

UNSTABLE BUILDING: VIRTUAL ENVIRONMENTS AND REAL RELEVANCE

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SUMMARY: Design is often romanticised as a solitary pursuit and the pedagogical framework within educational environments often cements this perception with the demand for individual student assessment. In popular journals the architect as artist is celebrated for singular vision and the tenacity to realise that vision. However, in practice as designs evolve into construction the process becomes decidedly collaborative, with engineers, interior designers and contractors contributing unique parts as the design evolves to accommodate revision and change. This paper will bring evidence to bear that suggests the value in using Virtual Environments (VE's) is in their potential to facilitate collaboration, and not just in the popularised phenomenon of 3D or 4D model creation. We use design theorist Brian Lawson's design problem/solution mapping of *analysis, appraisal* and *synthesis* as a framework to scrutinize design and construction in the VE Second Life. Within this framework we draw on philosophical reflects by Ludwig Wittgenstein and appropriate cultural theory from Richard Sennett, Mary Douglas and Lewis Hyde. Which provides a theoretical underpinning to our observational evidence that suggests VE's contribute to Lawson's constituents of analysis and appraisal as well as 3D synthesis. Striations, breakdown and friction are brought to centre stage during collaboration in this virtual environment; we argue these facets to collaboration have value for emergent designers as important source of opportunity and innovation. Observations challenge attempts by popular collaborative software to expunge these clashes and conflicts from the design and construction process. VE's bring breakdown and conflict into focus, sensitising emergent practitioners to it's inherent potential for both problematic conflict and creative opportunity. Findings suggest that VE's have considerable influence not only for verisimilitude but for simulating the fluid or 'unstable' design and construction process and promoting the development of skills that Lawson contents are fundamental to the designer and which cultural theorist Richard Sennett posits are critical to the notion of craft.

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1. ANALYSIS: THE LANGUAGE OF DESIGN AND WITTGENSTEIN'S GAME

This section of the paper will interrogate the theory of play before using it to examine a test case in VE design. Design theorist Brian Lawson explains 'analysis' within his design trinity as the exploration of relationships, patterns and structures (Lawson, 2006). He draws parallels between the design process and the game of chess. For although both are rule-based systems the presence of boundaries, regulation and rules do not preclude opportunities for creativity and innovation. Design theorist Richard Coyne has exposed the notion of play to further scrutiny; he invokes the philosopher Ludwig Wittgenstein to claim it has relevance within design and construction. Coyne (2007, p. 71) resists framing design as a methodological or systematic process of rigid causal relationships, he goes further than Lawson to argue that design is essentially a hermeneutic or dialogic game, where meaning and understanding are in constant flux.

1.1 Boundaries

Wittgenstein claims one of the main learning outcomes from play is an awareness of the game boundaries. According to Wittgenstein (2003, p. 28-29) it is here—as the boundaries of the game become blurred and indistinct—we begin to recognise where advantage can be gained during play. Boundary transgression has strong cultural and historical association with danger according to anthropologist Mary Douglas (1978). The Ronan Point apartment collapse in the UK attest to the dangers of recent boundary transgression in design and construction, where early attempts at bringing pre-fabrication across the disciplinary threshold from manufacturing to construction ended with fatal consequences. However, boundary transgression also has strong associations with creativity and innovation. Hermes the messenger God is found promoting commerce at the threshold between Gods and mortals. The cultural critic Lewis Hyde (1998) has written at length about 'trickster' figures of various cultures, which are found at crossroads and other locations where they might unexpectedly cross someone's path and find an opportunity to be seized. These opportunists are found at boundaries because this environment has a propensity for revealing the unexpected. While this location promotes newness and innovation it can have adverse effects on situations—like construction—that rely on a high level of prescription. Design and construction mitigate the unexpected with rules, procedures and regulations that promote a predictable design and construction process. Thus reducing the risk of incidents like Ronan Point.

Nevertheless play has relevance in this context as a mechanism that not only establishes rules but also sensitises participants to where rules and boundaries begin to blur and where—according to Wittgenstein—a creative edge may be gained. Arguably we see this behaviour already in contemporary design such as Mark Burry's (2005) work on Gaudi's Sagrada Família, which blurs the distinctions between design, architecture, manufacturing and programming; or the design firm *designtoproduction* (<http://www.designtoproduction.ch>) who are working with Shigeru Ban on the new Pompidou Centre in France, this design practice is comprised of a computer scientist and architect. In these examples the established design and construction sequence, or the design team do not adhere to normative industry conventions. Technological development has progressed in parallel with architectural innovations during the Twentieth century. The roof of St Pancras Station in London, the Sydney Opera House in Australia and more recently Zaha Hadid's Phaeno Centre in Germany are buildings where material technology and engineering has been critical in the design and construction of these buildings. It could be argued they are iconic because during their design and construction, disciplinary boundaries between—for example art, architecture and engineering—have momentarily been transgressed or blurred.

