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feminist review

Feminist Review
Issue 123, 106–125
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DOI: 10.1177/0141778919879766
www.feministreview.com
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new divisions of digital labour in architecture

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abstract

As architecture intersects with computer science to engage with large-scale data sets and informational systems, this demands new skills, competencies and commitments. Informed by the findings of an online survey, this article explores how, who and to what extent those in the profession of architecture are investing in technology knowledge and skills, and under what material conditions this occurs. Survey data collected from five large-scale architecture practices in Sydney, Australia finds that while technology-related skills are highly valued in the profession, more men than women are engaging with computationally intensive software and technology skills building remains a largely unstructured and often self-directed enterprise. Drawing on feminist technology studies and digital labour perspectives, it is argued that the drive to computationalise the profession of architecture rests heavily on discretionary, aspirational and invisible labour practices that disadvantage employees with lesser reserves of economic and social capital, and particularly women. This further contributes to revealing neo-liberalism's influence on the concrete practices of the architecture workplace and highlights how the diminished structural role of employers breeds uneven opportunities and inequitable working conditions.

keywords

computational design; architecture; digital labour; gender and technology; design research; technofeminism

introduction

Women entering the profession of architecture have long faced gendered structural barriers. Architectural historian and feminist scholar Despina Stratigakos (2008, 2016) argues that notions of creativity, as well as analytical, mathematical and 'technical' thinking, have been wilfully constructed as core masculine traits in ways to deliberately resist the feminine. Making visible, examining and redressing these barriers has been a core directive of numerous research projects and institutional policy directives over the previous two decades (de Graft-Johnson, Manley and Greed, 2003; Fowler and Wilson, 2004; Whitman, 2005; Treadwell and Allan, 2012; Matthewson, 2014, 2015; Anthony, 2016; Murray, 2017). In Western countries, including Australia, the USA, the UK, Canada and New Zealand, capturing data on women's representation and experiences in architecture education and the profession has established a robust, evidence-based platform to lobby for revised and new policy frameworks to address issues of gender diversity, wage parity and equity. A common phenomenon this research reports is that while women and men graduate from architecture schools at near parity levels, the number of women gaining licensure and rising to senior leadership levels in the profession is significantly less than parity (Whitman, 2005; Anthony, 2016; Stratigakos, 2016; Parlour and Matthewson, 2017). With a focus on the 'leaky pipeline' of women's career progression, the issue of gender in architecture is now framed as a problem of retention. While this body of research has significantly contributed to unpacking the complex social and cultural conditions that influence the under-representation and attrition of women in architecture, the reputedly gendered nature of the architecture technology sector has remained largely unexplored.

With growing expectations that architects 'should learn to code' and engage with data intensive practices in the design, production and delivery of architecture (Celanto, 2007; Deutsch, 2015; Aksamija, 2016; F. Bernstein, 2018; Deutsch, 2019), it is a timely point to examine gender and technology relations in the profession. This directive recognises that technology is a 'significant site of gender negotiations in relation to occupations, symbols, and identities', and equally that gender can profoundly 'influence the design and use of technologies' (Lohan and Faulkner, 2004, p. 319). The research project discussed here takes up key issues that have long engaged feminist scholars, namely women's experiences with technology in the workplace and during periods of technological change, as well as recent feminist perspectives that critically examine new conditions of work in the global digital information economy and under neo-liberal capitalism (Terranova, 2000; Gill, 2002; Gregg, 2011, 2015; Duffy, 2016, 2017; Jarrett, 2016; McRobbie, 2016). More specifically, based on the findings of an online survey distributed to five large-scale architecture practices in Sydney, Australia, this article explores technology-related changes to ways of working in the profession of architecture by examining conditions of technology access, use, roles and skills development. Significantly, the survey data indicates that while technology-related skills are highly valued, more men than women are engaging with computationally intensive software, and technology skills development is a largely self-directed and informal enterprise. The survey data further points to employee perceptions that technology skills development is a generally discretionary practice, yet also a tacit expectation. Feminist digital labour concepts such as aspirational labour (Duffy, 2016, 2017) and invested labour (McRobbie, 2016) operate here to draw out the argument that technology skills development in the profession of architecture exhibits an aspirational logic as it relies on extra-organisational employee contributions and commitments that are not necessarily compensated but are nonetheless beneficial to the employer. Consequently, where technology skills development in the profession of architecture is unstructured it becomes an invisible labour practice that in turn creates uneven opportunities. For those with lesser reserves of economic and social capital, and particularly professional working women, developing technology knowledge and skills outside of work time may not be an option. As such, it will be argued here that the pervasive sense of time poverty reported by the survey respondents and the gendered character of the architecture technology sector connect to deeply rooted gender inequalities in the domestic sphere that continue to influence working women's disproportionate share of unpaid household labour (Wajcman, 2015; ABS, 2017; Ruppanner, 2017).

