University teams.

At the heart of the event was a research project exploring a key interest of the Lab, in design for manufacture and assembly (DFMA). A major part of the cost of the Lab was for the accommodation and services for a number of computer numerical control (CNC) routers, cutting tables and mills intended to teach and research large scale digital fabrication and modern methods of construction. FAB FEST provided a vehicle to test both the possibilities the new technologies offered, and ideas around designing and fabricating using a novel DFMA approach.

The funding for FAB FEST was subject to a competitive grant process and over three applications won total funding of £233,000. The three FAB FESTs involved 31 universities from 19 countries, and 18 architecture offices.

Fig. 44
FAB FEST '16, '17, '18, Promotional Posters.

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46

Fig. 45
Exploration of Robotic Cinematography, 2018

Fig. 46
Investigation into Robotic Carving, 2018

Fig. 47
Outcome of Robotic Experimentation with Advanced Carbon Fibre Composite, 2018

47

Architectural Robotics Theatre

The Architectural Robotics Theatre project (ART) was designed to activate the industrial robots in the Lab, providing funding for us to pursue the research required to develop new applications for architecture and construction, while simultaneously engaging a wider audience, both students and others in the potential for automated manufacturing in the construction industry. At the heart of the design of the Lab was the idea of transparency, and of making the objects and processes within the Lab as open as possible to passing as well as engaged viewers. The design therefore made use of the unique location of the Lab, with its window facing Marylebone Road, one of London's busiest traffic arteries, as well as Madame Tussaud's, one of Europe's busiest tourist attractions. The design of the Lab maximised the value of the location by placing one of our three industrial robots in the window, mounting it on a five-metre rail, and building the cell to house and make the robot safe out of glass. The design for the robotics theatre project added lighting and a planned series of workshops and events to capitalise on the design. Two grants were won to support the project of £60,000 each.

Industrial robots are relatively new to architecture and there are as yet few established uses for the technology. They differ from other computer numerical control machines in that they are highly programmable, and can be used to realise all manner of automated manufacturing process. On the other hand, they require a deep understanding of the process to be automated, and knowledge of how to programme the robot path to successfully execute the process. They are therefore highly capable, but also highly demanding tools, required significant expertise and an investment of time. The ART project allowed us the time to research and develop a number of speculative and experimental processes, some of which were then translated into the core capabilities of the Lab. Processes investigated included robotic milling, drawing with light, weaving, carving cinematography, light installations, heliodon and others. The outputs of the research were used in numerous teaching workshops, as well as forming the basis for an Innovation UK grant application for £345,000 with the leading robotics and automation firm Loop Technology. The grant was not successful first time, but we are modifying and re-submitting the proposal in the next year.

One of the major outputs of the ART project was the development of a new process for laying down carbon fibre into complex forms, without the use of expensive, time-consuming and non-sustainable moulds. The process was shared with Affan Innovative Structures LLC, one of the world's leading manufacturers of advanced composites for the construction industry, who then partnered with the Lab to create a scale-pavilion based on the findings of the research.

The Fabrication Lab developed the design for the pavilion to offer a rigorous test of the methodology and process, and Affan funded the construction of the mini-pavilion, using very lightweight but very strong carbon fibre composite. The pavilion, manufactured in Dubai, was shipped to Korea for the UIA 2017 Seoul World Architects Congress and exhibited by Scott and Magnisali from the Lab team together with Affan.

The project provided a chance to test a new model for working with new robotic processes and for working with industry. It led to the development of other processes using carving and weaving, and eventually to the grant proposal to explore this method and others with Loop Technology.