Transgressions such as these are increasingly common in digital environs. They have been popularised by 'mash-ups,' where someone mashes together two or more unconnected Web 2.0 technologies. Helsinki City Transport is one such example, which has appropriated Google maps and GPS technology to produce a 'live' bus map. Increasingly application developers are capitalising on this digital transgression by releasing application-programming interfaces (API's) and software development kits (SDK's), allowing the public to appropriate their applications to create new ones. This culture of appropriation and innovation is flourishing in digital environs with—for example—the iPad SDK released simultaneously with the iPad to encourage new applications and unanticipated functionality. We suggest this spirit of innovation and appropriation found within this digital culture are migrating to the design process. By supporting key aspects of Wittgenstein's supposition regarding play, they promote the blurring of disciplinary boundaries and attune participants to seek advantage and seize resultant opportunities.

1.2 Bending design rules

A second lesson to be gained from play—according to Wittgenstein—is an understanding of rule-based organisational systems. Play provides a framework for understanding when and where rules can be selectively applied or ignored. The theorist Richard Sennett has noted this behaviour in ‘experts’ such as diagnosticians (Sennett, 2008, p. 246-249). While novices in this field adhere strictly to the rules and protocols of diagnosis the experts do not. Sennett singles out the expert’s sensitivity to seemingly unrelated symptoms and details that enable the recognition of particular procedures that might be relevant, which they move directly to. An intimate understand of the rules and constituents of a problem would seem to be paramount, particularly if an advantage is to be gained from breaking them.

Returning to design and construction, the making of a building is a highly complex procedure and instruments such as the UK’s RIBA Plan of Work (Cox and Hamilton, 1995) prescribe much of its execution. However, successful design and construction can also be found breaking away from these protocols. Lawson cites architect Eva Jiricna, who does not adhere to the RIBA Plan of Work and progress from general to detailed design, she begins the design process by resolving the detailed juxtaposition of material. Only after sympathetic juxtapositions have been resolved will the designer then progress to resolve general spatial configurations; Carlos Scarpa’s detailed design at Castelvechio is informed by manual craft techniques for shaping timber; Libskind’s Jewish Museum in Berlin is perhaps the most recent radical departure from design protocol and procedures where sloping floors, ceiling and skewed walls are use to deliberately disorientate. The entrance and layout arrangement contradicts standard principles of way finding, which makes orientation within the building problematic. This is Libskind’s intention, however it is arguably the designers understanding of these design rules that contributes to his success at breaking them.

Valid reasons for the proliferation of rules and protocols in design and construction have been widely discussed by other scholars (Schmidt and Wagner, 3002, Ruddock, 2006, Peansupap and Walker, 2005). It is a complex environment were hundreds of people and dozens of companies coordinate their efforts over the course of months to construct a building, which has to conform to many regulations. While good construction practice is associated with rules, bad construction practice is by default associated with breaking them. However, as the previous examples attest innovation during design and construction can also emerge from bending and breaking these rules.

Digital technology is synonymous with breaking rules through hacking hardware and software. Websites such as MAKE (<http://makezine.com/>) and devices such as Arduino (<http://www.arduino.cc/>) represent a continually increasing community with the ability to hack hardware and software and the willingness to share this knowledge. As we shall see in the following section, with considerable online communities and resources, VE’s present an environment in which participants are more attuned to these behaviours, and are potentially a valuable testing ground for these more arcane skills of design.

1.3 The Living Sketchbook project

The ‘living sketchbook’ is a design project that took place between March and June 2009 at the University of Auckland in New Zealand. It was conceived in the spirit of the designer’s sketchbook, which has historically been part of the artist and architects toolkit and is a dynamic tool that supports design process rather than the final product. The VE chose for this project was Second Life as it facilitated collaboration, simple design components and also elementary programming possibilities.