Conceptualising gender and technology relations in architecture through the lens of contemporary feminist theories of digital labour provides a way to situate the findings of this research within the broader context of post-industrial capitalism and the so-called feminised labour conditions of the global digital economy that increasingly demand versatility, flexibility, mobility and invested labour practices outside of the traditional workplace. The following sections of this article set out the key concepts and theories that have shaped the research, its questions, data collection method and interpretation of the initial findings. The article concludes by reflecting on what a digital labour perspective reveals to us about the contemporary conditions of labour in the profession of architecture, as well as conditions for women in the Australian workforce more broadly.

gender, technology and architecture as labour

The issue of women's absence from professional contexts such as engineering, construction and computer science has been well explored in relation to technology and from feminist technologies studies (FTS) perspectives (Cockburn, 1985; Margolis and Fisher, 2002; Faulkner, 2006; Lagesen, 2007; Gill *et al.*, 2008; Sørensen, Faulkner and Rommes, 2011). While these professions are categorised as technoscientific fields and architecture's identity is more strongly tied to notions of creativity and thus typically situated within the creative industries, they are all professions that have commonly been theorised as exclusionary masculine cultures. This draws on the larger historic cultural bias wherein 'technical' skills and competencies are seen as core traits of men/masculinities (Cockburn, 1985; Lohan and Faulkner, 2004; Wajcman, 2004, 2009). The construction of masculine identities tied to technical competence has bred difficult-to-shift stereotypes that see men has having a 'natural affinity with technology ... [whereas] women supposedly fear or dislike it. Men actively engage with machines, making, using, tinkering with, and loving them. Women may have to use machines, in the workplace or in the home, but they neither love nor seek to understand them' (Bray, 2007, p. 38). Vivian Lagesen (2015, p. 724) reflects that the 'women's deficits' model, which suggests women lack interest, skills and motivation or have negative attitudes towards technologies, remains a problematically common way to explain the under-representation of women in a range of technical fields.

Recent attention to the interrelationships between architecture, technology and gender has highlighted an absence of women in the architecture technology sector (Davis, 2014; Higgins, 2015; Doyle and Senske, 2017; Doyle and Forehand, 2018; Doyle *et al.*, 2018; Volz and Caldwell, 2018). This is based on, for example, women's low participation rates in delegate and speaker statistics at a prominent architectural technology industry conference, Buildings Infrastructure Lifecycle Technology (BILT) (Volz and Caldwell, 2018). From the BILT event held in Australia and New Zealand in 2018, scholars report that

'84.5% of the 500 odd delegates were men' and 'six of the 77 speakers ... were women', adding that further online searches for the job title 'BIM Manager' returned 'just four women' (*ibid.*). In an American context, scholars have further theorised an architecture technology gender gap based on low participation rates for women in computer-aided design scholarship, including 26 per cent female authorship of academic papers from 2010 to 2016 in the prominent North American-based conference of the Association for Computer Aided Design in Architecture ACADIA (Doyle and Senske, 2017). To address this, Shelby Doyle and Leslie Forehand (2018) call upon the traditions of feminism and, moreover, Donna Haraway's (1991) cyborg feminism, to argue for the (restored) visibility of women's contributions in the architecture technology sector. More specifically, 'computational design' tools and practices are positioned both as opportunities to better equip the discipline and profession of architecture to address wider issues of social and economic equality, as well as ways to disrupt gender norms around technology use and realise more inclusive ways of working (Doyle and Forehand, 2018; Doyle *et al.*, 2018).

Calls for inclusivity in, but moreover *through*, the architecture technology sector skirt around the technologically determinist rhetoric of disruption oft-associated with the global digital economy, where individual and collective forms of agency and empowerment are connected to the so-called affordances of Web 2.0, namely sharing, collective intelligence and participatory culture. Within the architecture technology sector, computational design is an umbrella term that can encompass a wide ecology and combination of allied digital and computational technologies, software and systems. Yet, computational design is also a conceptual phenomenon deployed provocatively to imagine as much as describe a paradigm shift and a categorically different approach to the design, delivery and production of architecture that will displace hierarchies that have long-structured the profession's identity, its relationships to other industries and its ways of working within it (Celanto, 2007; Menges and Ahlquist, 2011; Gerber and Ibañez, 2014; Deamer, 2015a; Menges, 2015; Ratti and Claudel, 2015; Aksamija, 2016; Burry and Burry, 2017; P.G. Bernstein, 2018; Leach and Yuan, 2018). While architecture has long been 'computerised', having enrolled computers and computer-aided design (CAD) software to replace manual aspects of drawing and documentation since the 1980s, a combination of software developments and increasing computing power since the early 2000s has influenced a growing embrace of computational methods and systems, including building information modelling (BIM)[1] (Carpo, 2013; Gerber and Ibañez, 2014; Aksamija, 2016; Carpo, 2017).

The difference between computerisation and computation in the production of architecture, as architecture scholars Achim Menges and Sean Ahlquist (2011) articulate, is a difference in the handling and generation of information. Where a computational method '... *deduce*[s] results from values or sets of values', a computerized method '... simply *compile*[s] or associate[s] given values or sets of values' (*ibid.*, 2011, p. 10, emphasis in the original). In this way, computational methods are reasoned as a form of design thinking and problem solving through 'cognition, simulation, and rule-based logic' (Terzidis, 2003, p. 69). With this distinction, computerisation—and namely 'traditional' CAD—is relegated to the status of a tool that merely *translates* design decisions into a digital environment, whereas computation *informs* and shapes design decision-making. Hence, and in the scholarly

[1] BIM typically refers to the use of a proprietary software platform—and is most commonly associated with the built-for-purpose Autodesk Revit software—by multiple building project stakeholders, namely architects, engineers and constructors, who can then access, contribute to and share various forms of data associated with a single 3D virtual model.

architectural imagination at least, computational design is afforded an intellectualised, and thus distinguished and elevated, status.

