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Abstract. This paper shares a novel educational programme that is attempting to detect and nurture emerging transdisciplinary fields of creative production, and stage architectural education as a holistic environment for initiating new forms of practice. Its experimental pedagogy uses physical and virtual prototyping to build and critically examine future applications and socio-spatial implications of emerging technologies. This article contextualises the development of a transdisciplinary programme in relation to the field of media art. It presents our approach to building a transdisciplinary course and the preliminary results of a programme now entering its third year.

Keywords: Transdisciplinary; Pedagogy; Architectural Design; Performance, Interaction

Introduction

The converging fields of digital networked media, smart materials, robotics and artificial intelligence are creating novel forms of synthetic agency that animate our built environment. These advances are precipitating entirely new forms of creative practice that span across architecture, art, design, performance and engineering. They span from the scale of urban sensor networks governing the performance of our city infrastructure, to building systems responding to human occupation and environmental conditions, to context-aware wearable and mobile technologies providing personalised experiences, mediating our engagement with the built environment. The theater of the everyday is now a data rich environment for interaction and today's intuitive communications services are shaping social relations from the interpersonal to the global ones. As a consequence of this dramatic reformulation of social, spatial and technological relations, in 2017 The Bartlett School of Architecture, at University College London (UCL), launched Design for Performance and Interaction (DfPI), a Master's in architecture programme to critically engage these accelerating transformations. The disruption of emerging technologies is explored through the programme's central tenet that the creation of spaces for performance and the creation of performances within them can be symbiotic design activities. The approach is novel and has generated a unique space for examining overlaps between architectural education and other pedagogic practices and discourses engaged in designing near futures. This article contextualises the development of a transdisciplinary programme in relation to the field of media art. It presents our approach to building a transdisciplinary course and the preliminary results of a programme now entering its third year. It is visually illustrated by student work that has emerged in the first two cohorts of graduates.

Pedagogic context: computational entanglements

A classical view of the disciplinary institutions imagines pure and stable branches of knowledge, divided and organised rationally. In practice, disciplines are mutable, historically contingent organisations, growing and shrinking, heterogeneous and fractious at times. In a traditional institutional model, when common challenges are

found across departments, a multi-disciplinary approach decomposes problems into sub-parts that are addressed by disciplinary expertise. This compartmentalisation can lead to territorialising research, and often reinforcing disciplinary traditions rather than challenging them. A historical example of where this hampered progress in research can be found in the multi-disciplinary development of early artificial intelligence (AI) and autonomous robotics. Mechanical, electrical, and computational design challenges were decomposed and dealt with as modular problems independently of one another (Brooks, 1999). The incorporation of social sciences, such as psychology, further siloed study with insufficient dialogue between the humanities and sciences. Phil Agre's critique of early AI research illuminates how disciplinary structures with their own self-reinforcing conceptual schemata had limited the scope for self-critical practices within the emerging field. He describes how «disciplinary culture, runs deeper than we are aware» and can make it «actually impossible to achieve a radical break with the existing methods of the field» (1997).

Disciplines are almost conservative by nature. Hence, in recent decades, inter-disciplinary approaches have become popular to create productive spaces of collaboration. Disciplines can overlap to varying degrees, sharing methods and content. By contrast with the decompartmentalising nature of multi-disciplinary approaches, inter-disciplinary research integrates practices often motivated by a shared view that existing modes of working are unable or unwilling to tackle emerging challenges. In its basic form, interdisciplinarity allows for a task to be addressed by a novel arrangement of overlapping expertise. A more reflexive, critical interdisciplinarity can also further epistemological concerns, revealing inherent structures (such as self-reinforcing conceptual schemata) and disciplinary relations that uncover potentially productive new areas of research and practice. An example of productive interdisciplinarity can be found in the development of Science, Technology and Society (STS) research, addressing a gap between social sciences and engineering. STS emerged from a growing recognition that classical disciplinary models of technological study were inadequate in critically examining the complex reformulations in social, spatial and technological relations. This is no small challenge. Technologies such as computing are so ubiquitous, Phil Agre argues, that they are «found contributing to the evolution of the activities and relationships of so many distinct sites of practice – that we have no idea how to begin reckoning their effects upon society» (1997).

Curator Paola Antonelli uses the phrase “Knotty Objects” (2015) to convey the challenging task of disentangling the complex interrelating agencies of art, science, design and technology. When roles and boundaries between disciplinary practices become indistinguishable, some practitioners look beyond disciplines entirely for models that reject discrete historical organisations of knowledge. «Interdisciplinary work is when people from different disciplines

work together. But antidisciplinary is something very different; it's about working in spaces that simply do not fit into any existing academic discipline—a specific field of study with its own particular words, frameworks, and methods» (Ito, 2016).