1.3.1 Boundaries

Boundaries were established and negotiated; the class of 100 students all occupied a single virtual space. This is in stark contrast to typical engagement with design technology where a student or practitioner would usually work in isolation within a CAD program. Simultaneously the students were also negotiating disciplinary boundaries, most notably between architecture and programming. Most of the class engaged with some computer coding, adding reactive or animated properties to the environments they were creating. One project illustrated in Fig. 1, chose to be a learning environment. The project designers created a series of space that prompted participants to change the code that was generating the space, create objects and appropriate the designers code to create new objects. Occupants of this space could then learn about design through programming by ‘reprogramming’ their space and immediately experience the effects.



FIG. 1: Participants looking at and changing code. Project by Ben Flux and Arthur Gearhead

In line with Wittgenstein’s supposition regarding play the participants were engaged in understanding the boundary between the ‘games’ of spatial design and programming. Although many of the projects remained in a playful state some participants—such as the designers of the learning environment—were quick to capitalise on the potential of this transgression.

1.3.2 Rules

Contending with rules was perhaps more problematic, as part of the attraction of a virtual environment is that ‘rules’ of the built environment can be discarded. This was taken to extremes in a project—illustrated in Fig. 2—that aimed to create a place to disorient the occupants and draw parallels with death and personal loss. The sense of disorientation was extreme, to such an extent that some participants found the experience confusing and unfulfilling. The absence of any architectural way finding cues made it a problematic space.

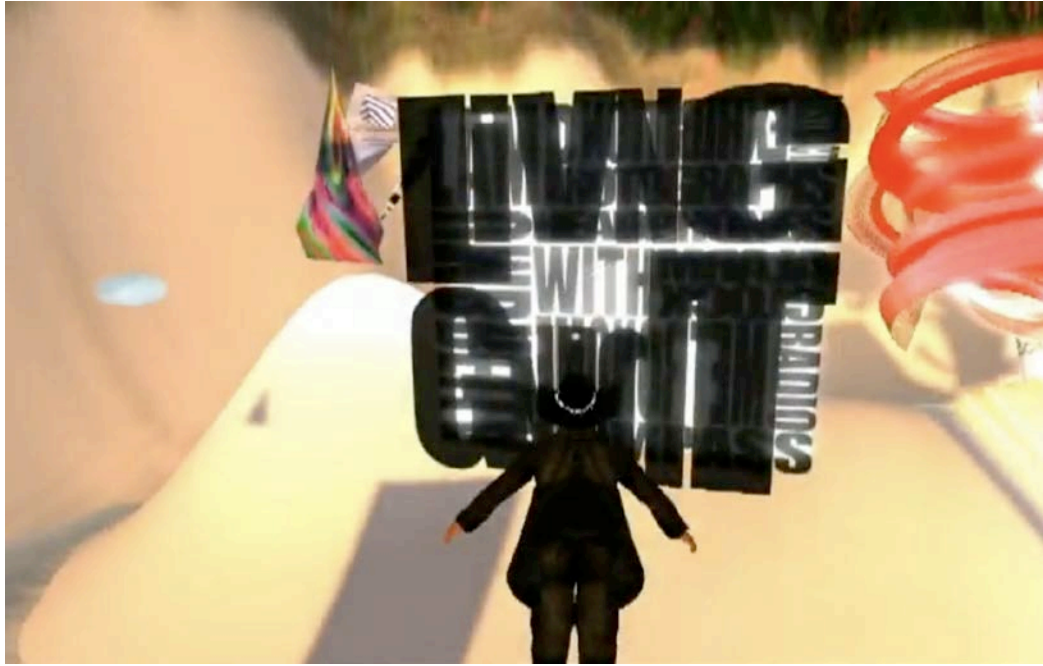


FIG 2: Environment created to disorientate and confuse.

While it is inappropriate to compare this with Libskind's venture into disorientation, it does add currency to Sennett's supposition regarding the differing ability of the novice and expert to successfully break rules. Equally poignant is the project illustrated in Fig. 3, which chose to create a 'train track' to assist way finding and movement around the designer's environment. Applying classic design rules to this VE resulted in a surprisingly prosaic experience, suggesting traditional rules also have their limits within new design/construction environments and collaborations.



FIG 3: Train track around an island. Project by Baha Bellingshausen.

Design process can be marginalised in favour of promoting imagery of seductive final buildings; this course was seeded with the notion of the sketchbook to momentarily bring design process to centre stage. There is no prescription here for successful design process just as there is no prescription for success in a particular game of chess. Just observational evidence that suggests design activity within VE's can contribute to an increased understanding of the more arcane aspects of creative practice, collaboration and inter-disciplinary activities like design.