In one of the more radical technocreative imaginaries that connects architecture with new economies and systems that leverage the affordances of digital technologies, the Internet and participatory culture, Carlo Ratti and Matthew Claudel (2015) imagine an 'Open Source Architecture' of dynamic and participatory processes, networks and systems. Here, collaborative and interactive software tools that are already used in architecture, including 'parametric design tools like Grasshopper, Generative Components, Revit and Digital Project' (*ibid.*, p. 125) are seen as central to new practices of shared design agency and communal making. The Open Source Architecture imaginary de-seats the primacy of the architectural figure in the processes of production by elevating collaborative practices and commons-based production enabled through software systems and technologies. This includes dissolving architecture's 'producer' and 'consumer' dichotomy by facilitating ways for end users to participate in more open, transparent and flexible design processes, extending to crowd-sourced project funding models. From a less politically charged perspective, others such as Achim Menges (2015, p. 32) place emphasis on the ways that 'truly computational making' can extend the architect's structural and tectonic knowledge, as well as their control of the processes of production, to restore disciplinary forms of agency lost since the Renaissance. From a feminist perspective, Doyle and Forehand (2018) see the architecture technology sector as a locus of power and influence, and in recasting computational design as a new and feminised or post-gendered way of working in architecture, they impart a call to action for cyborgs to reclaim technologies both in use and discourse.

Disrupting longstanding ways of working in architecture and indeed salvaging the profession, architecture scholar Peggy Deamer (2015a, 2015b) reasons, firstly requires reconceptualising its work as labour, which is no simple task given that the profession's constitutive identity origins lie in its intellectualisation and cleaving from the manual work of construction. While notions of labour are implicit in examinations of the profession that have explored its social and cultural complexities (Blau, 1988; Gutman, 1988; Cuff, 1991), gendered dimensions (Matthewson, 2015) and technological practices (Loukissas, 2012; Cardoso Llach, 2015, 2017), labouring in architecture is more generally subsumed within narratives of projects (buildings), historiographies of architectural figures and innovators and profiles of creative geniuses (starchitects). And while numerous accounts have traced the technical and cultural shifts from computerisation to more computationally intensive practices in the profession (Picon, 2010; Lynn, 2013; Carpo, 2013, 2017; Goodhouse, 2017; P.G. Bernstein, 2018; Wright-Steenson, 2017), few have attended to the implications of this shift from the perspective of labour (Deamer and Bernstein, 2010).

Conceptualising architecture through the lens of labour provides a way to reveal not only the wider array of actors that contribute to its processes of production but also its conditions of work, divisions and relations. As work undertaken in the profession typically generates non-material products, such as data, ideas, knowledge and symbolic manipulation, and involves intellectual, cognitive and communicative skills, it can be firmly situated within the realm of immaterial labour (Lazzarato, 1996). For Deamer, who draws on Maurizio Lazzarato's (*ibid.*) radical Marxist interpretation, immaterial labour constitutes a profound way to re-conceptualise labour relations in architecture. Here, Deamer (2015b) more specifically ties notions of agency and autonomy that Autonomist Marxists locate in the collective and shared 'general intellect' of cognitive capitalism, to the organisational logic of BIM systems, or what she terms 'knowledge parametricism'. Her reasoning holds that as BIM 'foregrounds the information that lies behind design, accesses intelligence, not just form, and allows/demands collaboration' (*ibid.*), it generates value through modes of socially embedded cooperative work that troubles architecture's entrenched organisational distinctions and hierarchies. Yet, while the ideologies and technical capacities of BIM and computational design might align with the radical potential of immaterial labour, this emancipatory potential is significantly tempered by the ways these systems are taken up in the profession. In this way, the technocreative imaginaries that locate the potential for disruption and agency in the *capacity* of technological systems problematically overshadow the ways the socio-organisational contexts of the profession, which are already complexly structured by hierarchies and power dynamics, forcefully shape and influence who and how technologies are used.

More recent strands of FTS, including technofeminism (Wajcman, 2004, 2010) and material feminism (Barad, 2003; Suchman, 2007; Lagesen, 2015), emphasise the 'doing' of gender and technology relations, and of the sites and situations where technologies and subjectivities are co-configured. In foregrounding concrete practices, technofeminism and material feminism reject the tenets of essentialism associated with notions of oppressive masculine technologies, as well as cyberfeminism's optimistic 'blank slate' and agentic view of digital technologies in the Internet era. Feminist digital labour perspectives further operate to bring the micropolitics of labouring with and through technologies into clearer view. Particularly, the digital labour lens directs critical attention to the contradictory logic of immaterial labour. This shows how the traits of sharing, collective intelligence, flexibility and adaptability, which carry radical political potential in the Autonomist Marxist reading of immaterial labour, have been enrolled into contemporary global digital capitalism in ways that conceal practices of exploitation and inequality (Gill, 2002; Gregg, 2011, 2015; Jarrett, 2016; McRobbie, 2016; Duffy, 2017; Graham, Hjorth and Lehdonvirta, 2017; Shaw and Graham, 2017).