In the inaugural essay for the *Journal of Design and Science*, architect and researcher, Neri Oxman argues “that knowledge can no longer be ascribed to, or produced within, disciplinary boundaries, but is entirely entangled” (2016). She points to MIT Media Lab's use of the term “antidisciplinary” to demonstrate its disregard for institutional branches of knowledge, engaging vigorously in complex intertwined subject matter. It is notable that the Media Lab emerged out of MIT's architecture school, incubating collaborations that, for the time, stretched far beyond architecture's traditional subject matter. Its founder Nicholas Negroponte set out its agenda in a briefing where he described the Media Lab as “designed to be a place where people of dramatically different backgrounds can simultaneously use and invent new media, and where the computer itself is seen as a medium -- part of a communications network of people and machines -- not just an object in front of which one sits.” (Rowan, 2012). This was not a new idea, however. Decade's before the founding of the Media Lab, the notion of the computer as media has been enticing artists seeking novel forms of expression.

Early exhibitions, such as *Cybernetic Serendipity* held at the Institute of Contemporary Art, London, in 1968, and the presentation of computer generated graphical works by Frieder Nake, Georg Nees, and Herbert Franke at the 1970 Venice Art Biennale, helped to establish a sense of an emerging field. Electronic art, cybernetic art, systems art, computer art, interactive art, new media, multimedia, digital media, digital art, are just some of the terms used in an effort to define a diverse and amorphous field of creative practitioners that emerged. Its slippery resistance to definition is a symptom of its germination in an era of computational entanglements. Today, prefixing media, art or architecture with the word ‘digital’ seems somewhat quaint. It also fails to reflect recent developments in life sciences that are revealing the computational and creative potential of harnessing biology as media as well. Hybrid Arts is a term employed by an organisation, such as *Ars Electronica*, to throw a wider net, yet it has failed to achieve popular use. And so, embracing the transmutability of the field as its defining feature, I will refer to it simply as media arts.

The emergence of media arts in the context of a discussion of disciplinarity is important, as it represents the clearest example in the arts, of explicit transdisciplinarity. Widening computational literacy, enabled by networked and open source communities, has driven the development of interoperable tools that blend previously distinct practices of sound and music production, illustration and graphics, movement and performance, biology and robotics, installation and architectural design. This computational fluidity has the effect of dissolving disciplinary boundaries, and developing not only hy-

brid forms of existing practices, but also the emergence of radically new forms of practice. This is the distinction I make between interdisciplinarity and transdisciplinarity. As someone who has spent the last decade working collaboratively between interaction design, performance, robotics and installation art, while teaching within a school of architecture, I personally characterise my practice as transdisciplinary. Terms like anti-disciplinary and post-disciplinary in my personal view can sound a little hyperbolic when used by Directors of academic institutions, no matter how radically they may view themselves and their colleagues. Those practitioners operating entirely free of academia and institutional frameworks may perhaps be more comfortably able to describe their practices in these ways, but a cursory study of the field of media art and the more experimental domains of architecture will reveal many practitioners balancing artistic and academic practices.

Methodology: foundations of a transdisciplinary programme

The formulation of DfPI began with establishing a working group consisting of key Bartlett staff working in performance, media and spatial practices. In parallel we turned to London's leading studios specialising in performance and interaction who exemplify transdisciplinary practices rooted in architectural methodologies. These included Umbrellium, Bompas and Parr, Scanlab Projects, Stufish, and Jason Bruges Studio. Principle aims and requirements were mapped out including the need for space to fabricate, test and perform interactive installations and performances. The typically compact central London studio environments of UCL's Bloomsbury campus were unsuitable and so the Faculty took the opportunity to add to its estate by becoming a resident of Here East, the former media complex of the 2012 London Olympics that had been regenerated after the games to provide over a million square feet of versatile spaces for creative and technology companies and institutions. Today's tenants include Studio Wayne McGregor, Ford's Smart Mobility Hub, BT Sport, and Plexal, a co-working space for technology start-ups. A stone's throw over the adjacent canal is Hackney Wick, the densest concentration of artist studios in Europe. This diverse ecosystem of creativity and technology offered ideal conditions for The Bartlett to partner with UCL's Faculty of Engineering Science to take up residency at Here East and develop new educational programmes and research to benefit from this context. In line with the central tenet of DfPI – that the creation of spaces for performance and the creation of performances within them can be symbiotic design activities – we took an active role in not only designing the course but also the facility where it would take place. Core facilities include a large scale ‘Black Box’ Studio with theatre lighting and a dance floor, a 12-Channel Surround Sound Chamber, ‘Artificial Sky’ Lighting Studio, a Virtual and Augmented Reality Studio with high performance GPU Computing, and a