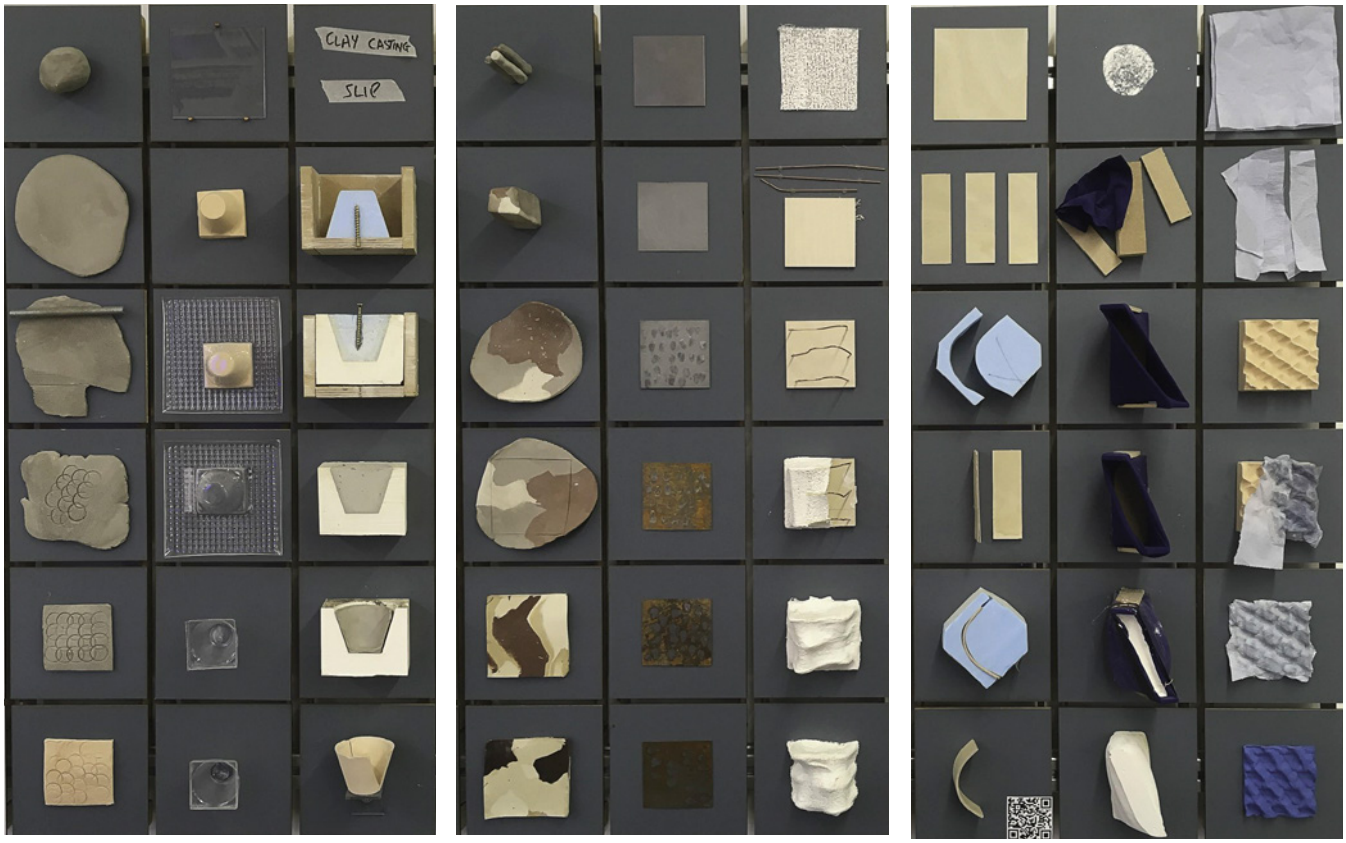
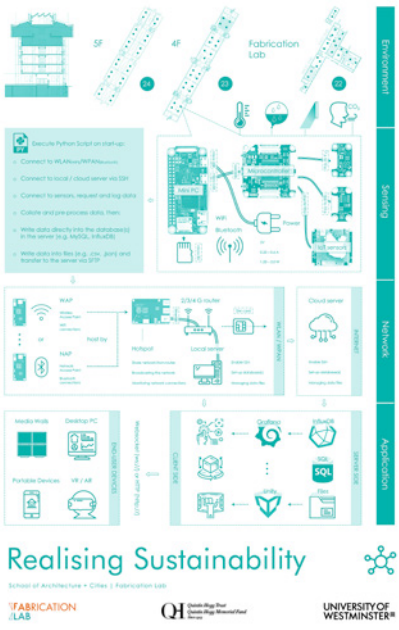
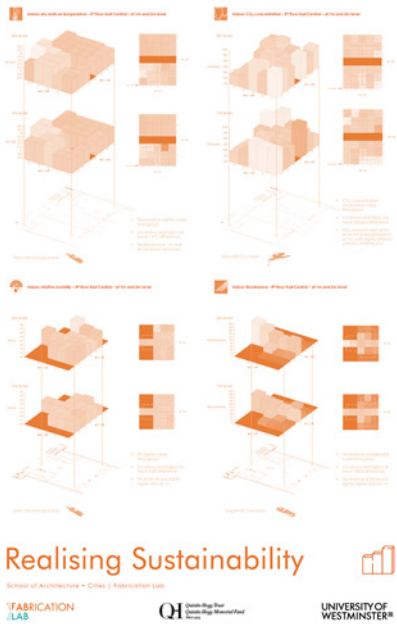