The notion of digital labour is taken up in numerous disciplines. In human geography, digital labour has been discussed in relation to the delocalisation of work and the socioeconomic implications of displaced labour markets (Graham *et al.*, 2017). In urban studies, the notion of digital labour has been connected to the everyday production and consumption of digital data and its relationship to spatial politics (Shaw and Graham, 2017). And, in media studies, scholars have adopted the lens of digital labour to draw focus to the precarious and unwaged forms of labour that propel digital media economies (Terranova, 2000; Gill, 2002; Gregg, 2011, 2015; Jarrett, 2016; McRobbie, 2016; Duffy, 2017). In Kylie Jarrett's (2016) work, the Marxist feminist theorisation of domestic labour is reengaged in the analysis of the unpaid yet economically valuable contributions of Internet labourers. Similarly, uncompensated work is explored in Brooke Duffy's (2017) study of an enterprising and digitally networked younger generation of new media producers from which she theorises the concept of 'aspirational labour'. Closer to the creative context of the architecture industry, Angela McRobbie (2016) traces practices of invested labour in the fashion trade and draws links to the feminisation of work under neo-liberal capitalism and the increasingly precarious conditions of careers and professions. As they are linked to larger economic and political forces, aspirational and invested labour concepts can be readily drawn into critiques of other workplace cultures such as architecture. While architecture is not an industry born of the global digital information economy, it is nonetheless implicated in and influenced by new and emerging sources of capital and resource. Viewing architecture's drive to 'computationalise' through a digital labour lens draws focus to the social implications of this shift and to the question of what now counts as labour in salaried professional contexts.

collecting data on gender and technology in architecture: the survey

Architecture's relationship to digital and computing technology is changing (Carpo, 2017; P.G. Bernstein, 2018; Deutsch, 2019). Automating workflows using algorithmic methods and applying coding skills for software customisation are now seen not only as desirable competencies for employees in the profession, but also as allowing the profession to work in more efficient and productive ways (Deutsch 2019, p. xx). Yet, opportunities to develop technology skills and to lead technology innovation are not necessarily evenly accessible to all architecture employees. Accordingly, this research has sought to collect empirical data to better understand how, who and to what extent those in the profession invest in developing new technology knowledge and skills and under what material conditions this occurs. To do this, the research recruited five large-scale architecture practices in Sydney, Australia to participate in an online, anonymous survey. Since the mid-1990s, survey tools have been widely adopted in engineering and construction research as a way to measure information technology (IT) use, adoption and diffusion (Howard, Kiviniemi and Samuelson, 1998). Surveys have been equally popular in BIM adoption research in the construction industry (Samuelson and Björk, 2013; Jung and Lee, 2015; Kim, 2016), and in urban planning where, for example, researchers have used large-scale online surveys to explore low usability issues connected to computer-based Planning Support Systems (PSS) (Vonk, Geertman and Schot, 2005). In architecture, survey methods have been adopted to quantify IT use, such as computers, software and networks (Coyne, McLaughlin and Newton, 1996; Cichocka, Browne and Rodriguez, 2017), and to explore BIM implementation (Son, Lee and Kim, 2015; Herr and Fischer, 2017; Hochscheid and Halin, 2018; Ishizawa, Xiao and Yasushi, 2018). In each of these examples, survey methods have proved useful for testing hypotheses about the challenges of technology adoption, implementation and use, and for eliciting key themes to inform subsequent in-depth interview methods.

The online survey designed for this research was structured in three sections, including demographics; architecture technology use and competency; and attitudes to architecture technology. The survey comprised ten closed questions, four Likert-scale questions, an open-ended question and the option to provide additional comments and/or details to be contacted for a follow-up interview. The first section of the survey asked questions about the respondent's age, gender, education level, professional qualifications (licensure/registration) and years of work experience.[2] The second section asked questions about technology use and capabilities, from software to digital fabrication technologies, construction robotics, virtual reality (VR), augmented reality (AR), game engines, Arduino and data-mining.[3] The survey further asked respondents to nominate the ways that software skills and knowledge are learned, such as self-taught, continuing professional development (CPD) courses, as part of a tertiary qualification, as part of a university post-professional course, online tutorials or other avenues.

[2] The survey did not ask questions about locations of institutions where respondents received their qualifications, nor their cultural backgrounds.

[3] The survey did not ask specific questions about the use of machine learning (ML) or artificial intelligence (AI) in architecture.

Subsequent questions in this section also asked whether workplaces encourage employees to acquire new software skills and/or knowledge of emerging technologies, and in what ways this is promoted or advanced, such as via in-housing training, CPD courses or encouragement from co-workers or mentors. The final section of the survey asked respondents to rate how they value software skills and knowledge of emerging technologies in relation to their work along a Likert scale. The penultimate open-ended question asked respondents to identify barriers to attaining advanced software skills and/or knowledge about emerging technologies, and the final question opened to further comments.

The study invited large-scale architectural practices (defined as $>$ 100 employees) with offices located in Sydney, Australia to participate in the survey. As opposed to recruiting through an institutional membership body such as the Australian Institute of Architects (AIA), this approach reflects a purposive sampling intent to capture the potentially diverse range of architecture technology labourers in architecture, and namely those who do not identify as architects. It was reasoned that larger-sized practices would better reveal this diversity. From the five architectural practices that consented to their employees participating in the survey, 102 complete responses were received between August 2017 and January 2018. Consequently, the survey netted data spanning multiple architecture practice contexts. While this reflects a potentially diverse range of work systems and organisational management structures, these contexts are unified by the macro-social systems, structures and regulations of the legally recognised architectural profession.