2. APPRAISAL: PERCEPTION AND THE HERMENEUTIC TURN

This section will focus on 'appraisal' the second constituent of Lawson's design trinity. Sennett's writing on craft identifies explicit characteristics of this aspect of design, and we interrogate these qualities using philosopher Martin Heidegger's suppositions on being and the hermeneutic turn. Some of the characteristics of appraisal identified by both Lawson and Sennett are expunged within popular CAD software. Although CAD is now widely suited to verisimilitude and the documentation of production information, the Living Sketchbook project discussed in the previous section suggests that characteristics of archaic VE environments may be more effective for promoting appraisal as part of the design process.

2.1 Strategic moves

Lawson invokes the highly sophisticated and skilled game of chess to help explain appraisal. Liking it to the player's ability to consider their current move in regards to both the confined current situation and the broader goal of winning the game. The strategic move may be to sacrifice a piece or change strategy, momentarily disadvantaging the player in lieu of long-term gain. Notwithstanding the subtext of sophistication and intellectualism that the game of chess invokes, Lawson's example is also suggestive of scale. For any given move, the micro-scale of an immediate context may conflict with the macro-scale of the overall aim to win the game. The question of *how to move* is intertwined with the question *why to move*. Sennett contests that moving between these scales of perception is key to notions of art and creativity often theorised in terms of *techné* and *poiesis*.

Theorists Deleuze and Guattari suggest there is a tension between the micro and macro scale, which they couch in terms of the smooth and striated. Within design and construction this resonates with Sennett's suppositions regarding how and why to progress design and construction, which are—arguably—questions of observational scale that often conflict with each other. As within the game of chess these questions are conjoined and success is achieved by contending with both.

Unlike design, construction is often perceived as unwieldy, much of the current research typically aims to increase systemisation and procedure (Amaratunga et al., 2001, Bowden et al., 2006, Cushman and Cornford, 2003, Roy et al., 2005). Problem identification and resolution receives particular attention, as they can be costly if not identified and acted upon. Observations on construction sites point group problem solving during construction being frictional; although evidence suggests it is effective (McMeel, 2009); competing positions and conflicting suggestions slowly converge before a solution is found. We couch this in terms of Heidegger's hermeneutic turn where—during group problem-solving—any participants understanding and perspective on a problem is incrementally changing as participants discuss their needs, objections and alternatives.

2.2 Striations between how and why

Sennett suggests history has created a schism between the questions of how and why. He claims *poiesis* or craft has been diminished by its historical fracturing into the components of practice and theory. Invoking Hanna Arendt, Sennett (2008, p. 6-8) frames this as *Homo faber* or man as maker, and *Animal laborans* or the drudge of routine. *Homo faber* is the theorist who asks why, while *Animal laborans* is the practitioner who asks how; it is necessary that the craftsman can ask both. We use the term craftsman in its broadest sense, the designer, programmer or builder can all exhibit characteristics of craft in their work. According to Sennett historical development has marginalised the practitioner in favour of the theorist, however our contemporary condition—he suggests—has much to gain from a resurgence of making and a more equitable relationship.

Current involvement with technology would seem support this, with recent publications privileging making as much as the designing (Kolarevic, 2003, Kolarevic and Klinger, 2008). Computer Numerical Control (CNC) routers and robotics are being employed and bringing designing and making closer together, creating a resurgence of craft. Although finished products seem incredibly precise, the process is not without problems and challenges. Unlike technology for design, technology for making would seem to create a greater involvement with the imprecise, fluid and dynamic. Participants are forced to engage with the questions of both why and how to proceed.

Involvement in making and the tensions between the precise domain of digital technology and the imprecise process of making is precluded from popular CAD software. The precise location of a door in a measured drawing may be modified during construction to align with a standard brick or concrete block dimension. Imprecise virtual models produce precise drawing, however when these models are reused they can be problematic. Plume and Mitchell (2005) cite examples where ad-hoc information is included in modelling software to promote a particular workflow and later hinders other aspects of the project develop. Ignoring either the precise or the imprecise would seem to be problematic; the potential inherent in virtual environment may be that they are *not* tailored to promote a particular design or construction behaviour or workflow. Second Life is an example of a gaming platform often referred to as a Massive Multiplayer Online Role Playing Game (MMORPG). These platforms typically involve many participants and would seem to have currency for design and construction as—like observed design and construction—they include and expose multiple participant to manifold strategies, intentions and goals that must be negotiated.