Fig. 48
Display of Material Processes in the new Material Library, 2018

Fig. 49
Publicity Posters and Project Communications for the Realising Sustainability Project, 2018





Materials and Building Systems Research Centre (MBSRC)

The Materials and Building Systems Research Centre (MBSRC) aimed at creating an innovative materials and construction details library in the Lab to form the foundation for research into new materials, as well as a library of scale samples to allow research into modern methods of construction, as well as providing a hands-on teaching tool for students. Girardin and Scott applied for competitive funding and won £115,000 to complete the project.

The MBSRC built on the core principle of the Lab of providing a seamless transition between diverse technologies – that had previously be siloed into independently managed workshops. It thus opened the way to the benefits of combining the full ecosystem of advanced digital technologies. Where there had previously only been basic materials testing – compression, tension, bending and shear – the project brought a diversity of materials in combination with these tools, as well as access to the growing web-based resources being developed elsewhere in the Lab.

Girardin and Scott also sought professional collaborators for the project, to both introduce further expertise as well as opportunities for research and knowledge exchange. The Lab therefore partnered with Material Driven, and dynamic Materials consultancy. The Lab currently has on loan a significant part of their permanent collection of samples held in the Lab's library, created through the MBSRC grant, for use by students and researchers.

Realising Sustainability

Realising Sustainability was a partnership with Dr Rosa Schiano-Phan, Reader in Architecture and Environmental Design. It was a new type of project designed to provide research in this area, at the same time as it contributed to the teaching programme, and provided the basis to work with the Estates and Planning Department in the University, and influence energy use in the numerous University buildings.

The project built on the technical infrastructure and network of IP addressable displays that had been included in the design of the Lab to make ideas like Realising Sustainability possible. The project combined the Lab displays with Internet of Things (IoT) sensors, and information gathered in conjunction with the Facility and maintenance managers of the building who provided access to the building energy management system (BEMS). While there is abundant information available through modern sensors and networked computing, it is not typically visible to the people who use the building and influence the way it functions in practice.

Realising Sustainability gathered and displayed the data to change this state of affairs and make the issues comprehensible to both the built environment professionals in training on our courses, as well as the non-specialist business school students and staff. The research was backed up by a detailed post-occupancy evaluation study, and produced a journal publication as an output, as well as providing the foundation for an on-going relationship with the University estate management team, and a functioning set of technologies to be used in subsequent projects.

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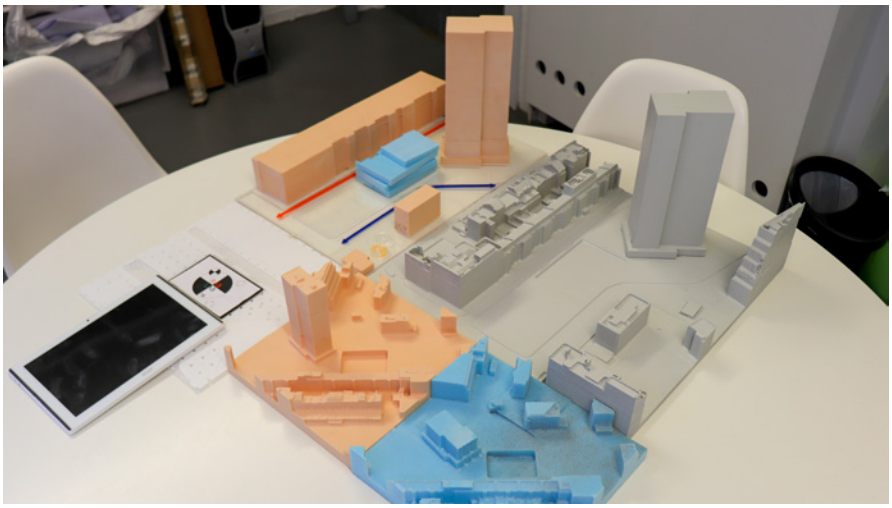