01 | Still shot from film by ScanLab Projects, revealing slices through Lidar scans of The Bartlett's Here East facility. Above you see a large auditorium and beneath it spaces for dedicated research labs

02 | @heyhexx (2018) by DfPI Students S.Yamaguchi, P.Liewatanakorn and P.Farahzadeh. An interactive social media responsive robot puppet theatre installation. Students developed physical models and scenography alongside integrating a variety of software systems from social media APIs to microcontrollers and robot arm control

330-seat multi-functional auditorium (Fig.01). All researchers and programmes at the facility share access to a state-of-the-art digital fabrication facility including CNC manufacturing equipment and industrial robotics. All of UCL's robotics research, which previously occurred in pockets around campus, were housed at the spacious new site allowing The Bartlett and Faculty of Engineering Science to share its large volume robotics for manufacture, inspection and testing, alongside Computer Sciences current research in autonomous multi-agent mobile robotics and UCL Medicine's surgical robotics. Such a facility is unique in the UK, with few international equivalents making it an exceptionally fertile environment for the establishing of a transdisciplinary programme.

The teaching team was assembled through an exhaustive search for academic and industry practitioners who demonstrated original and sophisticated engagement in at least two of the fields of architecture, design, performance and interaction. Many of those who were selected demonstrated an engagement with all four areas. Half of our teaching staff had architectural backgrounds but were evidently engaged in practices outside the professional architectural domain. These included an architect who was also a neuroscientist. Another had shifted from architectural practice to developing generative graphics for live performance. One more example was an architect working with Artificial Life techniques to design interactive environments. The most difficult challenge was to attract tutors who had no architectural or spatial design background, but who would feel comfortable in the context of the Bartlett. By reaching out to the Media Arts community, we were able to headhunt a mechatronics engineer, game designer, sound designer, film maker, computer scientist, dancer and choreographer who had worked across disciplinary boundaries in performance and interaction.

Teaching structure

The programme is structured over 15 months, which allows for an important three-month overlap between incoming and graduating students. This overlap is designed so that the output of the previous cohort can inspire the incoming students who arrive in September and graduate the following year in December. Three integrated modules run in design, theory and skills throughout the first six months (2 terms) of teaching. This preliminary period is focused on introducing a range of technical expertise and theoretical frameworks, through design workshops and critical writing exercises. Theory is drawn from performing arts, digital media, spatial interaction, anthropology, sociology, cybernetics, cognitive neuroscience and aesthetics. Skills training begins with an introduction to coding techniques for beginner students, and advanced classes for those coming from computational backgrounds. Once a baseline of understanding is established, students are exposed to a variety of scripting and visual programming approaches for manipulating a range of media, including computer graphics, sound, physical com-



puting and robotics. Design workshops also introduce a range of techniques in animation, choreography, photography, film-making, 3D modelling, mechanical simulation, and fabrication.

The second phase of the programme shifts from tutor led intensive workshops to students establishing their thesis agendas typically in groups of 2 or 3 though some choose to work independently. The remaining 9 months are led by these agendas in continuous conversation with their design tutors. Individual students also declare a theoretical interest typically aligned with their design work and begin constructing their written dissertation with the support of a network of specialist theory tutors. Terms end with 'Project Fairs' at Here East where student work is presented to the public as a marketplace of prototypes and ideas. Traditional jury based 'Crits' also take place halfway through term so that students develop the ability to present their work to large audiences. Final submission of a portfolio takes place in early December with a graduate show at The Bartlett's Central London campus in Bloomsbury.

Results

We were pleased to find that there was a great amount of interest for a transdisciplinary masters. On announcing the new programme we received over 100 applications and accepted 35 students into the inaugural cohort. We have seen a 40% growth each year in applications and an increasingly diverse range of students applying. Our current cohort is a mix of 55% from backgrounds in architecture, interior and urban design balanced by a mix of digital media, fine art, performance and theatre students, with a few coming from computing,



03 | (Un)Balance (2018) by DfPI Student Elyne Legarnisson is an interactive experience in XR (extended reality) inviting participants to play on the edge of stability

04 | CuGo (2019) by DfPI Students Kongpyung Moon and Peng Gao 2019. An CuGo is an interactive board game, where human and robot players collaborate to achieve a shared goal. The students developed the modular robot blocks, the game logic and the robotic interaction software

robotics, psychology, literary theory, economics and fashion. The trend seems to show increasing numbers of students coming from outside spatial design disciplines. Our current class of 45 is reaching close to our planned intake limit so as applications increase, we will be able to benefit from being increasingly selective about those we select.

