Architecture-Human-Machine (re)configurations

Examining computational design in practice

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This paper outlines a research project that explores the participation in, and perception of, advanced technologies in architectural professional practice through a sociotechnical lens and presents empirical research findings from an online survey distributed to employees in five large-scale architectural practices in Sydney, Australia. This argues that while the computational design paradigm might be well accepted, understood, and documented in academic research contexts, the extent and ways that computational design thinking and methods are put-into-practice has to date been less explored. In engineering and construction, technology adoption studies since the mid 1990s have measured information technology (IT) use (Howard et al. 1998; Samuelson and Björk 2013). In architecture, research has also focused on quantifying IT use (Cichocka 2017), as well as the examination of specific practices such as building information modelling (BIM) (Cardoso Llach 2017; Herr and Fischer 2017; Son et al. 2015). With the notable exceptions of Daniel Cardoso Llach (2015; 2017) and Yanni Loukissas (2012), few scholars have explored advanced technologies in architectural practice from a sociotechnical perspective. This paper argues that a sociotechnical lens can net valuable insights into advanced technology engagement to inform pedagogical approaches in architectural education as well as strategies for continuing professional development.

Keywords: *Computational design, Sociotechnical system, Technology adoption*

INTRODUCTION

"...our lived experiences with technologies never quite mirror the overly optimistic or pessimistic descriptions of their effects" (Ratto 2011, p.253).

What does it mean to talk of advanced technologies in contemporary professional architectural practice? In one sense, the umbrella term computational design captures a wide and allied set of advanced technologies and technology-related practices, from parametric models, generative algorithms, and simulations, to digital fabrication technologies. Definitionally, and in an architectural context, computational design thinking and methods are often framed as antithetical to computer-aided design (CAD) approaches, and by virtue of this are typically afforded a more 'advanced' status. That is, while CAD is reasoned as the digitisation of extant and habitual architectural practices largely unchanged since the Renaissance, scholarly and journalistic accounts position computational design thinking and methods as those that are, by contrast, significantly reconfiguring architectural design practices and processes (Bredella and Hofler 2017; Carpo 2017; Celanto 2007; Gerber and Ibañez 2014; Hensel 2013; Leach and Yuan 2018; Menges 2015; Menges and Ahlquist 2011; Picon 2010, 2015; Scheurer 2010; Sheil 2005, 2008; Tedeschi 2014; Terzidis 2006). While much emphasis is placed on articulating the affordances of computationally transformed design practices in architecture in terms of performative and responsive buildings, enhanced material knowledge, and the romantically charged ideal of the (re)empowered designer/-maker, far less attention has been directed towards the ways computational design thinking and methods are actually being *put-into-practice*, and by extension, their social implications. Given this, the research study described here adopts a sociotechnical perspective and empirical research methods in order to bring into view the potentially messier and more obstructive 'everyday' realities of advanced technology engagement in architectural professional practice contexts. Tracing everyday perspectives can operate to transcend the rhetoric of radical and positive disruption that is oft-associated with emerging technologies, to inform new models of learning and post-professional development initiatives. The following sections of this paper outline the overall study's theoretical grounding and methodological approach, including an initial survey and its findings, and their implications for understanding everyday computational design culture in architecture.

THEORETICAL FRAMEWORK: *A SOCIOTECHNICAL LENS*

The sociotechnical lens adopted in this research draws on theories and concepts from science and technology studies (STS) and the field of human computer interaction (HCI) that align more generally to a social constructionist paradigm. From this perspective, technologies, technological systems, and social orders are seen as co-created or mutually constitutive (MacKenzie and Wajcman 1999). Put another way, the notion of technology, whether framed as an artefact, body of knowledge, practice or system, is reconceptualised as a social construct (Bijker et al 1987; Suchman 2007; Suchman et al. 1999). While aligning to these general principles, the term 'sociotechnical system' more specifically refers to the study of work practices and organisational relationships in the context of technological change (Trist 1981). A key premise of sociotechnical systems research is the recognition of the interdependence of systems of work and the social environment. This advances the projective notion that by understanding the interaction between humans, machines, and the environmental aspects of the work system, pathways to affect change and improve situations can be forged.