51

Fig. 50
Technology Demonstrations at the Construction Sector Deal Dinner, 2018

Fig. 51
Hybrid Model Making with David Miller Architects, 2017

DMA Keep+

DMA have been one of the leaders in the field of Building Information Modelling workflows for architectural design, regularly publishing and presenting their innovative approach. The office model began more than 10 years ago, by systematically removing all the physical models that had accumulated in the office over many years, as well as removing the making of physical models from their design production process. Having spent 10 years deliberately excluding models, and with the technologies for creating them having advanced so quickly in this period, it begged the question of whether there might be a better way now of re-introducing physical models in some new form back into their process.

The project allowed the Lab to extend the opportunities for creating new roles for architecture students graduating through the Lab Assistant system. New posts, created in discussion with the RIBA were formed for 'Architectural Research Assistants' and 'Architectural Research Associates', positions which continue today as a fundamental part of the staff structure of the Lab.

Focus for the research soon settled on how to use digital technologies, including CNC machining, laser cutting, 3D printing, AR and projection mapping to incorporate physical models more efficiently into the design workflow, allowing for frequent, iterative versions. Solutions were found incorporating hybrid uses of all the technologies that were tried. Unanticipated findings included the importance of the model as a focus for social interaction, both within the design team, and with key stakeholders for the projects. It became clear that model-making could be the basis for social anthropological investigation of the unavoidably shared and collective nature of architectural design. Having completed this initial Keep+ project, the Fabrication Lab will be looking to extend this research with other offices investigating the generalisability of the approach to different office practices and types of architecture.

52

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Fig. 52
Opening the Helsinki Tea House with the British Ambassador to Finland, 2017

Fig. 53
Constructing the Helsinki Tea House outside the Design Museum, City Centre, 2017

Fig. 54
Shingling the roof of the Helsinki Tea House, 2017

The Helsinki Tea House

The Helsinki Tea House continued the Lab's investigation of the application of digital fabrication tools for traditional modes of construction, as well as its practice of fostering international collaboration between academic institutions and professional practice. The project built on the relationship created by Professor Harry Charrington with the Finnish Institute in London and the critically acclaimed Finnish architect, Sami Rintala, of Rintala Eggertsson Architects. Having completed several projects already, some in the Lab, and one sauna in Finland, the project proposed a new collaboration that would also include Aalto University in Finland, and the Design Museum in Helsinki which would help establish a site for the pavilion.

To celebrate 100 years of diplomatic relations between the UK and Finland, the idea for the project was to bring something typically English, Tea, and create a space for it to be celebrated in Finland – traditionally a coffee-drinking nation. The project was split into two phases that would involve Aalto and Westminster students in a creative exchange. The Aalto students came to London to work in the Fabrication Lab over Easter, and then the Westminster students travelled to Helsinki to build the pavilion.

All the students, as well as Scott, Girardin, Rintala and Helenius from Aalto were involved in the design process, and the advanced manufacturing facilities were used from both the Fabrication Lab and Aalto University. The CNC routers were used to create decorative panels from laminated Forescolor through-colour fibre boards, using a design that echoed William Morris wallpaper. The panels were shipped to Helsinki to join the timber frame structure for the pavilion, manufactured using the 5-axis CNC Mill in Aalto University. A group of eight students, all Lab Assistants working in the Fabrication Lab volunteered for the extra-curricular project. They travelled to Helsinki with three of the full-time Lab staff and worked for ten days first in Aalto, and then on site in front of the Design Museum. The central Helsinki site provided the perfect, design-oriented setting for the experimental pavilion, that combined both very traditional forms to match the traditional English beverage, with highly advanced design for manufacturing and assembly techniques.

The pavilion was opened by the British Ambassador to Finland, and remained on site for the whole of the summer. It became a major attraction in the City, and through the organisation of the Design Museum become a widely used setting for all kinds of ceremonies throughout the summer.