reflecting on the survey data: profiling architecture technology labour

The survey data reports a gender profile of 64 per cent men, 34 per cent women and 2 per cent other. Across the five participating architecture firms, women made up between 27 to 41 per cent of respondents. This distribution closely mirrors the gender composition of architecture professionals in Australia more generally, wherein the Australian Bureau of Statistics (ABS) 2016 census reports that 31 per cent of architects are women (AACA, 2018).[4] Over two-thirds of respondents were in the early to mid-career bracket of 25 to 34 years, of which 63 per cent are women and 32 per cent men. In the 35 to 44-year age range and above, the respondent figures for men were more than double those for women. In terms of professional experience, 31 per cent stated that they had 15+ years of relevant industry experience, and in this cohort 38 per cent were men and 17 per cent were women. While this might suggest an absence of women at a senior level in the architectural technology sector, it could also mean that fewer women in this age bracket responded to the survey. In terms of nominated roles, forty-two people indicated that they were registered architects (10W/31M/1X), ten people nominated the title of ‘computational designer’ (8M/2W) and four men identified their role as ‘BIM manager’. The computational designers and BIM managers were spread across the five participating architecture

[4] Out of the total of 16,991 people who nominated their occupation as ‘architect’, 31 per cent were women. In 2017 the Architect’s Registration Board in New South Wales reported a total of 4,118 registered and practising architects, of which 27 per cent were women (NSW Architects Registration Board, 2017, p.12).

firms. Notably, only three respondents nominated their role as 'architectural technologist'[5] and all were men over 45 years old. Overall, this data supports the hypothesis that fewer women are currently occupying architecture technology leadership roles in the profession.

In Question 8, respondents were provided with a list of fourteen software programmes known to be used in the profession of architecture, as well as two programming languages. Respondents were asked to nominate which software programmes they used in their current role and workplace, as well as their skill level on a scale of beginner, basic, intermediate and advanced. The list included software used for data management (Microsoft Excel), graphic work (Adobe Photoshop, Adobe InDesign and Adobe Illustrator) and the production of digital architectural drawings and models (CAD software: Autodesk AutoCAD, Autodesk Revit, Bentley Microstation, Rhinocerous 3D), and software requiring a level of computer programming knowledge, such as Grasshopper, Karamba, Kangaroo Physics Engine and the programming languages Python and Java (see also Figure 1). The data reports an overall respondent decline in software use and competency in relation to more computationally intensive software or software that involves a level of computer programming knowledge or skill. While 75 per cent and 87 per cent of total respondents indicated the use of Autodesk AutoCAD and Autodesk Revit software respectively, 45 per cent indicated that they used the visual programming software Grasshopper. A gendered division of software use and competency is further pronounced when looking at who engages with more computationally intensive software such as Grasshopper, with 73 per cent of the total forty-six respondents being men (34M/12W). While respondents who indicated an intermediate to advanced level in Grasshopper varied in age and experience, 89 per cent were men (11M/2W). Of the total twenty-three respondents who indicated use of the programming language Python, there were two women who nominated their competency levels as beginner and basic. This suggests that more men than women in the profession of architecture are currently engaging with more computationally intensive software. However, given the relative numbers of men and women respondents overall, this may not be significantly disproportionate. Equally, the data could be taken to indicate that the use of computationally intensive software in the profession of architecture is a niche skill.

In Question 9, survey respondents were asked to identify how they acquired software skills or knowledge from a list of options: self-taught, continuing professional development courses, as part of tertiary education, post-professional education courses, online tutorials and/or other methods. Almost all respondents indicated that their architecture technology skills were derived from self-teaching, and just under half of the respondents indicated they also used online tutorials. Notably, the responses to Question 9 also show that women favour more formal training settings such as university or tertiary programmes over online tutorials, while the reverse is true of men.

reflecting on the survey data: divisions of 'digital labour' in architecture

To understand technology use, roles and skills development in the profession of architecture and their relationship to gender dynamics, I draw on feminist theories of technology and digital labour concepts

[5] An 'architectural technologist' is a term that is generally more widely accepted, and moreover professionalised, in the British architecture industry (Emmitt, 2013).

