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Design and construction: Intersections of linear and circular design

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Abstract

The multifaceted structure of higher education often limits the full integration of design and construction teaching in schools of architecture, but the potential for a greater intersection of these knowledge bases does exist. Design education in the architecture studio is typically taught through a linear process, where students are required to produce a concept design, followed by a series of design iterations and lastly, technification of the design. Similarly, in practice, this process is linear, starting with a design phase followed by a construction phase. In both scenarios, this process leads to a predictable design outcome. Contrastingly, a circular design process has the potential to allow for a more open-ended negotiation with material, technology, process, and making.

David Pye's concept of risk in *The nature and art of workmanship* reflects these possible outcomes, whether predictable or exploratory, by situating them on a scale between workmanship of risk and workmanship of certainty. In addition to tools, techniques and materials to evaluate the level of risk in making, this paper suggests that design process is also an indicator of risk. Some architectural practitioners have embraced a workmanship of risk approach by following existing circular design processes or establishing their own circular processes. This paper will highlight the work of three contemporary South African practitioners who, by employing a design process that is circular and by working in a manner that is often continuous and collaborative, have clearly expressed signs of experimentation and a material consciousness in their built work.

An understanding of how practitioners, through the implementation of a circular design process, have been able to establish these moments of intersection between design and construction earlier, and continuously throughout the design and construction process, can assist educators in transferring this approach to the classroom. The value of this improved intersection will be, improved pedagogy that limits the silo effect, forefronting building technology as a design generator, and creating better and more adaptable designers that can cope with new futures.

Keywords: Circular design, design education, design process, intersections, workmanship of risk.

Introduction

In the built environment, the relationship between practitioner and technology is expressed through architectural design processes. In the South African condition, these design processes are not well documented or clearly understood. *Practice-led* research is a way of understanding the professional designer's nature of practice. Candy (2006, p. 3) states that practice-led research "leads to new knowledge that has operational significance for that practice". The intended outcome of this research

is to create prospects for architecture and elucidate architectural design approaches. Employing the outcome of this research in academia, by emulating practice, could potentially lead to an improved pedagogy in architectural education.

Plowright (2014, p. 2) states that "a method is present in architectural design every time a student, academic or professional designer takes on a project" and that "while methods and methodology are the more technical terms, in architectural culture, design process is used to mean a sequence of steps taken to arrive at a conclusion". In this paper, the term *design process* refers to this sequence of steps and encompasses both the design and construction phases of a project. Considering practitioners it relates to the term *praxis* which "refers to a collection of examples or techniques that may be used as *models of practice*" (Porter 2004, p. 116). In this paper, the term *circular design process* refers to a design process that allows for opportunities for feedback, or models of practice that allows practitioners to challenge the linearity of the sequence of steps.

This paper will highlight the work of three contemporary South African practitioners who, by employing a design process that is circular, have introduced the concept of *workmanship of risk* in how the architecture is made. It is not a comprehensive overview of their portfolios but will extract, and briefly examine, completed projects that have followed similar design processes. The paper will highlight how an open-ended negotiation with material, technology, and process led to experimentation and innovation in the built work of the practitioners. It is specifically in a better understanding of these circular design processes, where the potential lies to address the siloed nature of design education.

Design education and the silo effect

The multifaceted structure of higher education often means that full integration of design and construction teaching in schools of architecture is not possible, but the potential for a greater intersection of these knowledge bases does exist. Schwartz (2016, p. iv) notes that this multifaceted structure is largely due to regulated course loads, core requirements and accreditation guidelines, among others. Knowledge fields are often isolated from each other, placing them into different silos, in order to focus on specific skill sets. Herrmann (2011, p. 346) states that "as universities face ever-increasing standards of educational effectiveness, silos become more common as a means of clearly defining the many subjects of education". Although there is value in this, if these different knowledge fields are seldom connected, it "leaves students with an incomplete understanding of design as an inclusive synthetic act" (Herrmann 2011, p. 346).

Traditionally, the design studio has been seen as a laboratory where the intersection of knowledge fields, specifically design and construction can take place. The ideal of this *tectonic laboratory* is often not realised, where in addition to the silo effect, design is typically taught through a linear process, where students are required to produce a concept design, followed by a series of design iterations and lastly, technification of the design. This often leads to a predictable design outcome and does not explore the potential of the design studio to lead to synthetic design thinking. Innovative discovery is often made where the intersection of these silos take place, either through integrated subjects, transdisciplinary projects, or circular design processes.