While an existing body of scholarship has examined the culture of architectural practice from a sociological perspective and through ethnographic approaches (Blau1988; Cuff 1991; Matthewson 2015; Whitman 2005), with the notable exception of Daniel Cardoso Llach (2015; 2017) and Yanni Loukissas (2012), few have explored the implications of advanced technologies in contemporary architectural practice from a sociotechnical perspective. Recasting computational design through a sociotechnical lens reveals it as a system of interdependent relationships between humans, machines, and software, as well as disciplinary and organisational hierarchies, structures, and cultures. This creates a space to explore a different set of questions around the ways individual, disciplinary, and organisational notions of architecture are challenged by, but also challenge, resist, and influence the ways computational design thinking and methods are put-into-practice. From here, it is further possible to consider questions of agency in relation to technology-related shifts in the architectural profession, and of the stasis, redundancies, or changes in the social distribution of design work (Loukissas 2012). The question of (re)configured agency is significant here given computational design practices in architecture are described as increasingly significant to "negotiations of jurisdiction in architecture" (Loukissas 2012, p.17). Yet, while computational design may well constitute a burgeoning site of control and influence, it is also argued to be a key area of architectural practice wherein gender inequity is amplified (Davis 2014; Doyle and Senske 2017).

RESEARCH METHOD

If, as a number of scholars have more recently argued, access to technology and knowledge about technology in contemporary architectural practice is unevenly distributed (Davis 2014; Doyle and Senske 2017), it is a claim that finds scant empirical evidence. Computational design practices might be well accepted, understood, and documented in academic research contexts, but the extent and ways they are put-into-practice in the architectural profession is an inchoate research domain. Addressing questions of influence and extent, numerous studies in the engineering and construction fields, have examined technology adoption since the mid 1990s with a focus on measuring information technology (IT) use (Howard et al. 1998; Samuelson and Björk 2013). Similarly, examples of architectural research that have focused on the professional implications of advanced technologies have also quantified IT use (computers, software, and networks) (Cichocka 2017), and in other examples adopt case study approaches to explore specific technology-related practices such as building information modelling (BIM) (Cardoso Llach 2017; Herr and Fischer 2017; Son et al. 2015). Alternatively, Daniel Cardoso Llach (2015; 2017) and Yanni Loukissas (2012) have both undertaken more targeted "ethnographies of technologies-in-use" (Suchman et al, 1999, p.404-405; Suchman 2007). These examples follow HCI researcher Lucy Suchman's (2007) call for a commitment to "situated action", that concerns the examination of sociomaterial assemblages at the scale of human/nonhuman 'intra-action'. Suchman's (2007) conceptual distinction between intra-action and interaction is important here as it highlights how the recursive production of human/nonhuman subjectivities occurs through their encounters with each other (p.267). For Suchman (2007) it is in this space of intra-action, or practice, that "agencies-and associated accountabilities-reside" (p. 285). So, while quantitative methods are a productive way to identify, but not necessarily explain overarching patterns of technology-use, qualitative approaches can provide rich accounts of situated practices of technologies-in-use to address questions of influence and agency.

To begin to draw out sociotechnical configurations in architectural practice contexts-and their possible reconfigurations-this research has accordingly adopted a mixed-methods approach. This commenced with the design and implementation of an anonymous online scoping survey that aimed to understand the current extent of advanced technologies skills, knowledge, and applications in architectural practices and their perceived value, with the view to drawing out key themes to inform subsequent interviews and ethnographies of technologies-in-use. The survey questions were informed by a literature review and the aforementioned theoretical framework. The survey was made available online between August to December 2017 to employees of five larger-scale (considered >100 architectural employees) architectural practices in Sydney, Australia, who had provided written consent to participate in the research study. Recruiting participants through professional practices as opposed to, for example, an institutional membership body such the Australian Institute of Architects, reflects a purposive sampling intent based on the assumptions that larger-scale practices are likely to engage with advanced technologies for architectural work, and that those engaging with advanced technologies in architectural practices may not necessarily identify as architects. In short, this approach seeks to capture the diversity of architectural employees. This is further reasoned to offer ways to reflect on the similarities and/or differences in responses across multiple practice contexts. The survey included 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.