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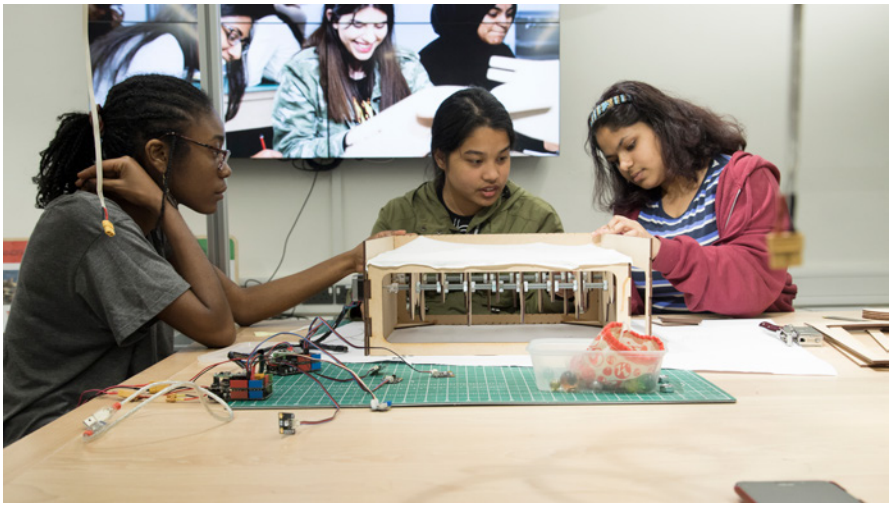

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Fig. 55
Tutoring for the Kinetic Climate Project, 2019

Fig. 56
College Students making IoT Kinetic Sculptures, 2019

Fig. 57
Team Photo, Kinetic Climate, 2019

Kinetic Climate 2019

Kinetic Climate built on ideas first explored in the Realising Sustainability project, combining them with the short-burst teaching workshop and exhibition formats central to most of the projects in the Lab. The technology of particular interest in Kinetic Climate was LoRaWAN, a new and exciting network technology that is becoming a major force in the growth of the Internet of Things (IoT). IoT promises to empower a transformation in how we use technology by allowing machines to communicate with other machines as well as us, and to have a similar impact to the internet and World Wide Web on how humans interact. LoRaWAN is important because it allows a simple yet effective form of communication with very low power and very long range. In place of the very restricted range of Wi-Fi that we are all familiar with, LoRaWAN capable devices can potentially communicate across many miles, while running a battery that may last several years. The Kinetic Climate project was proposed to test LoRaWAN in a novel way, and one that might include and educate young people and the general public in this potentially very exciting technology.

Following another central objective of the Lab to create a more sustainable built environment, the project proposal was to use LoRaWAN technologies to connect a series of public 'devices' with data and cloud-based AI monitoring the global and local environment. To maximise engagement with the public, the devices would take the form of IoT-powered sculptures, inspired by the art of the pioneers of kinetic sculpture including Jean Tinguely and Alexander Calder. Participants in the programme would be taught the digital fabrication tools in the Lab and supplied with kinetic mechanisms and IoT sensors developed by the Lab as part of the research. The challenge would then be to design the kinetic sculpture that would best engage and provoke passers-by in the energy use of the buildings we inhabit. The brief was to illustrate and dramatise the relationship between how we occupy buildings and their impact on the environment in order to potentially change the behaviour of building occupants and produce a more sustainable future.

The project was submitted to JISC, and won £8,000 funding. It was also proposed to the National Saturday Club, who provided a further £3,000 funding. A short-burst teaching workshop was held with a new group of participants for the Lab, comprising 16-18-year-olds. A small public exhibition was held at the end of the week's workshop for the young people to demonstrate the kinetic sculptures they had designed and fabricated in the Lab during the week.

A number of very engaging projects were produced by the students, as well crucially as key outcomes for the research agenda of the Lab. The funding financed the addition of a permanent LoRaWAN network within the Lab for us to continue to investigate and develop new uses for this important research platform for one of the fastest growing technologies today.