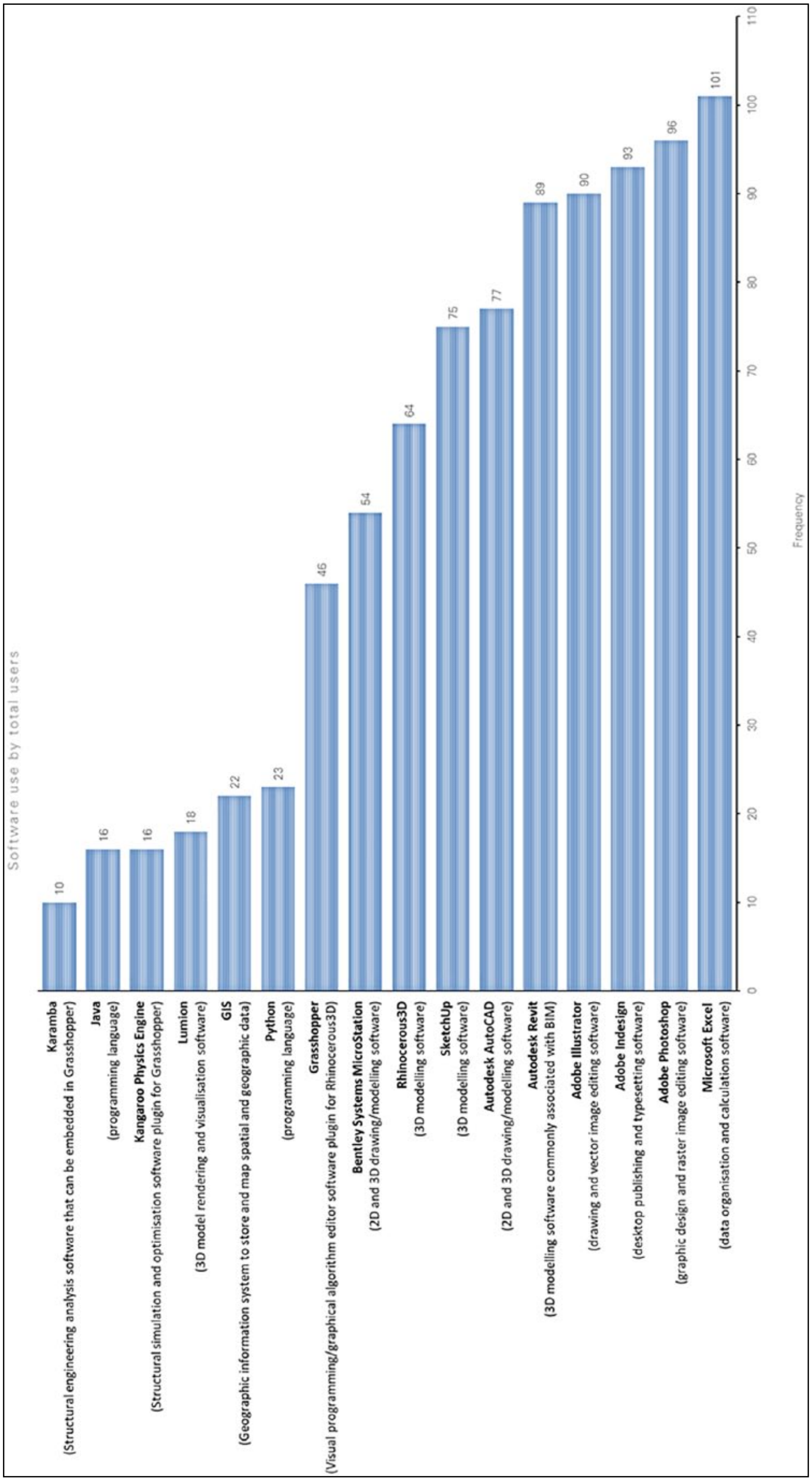

Figure 1 Responses to Question 8: Indicate which of the following software programmes you use in your current role (and level of skill if applicable)
Source: Calculations based on survey data

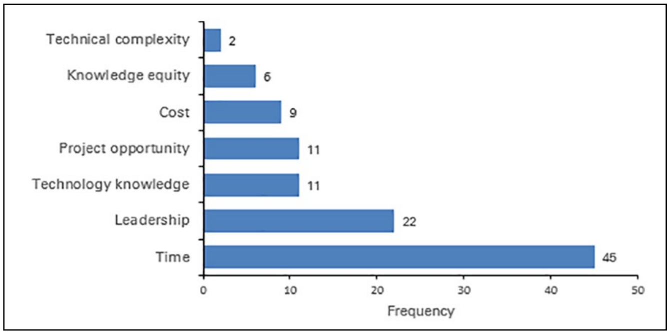

Figure 2 Coded categories from Question 16: What are the key barriers to attaining advanced software skills and/or knowledge about emerging technologies?
Source: Calculations based on survey data

such as aspirational labour (Duffy, 2016, 2017) and invested labour (McRobbie, 2016). This scholarship is particularly relevant to the interpretation and significance of responses to the penultimate and open question (Question 16) of the survey that asked: What are the key barriers to attaining advanced technologies skills and/or knowledge about emerging technologies? From the seventy individual responses received, seven key 'barriers' to technology skills and knowledge in architecture were identified and coded as Time, Leadership, Technology Knowledge, Project Opportunity, Cost, Knowledge Equity and Technical Complexity (see Figure 2). Professional and disciplinary ideologies that see logic-based computational methods as data-driven, mechanistic and thereby incompatible with architecture's creative humanistic 'ethos of artistic sensibility and intuitive playfulness' (Terzidis, 2003, p. 67) are implicated in several responses; however, after the primary barrier of time, socio-organisational themes of management and leadership figure most prominently in the responses.

While the vast majority of respondents cited 'time' as the key barrier to technology-related skills development, many respondents further attributed this sense of time poverty to onerous project conditions, workplace organisational practices, leadership and management structures and the cultural notion of striving for work-life balance. Collectively, these responses suggest that technology skills building in the profession of architecture is rarely prioritised over more conventionally 'billable' project tasks, nor scheduled or accommodated for during workplace hours. As one woman noted, '… training is really encouraged by senior staff members, but there is often so much project work that time for training does not exist', while other responses describe excessive project demands, 'intense' workloads, project time constraints and project deadlines. One respondent reported the challenge of 'Getting time to do training and research from my employer because projects always take over', while another reflected that since he is 'usually under pressure to complete "standard" work practices[, e]ncouragement or forced application [of new technology] on live projects would assist'.

Additionally, a number of respondents infer that technology training is a personal responsibility that is challenging to achieve, with one man expressing that it was difficult to, 'give on-self [*sic*] permission to take the time to learn', and another woman reflecting that an 'Intense work load means there is no time for personal development in these areas'. Respondents further cite the drawbacks that come with the responsibility to self-train, including that 'It is hard to commit time outside of work hours to attain advanced skills' and 'It is difficult to have a good life-work balance and still have time to attain new skills/knowledge'. Most emphatically, one respondent states, 'It is up to the individual, not the company to acquire the knowledge. It is up to the company to invest (the individual's time, fully or partially) to allow for the individuals to improve and gain experience'.