SURVEY FINDINGS

The survey structure comprised three key sections including general demographic data, technology skills and knowledge competencies, and attitudes towards technologies. The first section of the survey collected general demographic data about the respondent's age, gender, educational and professional qualifications and level of work experience [Table 1]. The following section asked questions about technology skills competency levels, and learning avenues. The final section asked questions about attitudes towards the value of engaging with advanced technologies in architectural practice. The general characteristics of the survey sample, as set out in Table 1, indicate that the majority of survey respondents identified as male, were aged between 25-34 years, hold a Master's level qualification, and have greater than 15 years of relevant industry experience. The survey then asked respondents to identify the software programs they used in their current workplace from a list of 16 options [Figure 1] as well as to rank their own competency levels. Notably, Figure 1 indicates a clear dip in responses to software use from examples such as Excel, Revit and AutoCad, to those who indicated the use of visual programming software such as Grasshopper and the programming language software Python. Those who indicated they used Grasshopper at an intermediate to advanced skill level varied in age, education levels, and years of industry experience, however 89% of these respondents identified as male. Similarly, while those who indicated they used Python at an intermediate to advanced skill level varied in age, education level, and years of industry experience, however 100% identified as male.

Having identified software and emerging technology use in their workplace, the survey asked respondents to indicate how they learned their software skills and knowledge [Figure 2]. A high number of respondents identified their software skills and knowledge as having been 'self-taught' and/or indicated they had used online tutorials over more formal modes of training. A subsequent question asked respondents to reflect on how new software skills and/or knowledge of emerging technologies are encouraged in the workplace. Responses to this question again pointed to less formalised technology-knowledge transfer in the form of in-house training and co-worker encouragement mentoring.

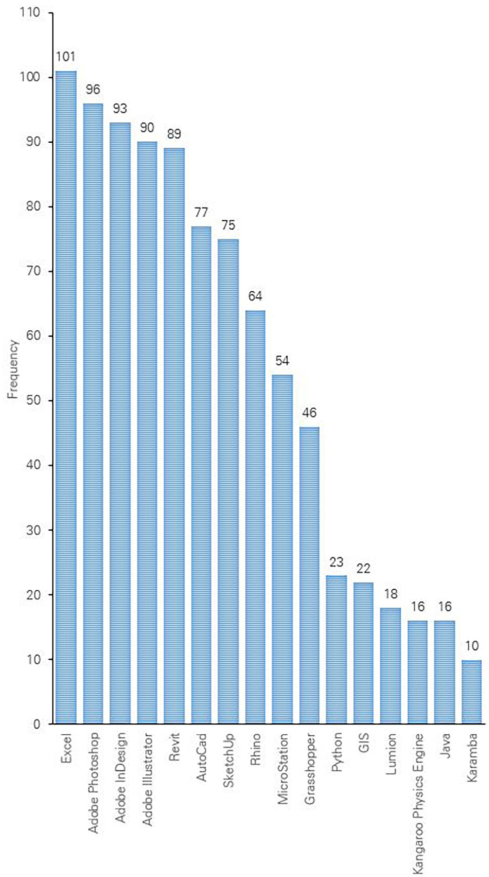


Figure 1
Responses to survey question 8. Indicate which of the following software programs you use in your current role

Table 1
Demographic attributes of survey respondents

Demographic attributes of the survey respondents

Characteristic	Number[1]	Percent
Gender		
Male	65	63.7
Female	35	34.3
Other	2	2.0
Age		
18 - 24 years	6	5.9
25 - 34 years	44	43.1
35 - 44 years	31	30.4
45 - 54 years	12	11.8
55+ years	9	8.8
Education		
Year 12 or equivalent	1	1.0
Undergraduate diploma	1	1.0
Associate diploma	2	2.0
Bachelor degree (incl. honours)	40	39.2
Postgraduate diploma	6	5.9
Master's degree	50	49.0
Doctorate	2	2.0
Years of experience (in industry)		
0 - 2 years	7	6.9
2 - 5 years	18	17.6
5 - 10 years	23	22.5
10 - 15 years	23	22.5
15 + years	31	30.4
Employment Status		
Architectural Graduate	32	31.4
Registered Architect	42	41.2
Architectural Technologist	3	2.9
Associate	1	1.0
BIM Manager	4	3.9
Business Development	2	2.0
Computational Designer	10	9.8
No Response	8	7.8
Time in current position/role?		
6 months	13	12.7
1 year	15	14.7
2 years	19	18.6
3 years +	55	53.9