2.3 Collaboration

It is traditionally the responsibility of the craftsman to change his perspective on the object of his attention. In contemporary construction the technology of design and the requirements of construction force participants to be increasingly myopic. They become incredibly skilled at being able to answer the question how, but this myopia potentially makes focusing on the distant question of 'why' more problematic. Sennett (2008, p. 246-248) supports this proposition in his discourse surrounding the antisocial expert. Pointing instead to the social expert being more successful, particularly when dealing with change.

VE's are not tailored to the specific needs of design and construction, some—such as Second Life—actively resisted pressure to add functionality that would make them easier to use for design and construction practitioners. Instead Second Life continues to build its facility for interaction by developing verbal and textual communication interfaces, which have been used to good effect by the real and virtual architect Keystone Bouchard. In this capacity VE's are perhaps well positioned to contribute to collaboration, negotiation and by proxy stimulate Lawson's 'appraisal' through individual and group design and construction processes.

3. SYNTHESIS: DESIGN, COLLABORATION AND CRAFT

In this section we look at VE's and their propensity for synthesis by scrutinising a design and virtual construction project. We argue there is limited value in photo-real and programmatic simulations but rather VE's present an opportunity to synthesise the dynamics of collaboration and the tensions between the smooth design and the striated process of constructing it.

3.1 The Kate Edgar project

In the second half of the year the same group of students involved in the living sketchbook undertook another VE project. This project required they take a design concept that had been developed elsewhere in the course and make it occupy the Kate Edger Building at the University of Auckland in New Zealand. The students would again use the popular VE Second Life, which they had learned in another aspect of the course. A site was designated on the island of Putahi in Second Life, which is a public island that anyone can visit although special permissions are required before a visitor can build there. Each student would construct a portion of the building within which to integrate his or her design intervention. In the process of realising their design they would have to negotiate with other participants that were designing and building in close proximity.

3.2 Building unstable buildings

The course organisers chose not to mediate the construction of the Kate Edger building, as the students had previously developed skills in this VE they were encouraged to negotiate the construction process amongst themselves. As illustrated in Fig. 4, quickly a form that could be recognised as the Kate Edger building emerged.'



FIG. 4: Section of the real 'Kate Edger' building and recognisable portion of the virtual model. Project by Hannah Ryan.

However, the building was highly fractured with floating walls, unresolved junctions and areas that could only be accessed by 'flying.' In line with Lawson's suppositions on design, synthesis, appraisal and analysis were occurring in no particular order; they were progressing iteratively with each informing the other. This also supports observation we have made elsewhere (McMeel, 2009) that design and construction are not mutually exclusive, rather they progress in parallel to each other. At a micro-scale elements could be recognised whereas the macro-scale continued to look chaotic, nevertheless one never gave way to the other, and these unstable design and construction processes remained in constant flux.

Returning to our claims regarding synthesis and its relevance within the design contest, we suggest that its value is not exclusively in verisimilitude; rather it is in the simulation of the forces that exist when operating with an inter-disciplinary ever-changing unstable environment. They render false any assumption that general macro-scale design descriptions are necessarily automatically resolved at the micro-scale. In fact, as we have theorised elsewhere it might never be totally resolved, rather participants converge and group understanding consolidates to a point where—although not perfect—participants can make progress.

3.3 Design and play

The Kate Edger project was framed differently than the previously discussed Living Sketchbook. In our previous discussion on play we theorised its importance in negotiating and understanding boundaries. During the design project within the Kate Edger we observed some effective negotiation of code, space and interaction within the VE, both in respect of the boundaries of disciplines and adherence to rules within such contexts.

Two students seized an opportunity to enhance both their projects, when—in line with Lawson's supposition regarding the game of chess—the students revised their propositions when they were well into the design process. They realised that both designs could be enhanced by closer collaboration (Fig. 5 and Fig. 6). In this instance the students were both attracted to a narrow walkway that was a bottleneck for pedestrian traffic at busy times during the day. Only when they began working on the VE site did they realise their common interest to

address this design problem. They were also exposed to each others different approach to addressing it. One student wanted to create a more ordered threshold, whereas the other chose to increase the chaos to encourage foot traffic to reject this route and adopt an alternative that would be provided. Without either's design succumbing to the other, they were able to negotiate a juxtaposition of control and chaotic components to refine a design proposition that enhanced each other project and produced a more sophisticate overall design.