This programme is in its infancy and it is too early to assess its impact, but indicators of certain trajectories are emerging in conversation between staff and students. One emerging area of enquiry is between architecture and dance, centring movement as a way of examining, understanding, and shaping experiences. Some of the experimentation in this area has been through physical kinetic work and some through virtual and extended reality experiences (Fig.03). Another area of rich enquiry is 'crossmodal interactions' and how a range of sensory inputs and outputs in relation to site and context can reveal new forms of situated experience. Site specificity is a particular strength of architectural education that has great value and is perhaps under-appreciated by those who have become so used to discussing it, and they do not realise how alien a conversation it is to large swaths of the creative industry. The productive power of the site to shape a design process is something that we wish to promote. We see it as a feature of the course that distinguishes it from much of media art or interaction design, for example.

A lot has been learnt in the early years of the course. A major challenge when bringing people from diverse disciplinary backgrounds is how to communicate ideas to one another. Different disciplines have their own representational methods, such as drawing, model making, storyboarding and writing. Students coming from further afield, such as robotics or music, can struggle in these situations, so we now teach animation tools to all students as a means to communicate in 4D. A tiered approach to teaching coding has also proven very successful with virtually all students showing confidence in discussing coding principles by the second term. Not only does this literacy give them access to a wider and deeper array of applications, it also gives them confidence to take on other technical challenges, such as learning to weld or producing machining instructions for a CNC Mill.

The design philosophy from the beginning has been to make things quickly, test them with the public and iterate multiple times. Only over the summer should a clear vision for the final 'Production' arrive, so feedback throughout the year is essential for students to shape their own thinking. The one-to-one format of the Project Fairs is far more popular with students than crits, and it appears to generate a lot more positive and useful feedback to build upon rather than what juries can deliver. Though not in our original planning, a key feature of the course to emerge has been a regular invitation to exhibit work at Ars Electronica, the leading annual international festival on media art in Linz, Austria. With thousands of discerning visitors to see the work, the quality of feedback is very valuable to



the students and greatly motivating. Other public exhibitions have included a pop-up exhibition at the Barbican Centre in August 2019 for the Life Rewired festival where we shared a variety of artificial life projects including Cugo (Fig.04) pictured below.

In early 2019 we were approached by the Tate, the UK's leading institution for contemporary art. Their Tate Collective Producers team had discovered our work while looking for a partner to put on a special evening event on the theme of the Bauhaus centenary. We were honoured that DfPI had been recognised for sharing some of the radical transdisciplinary spirit we felt the Bauhaus embodied. Ten projects by staff, students and collaborative partners were shown at the Tate Britain Gallery on 1st November 2019 including kinetic sculpture, projection mapping, DJ sets, animation, sound installation, robotic puppetry and dance with a recorded audience of 2835 visitors over the night.



Conclusion

When the Bauhaus was founded, society was questioning the role of humanity in an age of mechanical automation. The tension between human performance and machine performance inspired the design of kinetic sculptures, android costumes and geometric choreography. At the scale of architecture, entire theatre plays were imagined, composed entirely of autonomous machines, far beyond the technology of the time. Today with rapid advances in robotics and AI, such possibilities are within our grasp, and the tension between human and machine agency continues to provoke us on our Masters in Design for Performance & Interaction where we take advantage of the latest technologies to explore and advance their aesthetic possibilities.

The UK has historically maintained a rigidly vertical model to architectural education defined by professional accreditation. However, we are beginning to see a bifurcation of specialist programmes, particularly at postgraduate level, that one could compare to the carving up of medicine at the turn of the 20th century into distinct areas of expertise. Architecture has historically held a holistic identity between the arts and engineering, but it seems quite certain that as the complexity of designing and constructing the built environment increases, the calls for specialisation will only grow stronger. Our programme does not follow that call but rather resists the strategy of compartmentalisation and, instead, reaches radically further outside the discipline than virtually any other MArch programme in the country.

Literacy in coding, electronic sensing and robotic actuation, animation, digital simulation and fabrication techniques empowers students to realise physical and virtual prototypes that are tested in public settings including the Tate Britain, Barbican Centre and Ars Electronica. These materials and situated engagements with emerging technologies unpack and offer critical reflection on the ideologies, hidden assumptions and values shaping technological design. This practice of material and critical engagement we believe provides a means for navigating today's complex cultural, technological and socio-economic landscape and imagining its possible futures.

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