1. Number of participants n=102

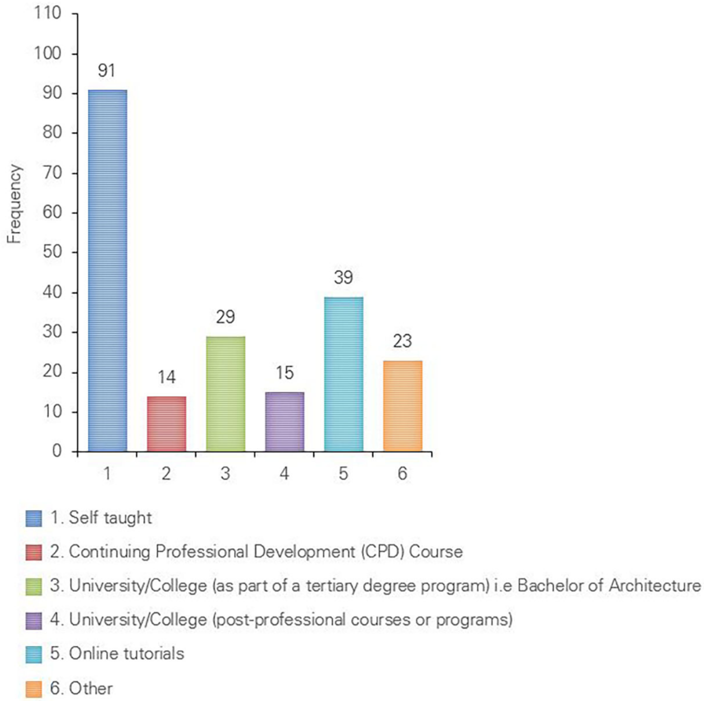
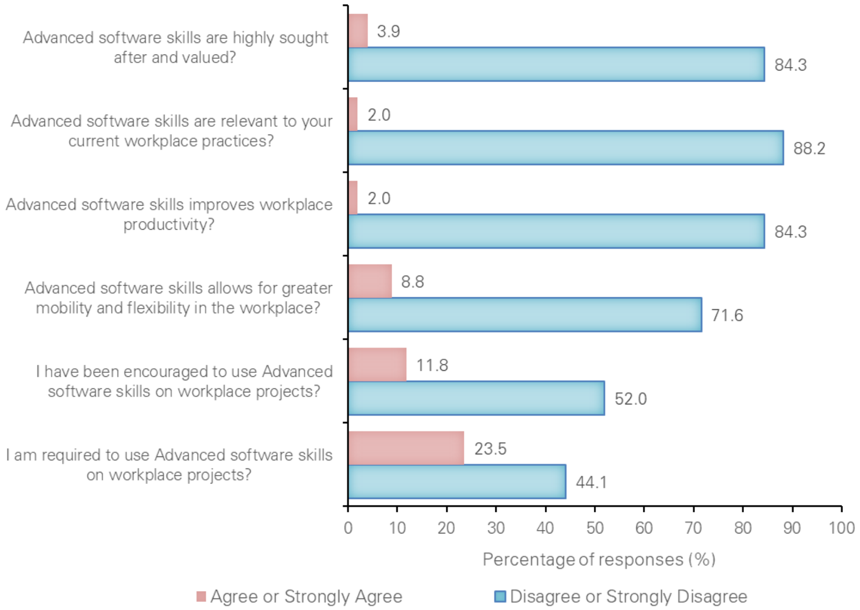


Figure 2
Responses to survey question 9. Select which option(s) best describes how you acquire software skills or knowledge

The last section of the survey posed a series of Likert scale questions on individual attitudes towards the value of engaging with advanced technologies in architectural practice. Respondents were asked to indicate their level of agreement to a range of statements from strongly disagree, to strongly agree [Figure 3].