Experimentation in the South African built environment

In the South African condition, the absence of experimentation and innovation in practice is evident in the limited scope of building technology employed in the built environment (Osunsanmi, Aigbavboa

& Oke 2018; Windapo & Cattell 2013). Fitchett (2009, p. 26) states that it is the responsibility of public bodies to take on the real risk of innovation in materials, construction processes, and structural systems, and that is only when the application of these becomes entranced in the built environment that they can be absorbed by the private sector.

This is not the case in South Africa, and it falls on practitioners to take this risk. There are many restrictions in the private sector that make experimentation and innovation in practice difficult. The current design process (design + construction), with work stages set out by legislation, has meant that phases of a project and different skill sets are often siloed and not fully synthesised (Figure 1). It is a linear process where design and construction are separated, with design seen as "the immaterial presaging of form" while construction is "the material act of actualising this form" (Stein 2011, p. 51). These processes are further removed from one another where different practitioners or even different practices complete different phases of the design and construction process. Schmidt and Kirkegaard (2006, p. 133) state that "the split between the design team and the industry makes it cheaper and easier to choose an existing product from the shelf than to challenge the technological ability of the industry".

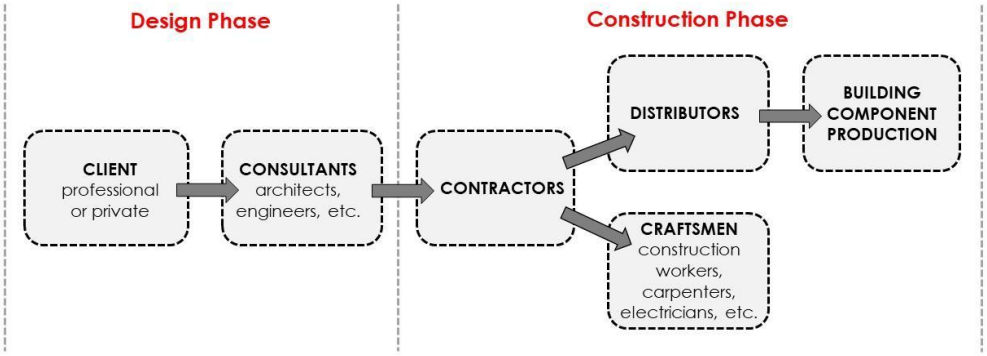

Figure 1: Linear architectural design process (Author 2022) based on a diagram by Schmidt and Kirkegaard (2006, p. 132)

Secondly, the introduction of the tendering system means that "the ability to create tectonic architecture with a close relationship between the expression and the materiality is limited" (Schmidt & Kirkegaard 2006, p. 132). The tendering process means that a design needs to be as complete as possible before construction commences, which leaves little room for experimentation or innovation after the design phase has been completed. Practitioners have to choose from off-the-shelf building components and cannot work closely together with the building industry and craftspeople in developing the design (Schmidt & Kirkegaard 2006, p. 132).

In many aspects, this way of working in practice is similar to the silo effect in higher education, generating few opportunities for *synthetic design making*, through either working transdisciplinary or establishing feedback loops, thereby not merging design and construction knowledge fields.

Workmanship of risk

Similar to the design studio, the process followed in practice is mostly linear, starting with a design phase followed by a construction phase. In both scenarios, this process often leads to a predictable

design outcome. A circular design process has the potential to lead to wider exploration by introducing the concept of risk.

> Authors such as Pye (1978) and Kolarevic (2008) both suggest that high risk can yield positive design opportunities. In other words, through risk in the material, tools, and techniques, the workmanship is pushed to its limit and new knowledge can be generated (Loh, Burry & Wagenfield 2016, p. 189).

David Pye's concept of risk in *The Nature and Art of Workmanship* (1968) reflects these possible outcomes, whether predictable or exploratory, by situating them on a scale between *workmanship of risk* and *workmanship of certainty*. Loh, Burry, and Wagenfeld (2016) formulate an analytical diagram (Figure 2) which allows practitioners to compare different making activities, and judge and evaluate the level of risk in making. This is done through a framework that highlights the relationship between tools, materials, and techniques. This author suggests that, in addition to a degree of uncertainty in the making process, a degree of uncertainty in the design process, can also be considered *workmanship of risk* and therefore has the potential to lead to experimentation and new knowledge.