The survey respondents' shared emphasis on time poverty, seen in relation to responses to Question 9 that indicate software skills and technology knowledge are largely self-taught, suggests that those motivated to do so are self-training in their own time using their own resources. An open response to Question 16 explicitly describes a respondent's choice to '... run our own laptops and PCs to try new software without [the IT department's] oversight'. This points to an expanded realm of work that extends beyond the physical geographical workplace to form distorted territories where labour, leisure, obligation, experimentation, interest and affective energies become indistinguishable. Judy Wajcman (2015) explores the temporal and spatial extensions of the modern 'workplace' through digitally mediated tools in terms of the collapse of traditional and normative distinctions between 'personal time' and 'work time'. Unpacking the contemporary assumption of universal time poverty, she argues that attention to the 'quality character of time' reveals how diverse social groups organise, value and experience time in different ways (*ibid.*, p. 5). Particularly relevant to this research is the perspective that time pressure impinges disproportionately on the professional and managerial class who work fifty-plus hours a week (*ibid.*, p. 65). From here, time pressure is further exacerbated for those long-hours professionals who form part of dual-career families and families with dependants.

Yet, it is the women juggling work, family and leisure who, Wacjman (*ibid.*, p. 82) asserts, feel time pressure most acutely. While the mechanisms influencing time pressure for working women undoubtedly vary, labour statistics from economically developed Western countries including the UK (ONS, 2016), the USA (Lachance-Grzela and Bouchard, 2010), Canada (Moyer and Burlock, 2018) and Australia (ABS, 2017; Ruppanner, 2017) all report that despite women's widespread participation in the paid workforce, they continue to contribute significantly more hours of unpaid domestic labour than men. The Australian Bureau of Statistics' (ABS) 2016 census indicates that the typical employed Australian woman contributed between five and fourteen hours a week to unpaid domestic labour (housework, grocery shopping, gardening and repairs) while the typical employed Australian man contributed fewer than five hours a week (ABS, 2017). This suggests that the deeply socialised and difficult-to-shift gender roles around domestic labour in the household are a mechanism of inequality which further contributes to influencing uneven opportunities in the workplace.

Where the employer does not play a structural role in technology skills development in the profession of architecture, the ensuing individualised approach that this research points to are discretional and often invisible labour practices. Not only is this at odds with the touted benefits of group-based learning more generally, but it also undermines the ability to work collaboratively on projects, which is a key way of working in the profession of architecture. The asymmetries of skill and opportunity that individualised training perpetuates are further highlighted by one respondent who notes:

> One of the largest hurdles in advancing in software skills/knowledge is ... that we must work in teams where people aren't expected to understand advanced technics. This means advanced workflows are hindered as they are fed by, or feed into less advanced team members.

Further shaping technology knowledge in the profession of architecture into an uneven terrain of those in-the-know and those 'less advanced' are divisions of labour that are drawn along age or generational lines. For example, one survey respondent argues that 'seniority is correlated with technological incompetence'. Another respondent points to 'Inertia in the adoption of recent developments in technology by more senior/traditional staff', and still another argues that 'Employers want new emplyees [*sic*] with good skills but are far less interested in training existing employees to gain those skills'. This suggests bias in access to technology knowledge and skills within professional workplace contexts, connected to the assumption that a younger generation of architecture graduates will 'retool' the profession (Deamer, 2012, p. 6). This is problematic, as while graduates might well be technologically skilled, as Phillip G. Bernstein (2018, p. 14) notes, they are also 'often those with the least understanding of the implications of those tools'. And with little to no professional industry experience, this places a significant burden on graduates to act as agents of technological diffusion and organisational change. Aptly borrowing a term from computing, Randy Deutsch (2019, p. 2) describes an emerging class of design technology specialists and leaders in the profession of architecture as 'Superusers' who seek to automate the industry through computational tools and processes. The Superuser, according to the architect and developer of Autodesk's Dynamo BIM software Ian Keough, is:

> [a] heroic character as she fights the often backwards and inept processes by which buildings are designed and constructed ... but also a melancholy character in that she works in an environment which is often unable to fully perceive her value or compensate her commensurate with her contribution both to the firm and to the profession. (Keough, 2019, p. xii)

According to the survey data, the 'Superuser' figure is already facing hostility and pushback from more experienced architecture employees, with one man in the 45- to 54-year age range arguing that 'older technology such as AutoCAD and a pen is just as relevant for documentation ... scripting is a tool and doesn't convert to working drawings. Universities are putting out architects who can't draw, document or conceptualize without a computer', and another stating that '... an over reliance on Computer Technology is producing graduates that are not able to draw & sketch and detail'. Associating technological competence or capability with young or graduate employees and hiring-in skill as opposed to re-skilling an existing workforce further emphasises the shift of risk, responsibility and career management onto the individual.