The final question of the survey posed an open-ended question asking respondents to identify the key barriers to attaining advanced software skills and/or knowledge of emerging technologies in their architectural workplace. This captured insightful responses that were coded into seven main categories including Time, Leadership, Technology knowledge, Project opportunity, Cost, Knowledge equity, and Technical complexity [Figure 4]. Multiple respondents identified architectural project demands on their own time as a key barrier to developing advanced software skills and knowledge of emerging technologies. In one example a survey respondent argued that "...there is often so much project work that time for training does not exist", while another commented that, "it is hard to commit time outside of work hours to attain advanced skills". Another respondent attested that "It is up to the individual, not the company to acquire [technology] knowledge", yet that this also relied on a practice investing cost and time for training. That it is the individual employee's responsibility to make time away from the demands of everyday architectural practice to pursue the development of technology-related skills, further points to the general view of technologies and technology-related knowledge as peripheral to everyday architectural work. This is echoed in the closely related second, third, and fourth iden-

Figure 3
Responses to survey question 13. what is your perception of the value of advanced software skills in your workplace?



tified barriers that describe constraints related to organisational leadership, technology knowledge, and project opportunity. Respondents indicate that organisational leaders lack knowledge of the value of new technology-related skills and practices, do not encourage or mandate training, and that architectural projects rarely provide suitable contexts to learn and test advance technology-related practices.

Notably, several responses to Question 16. related to the issue of knowledge equity. In one example, a respondent observed that “some staff are given the time to explore technology and others fall behind”, while another described “less advanced team members” as hindering the uptake of new software skills, processes and knowledge more generally. Respondents further pointed to the need for technology skills training to target “whole team” or project-based groups. Overall, the Question 16. responses highlight the multiple ways that the pursuit of technology innovation and technology knowledge transfer in an architectural context finds attitudinal resistance at both individual and organisational levels. One respondent commented that “design professionals seem to loath any type of data which structured”, suggesting a reluctance to view architectural design creativity on any other terms. Additionally, a number of responses to the final open-ended question of the survey echoed entrenched disciplinary and professional ideologies, and namely, viewing the relationship between architecture and technology as a human and non-human divide. In this way, rigid ideas of ‘the architect’, architectural practice, and notions of creativity all contribute to pre-inscribing acceptable territories in which new technologies and technology-related practices are permitted to occupy. For example, one respondent offered the view that new graduates that attain computational design skills do so at the expense of gaining more “practical knowledge” related to construction and documentation. In another example the respondent, perhaps misguidedly, stated that "scripting is a tool only and doesn't convert to working drawings".

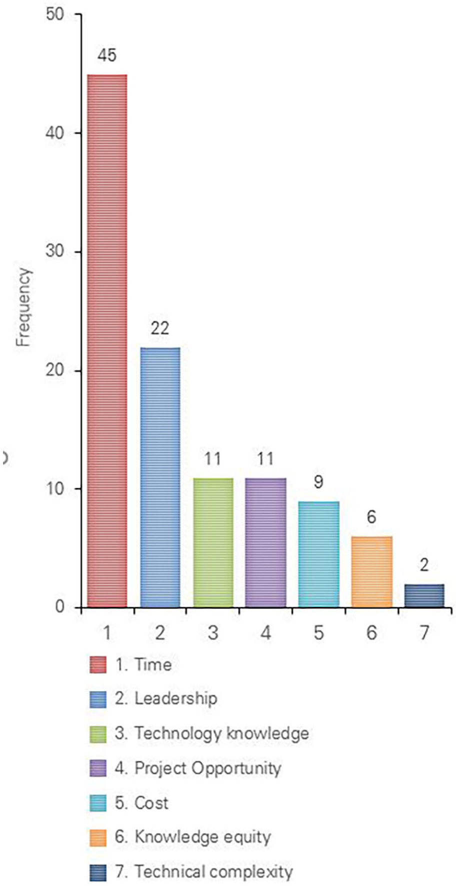


Figure 4
Responses to survey Question 16. What are the key barriers to attaining advanced software skills and/or knowledge about emerging technologies?