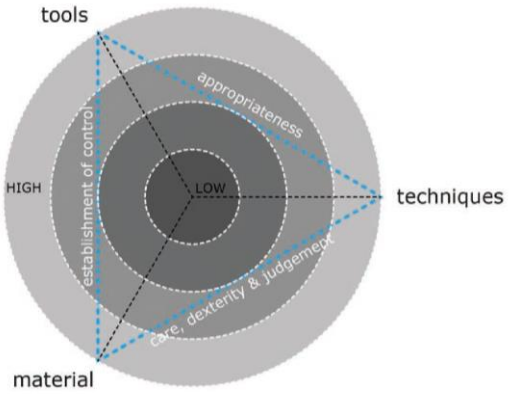

Figure 2: Possible outcomes situated on a scale between *workmanship of risk* and *workmanship of certainty* (Loh, Burry & Wagenfeld 2016, p. 192)

Existing and new circular design processes

A circular design process has the potential to allow for a more open-ended negotiation with material, technology, process, and making. This has the potential to lead to the development of innovative fabrication solutions and expressive form. In practice, circular design processes that follow a feedback loop already exist. Some of these are circular by nature, e.g., *craft mode* or participatory design, others have traditionally been linear but are managed in such a way that they have become circular through design, e.g., digital manufacturing. Some practitioners have however found ways to work, or continue working, in a more traditional manner by being actively involved in the entire process, embracing a *workmanship of risk* approach by following circular design processes.

Practitioners: Kate Otten, *earthworld* Architects and Peter Rich

Practitioners were selected for the experimental nature of their built work as is evident in the range of interpretations of tectonic expression. Schwarts (2017, p. xxvii) states that "architectural tectonics seeks a relationship between the design of space and the reality of the construction that is necessary for it to exist". In the case of Kate Otten, André Eksteen and Braam De Villiers of *earthworld* Architects, and Peter Rich, it can be argued that their architectural outputs are innovative and display a range of

responses. They have different ways of working but it is the circularity of their design process that they have in common. Otten's continuous involvement in the design and construction process inculcates a focus on craft and making in the design process, whereas *earthworld* Architects can be considered to be an experimental design practice, with a focus on digital manufacturing, while Rich's long history of working collaboratively established a strong participatory design tradition within the practice.

Kate Otten and *craft mode*

Traditionally craft has been defined purely as a form of execution, but current architectural discourse is expanding the definition to include the role of craft as exploration. Rossi (2017, p. 2) states "to consider craft is simply to be interested in making: to understand things, be they chairs or cities, as artefacts that demand asking how they have been made". Loh, Burry and Wagenfeld (2016, p. 187) write that "the authenticity of craft lies within the deeper structure of the practice". This broader interpretation of the term craft suggests a relationship between the process of making and craft. Stein (2011, p. 52) suggests the term *craft mode* and defines it as a developmental feedback between material and human intelligences.

Kate Otten Architects is a practice that is intrinsically aware of *craft mode* as design process and Otten (1998, p. 53) states that "the design process is a fluid one, often organic; a process that never ends even after the building is *complete*" and continues "simple, inexpensive, well-known materials and method are used in an innovative way. This is also where the people involved in the process – the artisans and craftspeople – become very important".

Otten's design education took place at UKZN (University of KwaZulu-Natal) and Wits (University of the Witwatersrand). It was particularly the foundation years at UKZN, dominated by the term *practice*, being taught by Rodney Harber (1940 -) and exposed to the Building Design Group (1968-1977), that instilled a passion for craft and making in her (Lokko 2016, p. 17). Otten started her practice (1989) with a project called the *Pineapple Republic*. It was one of a pair of semis in Melville that was renovated by Otten and her team of builders. A restrained budget meant that materials were recycled and reused in inventive ways (Otten 2013, p. 12). Otten (2013, p. 13) states that it is with this project that she started "experimentation with architecture and buildings".

Otten (2013) highlights the importance of experimentation through self-build projects, which she refers to as *construction for self*, that often have been testing grounds. "They are places where risks can be taken which would be dangerous or inappropriate with a client" (Otten 2013, p. 12). The *Pineapple Republic* was the first or a series of testing grounds, the *Love Shack* (2006) at Utopia in the Magaliesburg followed, then her family home *Our House* (2007) in Parktown North, and most recently and most ambitious *Lulu Kati Kati* (2010) in Melville (Figure 3). Otten actively engages in both the design and construction process, working as a *traditional* practitioner that is involved in the entire process.

Figure 3: Structure and interior view of *Lulu Kati Kati* (Kate Otten Architects n.d.)

Otten's way of working can be seen in the practice's Art Therapy Centre (1996) in Soweto. "The architect's role becomes that of setting down a precise design intention that is strong enough to allow for and incorporate the unexpected [...] The builder is not expected to just follow instructions, but to give interpretation to drawings, images shown or samples made with/by the architect" (Wolff 2008, p. 23). Both in the entrance pergola and the dome structure, main elements; columns, beams, height and proportion of the dome, are shown in drawings, but the positioning of secondary elements, and the exact texture and brick patterns, becomes the contractor's interpretation (Figure 4). This process includes the embedded knowledge of tradespeople and this collaborative approach is fundamental to realising these experimentations. Wolff (2008, p. 25) writes that "Kate Otten's working method is an open-ended design process that allows for the pleasures of making to be registered in the form and it is not reliant on a conception of predetermined perfection". Otten (Kate Otten Architects n.d.) states that for her "the 'making' of the building, is as significant as the design process".