FIG 5: Controlled spherical threshold. Project by Julian Cuadros.

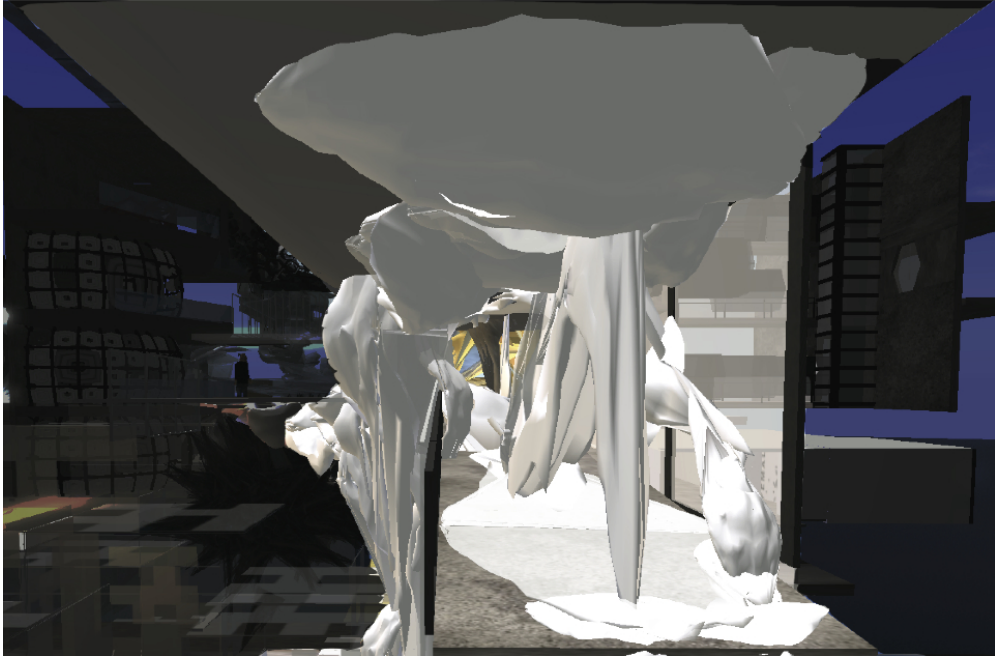


FIG 6: Project designed to 'throw the user into pandemonium' contrasted with the collaborators 'controlled threshold' in background. Project by Nathan Swaney.

Arguably this sort of close collaboration, dynamic contextuality and fluid design/construction is not represented in typical CAD software. Theorist and practitioner Mark Burry (2005) points toward this type of close collaboration and fluidity as a valuable method where overtly complex and sophisticated technology requires increasingly specialist operation. Although we don't propose Second Life as a substitute for CAD software, it does provide a platform that allows participants to explore—to the point of breakdown—disciplinary boundaries, their limits and the rules that govern these limits. As well as sensitising participants to inter-disciplinary conflict they also facilitate practice in identifying creative opportunities within this chaos and cross-disciplinarity.

4. CONCLUSIONS

This paper has drawn attention to Lawson's design constituents 'appraisal' and 'analysis.' Synthesis is understandably privileged within the ocular-centric nature of CAD and VE's, although we might now suggest this marginalises Lawson's other facets of the design process. Lawson, Heidegger and Sennett suggest analysis and appraisal are critical to techné, poiesis and thus craft. This adds currency to our hypothesis that these constituents and thus craftsmanship may also be exercised through design simulation within VE's. The Kate Edgar project demonstrates the design and building process in constant flux, with participants negotiating territory, tensions and interpretations. In this project, as in real construction the building remains fluid—although fluidity reduces—as construction advances. We do not claim that the disjointed and striated Kate Edgar construction has more value for design discourse than a smooth 3D model. Rather this type of conceptual 'model' has currency as it increases users understanding that conceptions of what is perceived as fluid and static within the design and construction process are constantly being negotiated.