Fig. 58
Experiments with AR using Models made in the Lab, 2017

XR Lab

The XR Lab represented an important departure for the Fabrication Lab. Having built the Lab around a wide range of new digital manufacturing technologies, it became clear that the world of technology beyond the Lab was advancing more quickly than anticipated, and increasingly was incorporating a more diverse range of digital tools. Having focused particularly on computer numeric controlled control of physical making processes, the technology that was gathering traction in professional practice and industry revolved as much about new forms of digital representation. In particular, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality tools were becoming commonplace, and the Lab would need to keep-up.

Following the policy that had been adopted throughout the project, funding was sought through competition, building on earlier successes, to fund the necessary expansion. The policy to expand and introduce new expertise to the Lab through collaboration and partnership was also adopted, and joint application was made to the Quintin Hogg Trust for funding for a new XR Lab, which succeeded in winning £270,000.

The XR Lab project was a joint venture with Jeff Ferguson, Senior Lecturer from the School of Computer Science and Engineering, and an expert in the field of XR technologies. The conceit for the project was for a single, dual-centre Lab, with half the tools being based in the University's campus in New Cavendish Street, and half in the Fabrication. Crucially, a significant part of the funding was used for new staff to expand the team, with the staff splitting their time between the two centres for the Lab. Following the usual policy, the Lab offered the opportunity to work as Assistant Software Developers to existing Lab Assistant staff.

The XR Lab has led to the creation of software research and development covering fields as diverse as new methods for conducting interviews in Psychology research, to virtual training for cycling safely in a busy city. The funding was provided for two years from the QHT. A second bid for £242,000 further funding was not successful, and the Lab continues, now more closely embedded with the Fabrication Lab. Two of the team originally recruited for the XR Lab remain as core members of the now expanded Lab staff.

Fig. 59
Visitors at Helsinki Tea House

CRITICAL SELF-APPRAISAL

The Fabrication Lab project evolved out of an apparently simple proposal to update a small digital workshop. The authors in retrospect correctly predicted a much more serious transformation of digital technologies than was then being considered, and identifying the need for a more original and rigorous research approach led to the present project. It was not anticipated however, how quickly things would change over the subsequent seven years. Technology has advanced and been adopted in the sector much more quickly than expected, and blossomed into a diverse digital ecosystem that has extended the scope of the project enormously. The authors have attempted and succeeded in large part to keep up with these developments as they have happened, the iterative and reflective approach used throughout affording constant changes of direction as needed. But it has also meant the project has grown exponentially in size, scope and complexity, and on numerous occasions tested the limits of what can be accomplished with the available resources. As a consequence, the project has kept pace with new developments, just, but it has yet to fully capitalise on the potential that has been built into the Lab through the process of its rapid expansion. There is a great deal more to offer over the coming years.

Secondly, it is worth noting that while the vast majority of the Fabrication Lab users and staff have been delighted with the new opportunities the Lab has created, not everyone has been positive about the changes it has introduced. Discourses, as Foucault is famous for noting, are inextricably linked to power relations, and where new subject positions were opened up through alternative approaches and their associated practices and discourses, the changes were interpreted by some as a threat to existing positions. Most of those involved with the project adjusted and realised that within new contexts there new opportunities for everyone. But this was not the situation for a small minority. While resistance to change was to be expected, it was not anticipated that it would at times be quite so vociferous, and that its impact would be quite so impactful in temporarily slowing the progress of the project.

Finally, the design, construction and installation of the spaces and tools within the Lab represents a major undertaking in its own right, and one that has been very well received within the University and beyond. The physical aspects of the Lab, though sometimes mistaken for the project as a whole, are but a small part of the Fabrication Lab project. By far the larger and more challenging work has been the design and implementation of the other, often invisible, heterogeneous elements that have been combined to realise the model for the Lab and produce the centre for teaching and research it supports. The approach that was adopted, while offering invaluable insights and motive for action, poses immense challenges. Action Research is typically undertaken in areas where the investigators can much more easily exert control over the practices they are researching, as for example in the case of education research where action research is often used. Combining the approach with a major live project, embedded in multiple institutions and organisations makes this experimental approach very difficult. The difficulty in executing the research does not affect veracity or the huge value of the research findings, neither does it undermine the enormous added value of creating positive institutional change simultaneous to conducting research. But it is worth noting for others considering adopting the research as model that undertaking such an approach should not be done lightly.

DISSEMINATION, ACHIEVEMENTS, PEER REVIEW

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