Most problematically, as Jarrett (2016, p. 166) notes, is that when labour practices are conflated with personal endeavour and become 'deeply embedded in personal and social identities [they are] not "experienced" as alienating impositions'. This deceit is also central to Duffy's (2016, 2017) notion of aspirational labour, which draws focus to how the uncompensated and independent work of social media labourers is incentivised in several key ways. Social media labourers routinely invest in yet-to-be-compensated present-day productive activities based on the promise of future—yet rarely guaranteed—career opportunities or rewards, but also on the basis of the '... much-venerated ideal of getting paid to do what you love' (Duffy, 2017, p. 4). This refers to a common adulation for work in the creative industries (McRobbie, 2016) where the notion that self-sacrifice will breed creative opportunity and thus self-fulfilment is a key contrivance designed to motivate individuals in both salaried and unsalaried contexts to contribute free labour. So, while salaried architecture professionals are protected by an award wage that determines national minimum rates for hourly pay commensurate with qualifications and years of experience, this becomes irrelevant if employees tacitly ascribe and shift certain activities outside of paid working hours status and/or frame them as pursuits of passion and creative fulfilment. McRobbie (2016) argues that such approaches evince a covert means of labour reform that undermines the basic conditions and rights of workers traditionally afforded by salaried work in the modern workplace. These perspectives find ready translation to the professional context of architecture, where the invocation of lifestyle appeals and idioms of 'doing what you love' have long been systematically perpetuated in both educational and professional architecture contexts (Deamer, 2012; Parlour, 2014; Deamer, 2018). And this is further underscored in Keough's (2019, p. xi) characterisation of the Superuser as an architecture/ design technology labourer who, in his opinion, does not 'self-identify' as a Superuser because '[f]rom their perspective, they're just having fun solving challenges and saving people time'.

Yet, do those survey respondents who nominated that they self-train in architecture technology invest in self-directed training on the premise of *potential* career gains? Have those who indicated skills competencies in more computationally intensive software self-trained outside of normal work hours because they are *having fun* and *doing what they love*? The survey data alone cannot answer these questions and its limitations in this sense are not insignificant. A voluntary survey is always inherently limited by who chooses to respond, as well as by the questions that inevitably shape the nature of the information collected. Furthermore, the data collected in this survey captures a snapshot of a point in time that is perhaps a pivotal moment. Repeating the survey in, for example, two years could be further instructive in this regard. However, this method cannot fully account for the potentially diverse range of individual experiences of technology engagement and use in professional architecture contexts and the range of social and cultural differences that intersect with gender that might factor in shaping these experiences. Left unanswered, then, are questions concerning the subjective dimensions of architecture technology labour—these are best suited to future in-depth interviews. Interview and narrative methods can further open up understandings of how and why people personally engage and invest in certain technologies and not others, to work towards revealing and articulating socio-organisational as well as interpersonal power relations.

conclusion

As architecture intersects with computer science to engage with large-scale data sets and informational systems, this demands new skills, competencies and commitments. This research has explored questions about how, who and to what extent those in the profession of architecture are investing in technology knowledge and skills development. The data collected in this survey builds a profile of contemporary architecture technology labour in an Australian context. It points to a gendered distribution of labour in terms of those engaging with more computationally intensive technology and in relation to technology leadership roles. It further reveals that although technology skills are highly valued, skills development is a largely unstructured and self-directed enterprise. When asked about the barriers to technology knowledge and skills, the respondents report an overwhelming sense of time poverty that further informs a prioritisation of project time—which is more conventionally 'billable'—over technology knowledge and skills development time which is indicated as a 'personal' and individual obligation. While gender norms and stereotypes about technology do not figure in any explicit sense as barriers to technology knowledge and skills development in the survey responses, notions of exclusion are expressed as a generational issue.

Bringing feminist technology perspectives and digital labour concepts to bear on the analysis of this data has provided an important alternate framework and language to situate architecture (technology) labour in a wider narrative. From here it has been argued that the drive to computationalise architecture rests heavily on discretionary, aspirational and invisible labour practices that can disadvantage certain social groups. This draws focus to a question of who is capable of investing in technology knowledge and skills training in the profession of architecture, as well as on what basis; as one respondent notes, 'some get time to explore and others get left behind'. The pervasive sense of professional employee time poverty reported here, seen in relation to global statistics that indicate women in paid work continue to carry much of the burden of domestic unpaid labour, suggests that a professional woman's capacity to pursue technology skills and knowledge is deeply entangled with and compromised by the gendered dimensions of the domestic sphere. In this way, that more men than women engage in the architecture technology sector appears to be less about computing technology aligning to feminine or masculine sensibilities, and more about the ways discretionary time is deeply gendered. This matters particularly when larger political and economic trends mobilise notions of 'life-long learning' and 'a work regime of constant training' (McRobbie, 2016, p. 9) that in turn destabilise traditional notions of careers, secure professions and professional work. Understanding how opportunities to develop technology skills in architecture are being negotiated inside and outside of organisational contexts is necessary to redressing the perpetuation of uneven career opportunities. This further contributes to highlighting how, within the Australian workforce, the structural role of employers remains significant to maintaining equal opportunities and equitable working conditions in the shift towards digital workplaces. As Wajcman (2010) reminds us, this is not a 'women's problem'; technologies, institutions, organisations and subjectivities need to be reshaped together.

acknowledgements

I would like to extend my thanks to the anonymous reviewers and the Feminist Review guest editors who provided many constructive comments that helped shape this article. Thanks also to my Research Assistant Matthew Trilsbeck and to the architecture practice participants and survey respondents. The ethical approval of this research (No. HC17507) was granted by the UNSW Human Research Ethics Advisory Panel (HREAP) Executive.

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