Lawson's understanding of 'appraisal' draws our attention to the value of collaboration within such environs. Bakhtin contends that opportunities for newness emerge from misinterpretations and manifold understandings, which multiple participants can effectively supply when exposed to a single phenomenon. Although Bakhtin is referring to the phenomenon of medieval carnival we suggest this has value in the design domain. Externalization, synthesis and misunderstanding create the potential for newness and creative opportunity. Consequently it should not be automatically expunged from the design and construction process. Thus software that seeks to preclude the potential for the unexpected from design and construction practices not only reduce creative opportunity but also prevent designers from developing an ontology to contend with it. In this project the collaborative environment of Second Life did not presume to mediate design discourse or collaborative practice, it supported emergent practitioners in developing a grammar for contending with the complexity of inter-disciplinary and the fragility of creativity in such contexts.

Lawson interprets 'analysis' as play; which has been exposed to considerable scrutiny regarding its currency to the design domain. Within this discourse it is suggested that play promotes collaboration with others, it advances problem solving and understanding rule-based environments. In particular we observed a testing of established norms of behaviours and the operational limit of rule-based situations. Coyne has advanced this thesis within the design domain, which adds support to the suggestion that VE's provide a useful testing ground for participants to explore where ideas, concepts and juxtaposition of form and behaviour begin to bend and fail. Play in the early stages of this academic year seemed to prove fruitful in the latter stages when self organising behaviour, negotiation and collaboration began to emerge along side the assumed behaviour of deliberate and considered design.

Although VE's have perhaps been appropriated for verisimilitude through their possibilities for environmental synthesis. They have considerable value for other more arcane and artist aspects of design practice, which should not be marginalise in lieu of verisimilitude. Although problematic to explicitly contain in digital frameworks, the evidence brought to bear in this paper suggests they can contribute to developing artistic techné as well as manual technique.

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6. REFERENCES

- Amaratunga, D., Baldry, D. & Sarshar, M.: 2001, 'Process improvement through performance measurement: the balanced scorecard methodology.' *Work Study*, 50, pp.179-188.
- Bowden, S., Dorr, A., Thrope, T. & Anumba, C.: 2006, 'Mobile ICT support for construction process improvement.' *Automation in Construction*, pp.664-676.
- Burry, M. (2005) 'Digitally Sponsored Convergence of Design Education, Research and Practice.' Paper presented in the Proceedings of *CAAD Futures: learning from the past*. Springer. pp 3-22.
- Cox, S. & Hamilton, A.: 1995, *Architect's Job Book*, RIBA Publications, London.
- Coyne, R.: 2007, *Cornucopia limited: Design and dissent on the internet*, MIT Press, Cambridge, Mass.
- Cushman, M. & Cornford, T.: 2003, 'Infrastructures for construction collaboration: The Cross Organizational Learning Approach.' *International Journal of IT in Architecture*, 1.
- Douglas, M.: 1978, *Purity and danger: an analysis of concepts of pollution and taboo*, Routledge, London.
- Hyde, L.: 1998, *Trickster makes this world: mischief, myth, and art*, Farrar, Straus and Giroux, New York.
- Kolarevic, B. (Ed.) (2003) *Architecture in the digital age - design and manufacturing*, New York: Spon Press.
- Kolarevic, B. & Klinger, K. R. (Eds.) (2008) *Manufacturing material effects - Rethinking design and making in architecture*, New York: Routledge.
- Lawson, B.: 2006, *How designers think: the design process demystified*, Elsevier Architectural Press, Amsterdam; Oxford.
- McMeel, D. (2009) *The Artistry of Construction*. Edinburgh: Edinburgh University.
- Peansupap, D. V. & Walker, P. D. H. T. (2005) *Factors Enabling Information and Communication Technology Diffusion and Actual Implementation in Construction Organisations*.
- Plume, J. & Mitchell, J. (2005) 'A Multi-Disciplinary Design Studio using a Shared IFC Building Model.' Paper presented in the Proceedings of *CAAD Futures*. Springer. pp 445-464.
- Roy, R., Low, M. & Waller, J.: 2005, 'Documentation, standardization and improvement of construction process in house building.' *Construction Management and Economics*, pp.57-67.
- Ruddock, L.: 2006, 'ICT in the construction sector: computing the economic benefits.' *International Journal of Strategic Property Management*, 10, pp.39-50.
- Schmidt, K. & Wagner, I.: 2002, 'Ordering Systems: Coordinative Practices in Architectural Design and Planning.' *Computer Supported Cooperative Work*, 13, pp.349-408.
- Sennett, R.: 2008, *The Craftsman*, Yale University Press, New Haven.
- Wittgenstein, L.: 2003, *Philosophical investigations*, Blackwell Publishing, Oxford.