DISCUSSION

Overall, the survey data suggests that respondents value technology-related skills and knowledge in and for architectural work, however do not necessarily have the time, organisational support, nor knowledge and infrastructural resources to productively and confidently engage with more advanced practices. This is underscored by the limited number of respondents engaging with what are defined here as more advanced software practices [Figure 1], together with the high number of responses [Figure 2] that indicated their software skills were 'self-taught'. This further supports the view that workplace organisations and hierarchies-structures, human resources, leadership and attitude-are significant determinants to advanced technology uptake (Son et al. 2015). Equally, these findings can be argued to uphold suggestions that access to technology and knowledge about advanced technologies in and for contemporary architectural practice remains unevenly distributed (Davis 2014; Doyle and Senske 2017).

While the research survey netted 102 complete responses it cannot be taken as statistically significant, nor representative of the general architectural profession. Additionally, it is necessary to acknowledge the fundamental limitations of survey methods that include the questions asked, the ways the questions are asked, and who ultimately chooses to answer them. It is challenging to motivate people to voluntarily fill in surveys, and in recruiting practices to participate in this research study, one declined on the basis of 'survey fatigue'. Most obviously, this survey is limited to the employee's perspective, and cannot necessarily account for an organisation's or managerial point of view. Nonetheless, a survey is a useful exploratory method, and the findings discussed here establish a basis to pursue and inform subsequent stages of qualitative research including semi-structured interviews, and ethnomethodological studies of technologies-in-use in architectural work sites (Suchman 2007).

CONCLUSION: *AGENCY AND OPPORTUNITY*

This paper has outlined a research project that adopts a sociotechnical lens to explore the culture of computational design in architectural practice. This has asked questions about how individuals access, engage in, and perceive technologies in contemporary architectural workplaces. This approach provides an alternate, and empirically-oriented vantage point from which to begin to critically examine discursive premises that variously argue computational design constitutes a radically transformed design practice, is of growing import to the negotiation of creative and organisational control in architecture and is a knowledge and skills domain wherein inequities remain pronounced. While the survey findings more generally suggest that individuals in architectural practices highly value advanced technology skills and knowledge, the data collected on technology skills, knowledge, and competencies points to a more restrained and delimited engagement with advanced technologies. With regard to 'who' is engaging with advanced technologies, the overall survey respondents identified as 64% male and 34% female (Table 1), however respondents indicating they engage with more advanced, computational software practices for architectural work largely identified as male. Respondent comments that addressed the perceived barriers to technology engagement in architectural practice strongly gestured towards a paucity of organisationally-led training, and by extension, an uneven distribution of advanced technology knowledge and skills. The comments further allude that advanced technology knowledge and skills are 'opportunities' that can be afforded to some individuals and not others, and that in the latter case, this then places significant onus on the individual to self-learn.

The notion of technology knowledge equity, that can be perhaps more inherently addressed in tertiary learning environments, emerges as a significant challenge for continuing professional development, this, as well as questions around the pursuit and motivation of technology-related changes to ways of working in architecture, and the corollary of technology-aversion (Carpo 2018), are subjects worthy of further research. As Wes Jones' (2014) asserts, historically architecture has self-interestedly expected new technologies and technology-related practices to enhance the discipline without wanting to entertain the attendant implications of organisational change (p. 29-30). Optimistically, that technological changes to ways of working *can* trigger 'occasions' for reconfiguration (Barley 1986) (albeit in heterogenous ways that are contingent on the structure of workplace contexts), also suggests unique opportunities to disrupt the status quo and to redress existing exclusions, biases, and inequalities. And it is from this perspective, that this research intends to continue to look inside everyday professional architectural contexts to locate occasions for reconfiguration, and the "conditions for action and possibilities for intervention" (Suchman 2007, p.276).

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