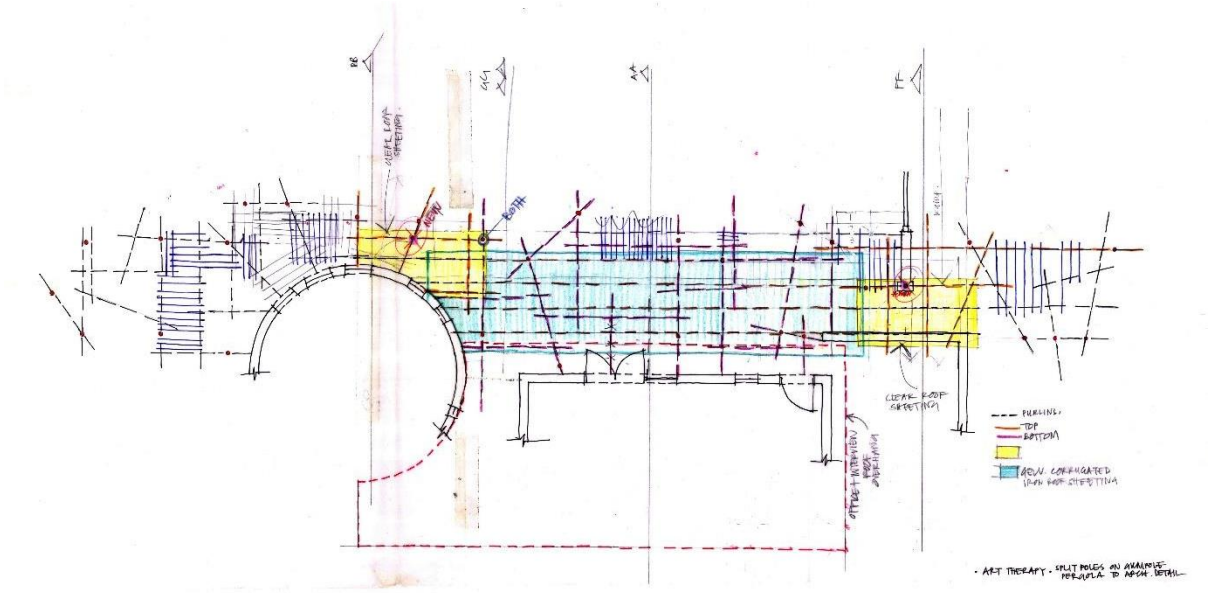

Figure 4: Sketch plan of pergola at Art Therapy Center (Kate Otten Architects n.d.)

earthworld Architects and digital manufacturing

Digital manufacturing in architectural design and documentation has often been a siloed process, but by purposefully designing the process to be circular, it has allowed practitioners to be actively involved in the entire process. A made-to-measure, direct-to-drawing process provides an alternative model for the designer to develop and manage fabrication with unprecedented involvement (Overall et al. 2018, pp. 173-175).

Loh (2019, pp. 40-42) looks at different approaches to digital fabrication in architecture and sketches out a 'digital material practice' approach that "impart[s] knowledge that can play a critical role in the design process". In a conventional approach, "digital fabrication enables designers and architects to realise their virtual models as physical artefacts, in the form of 'file-to-factory' procedure", therefore "digital fabrication is a means to an end to achieve the outcome" (Loh 2019, p. 41). In an alternative approach digital fabrication is deployed "as a means to calibrate and negotiate the virtual model with physical artefacts'' and "usually takes the form of prototypes that either function as proof of concept or as one-off production where the building itself is the prototype" (Loh 2019, p. 42). Here "the design intent is to explore novel fabrication techniques or material systems with the aim to capitalise on digital fabrication technology for material, spatial, or perceptual effects" (Loh 2019, p. 42) while seeking a sense of economy and buildability.

earthworld Architects is a practice that questions the relationship between digital processes and making. De Villiers and Eksteen state that "in our practice, we explore the role of architecture and technology (not industry) to bridge the gap between the system (non-tangible, abstract) and the physical (materiality, form, texture)" (earthworld Architects n.d.). Barker (2019, p. 28) states that *earthworld* Architects "argues for the reinvention of the craftsperson, using new technologies, as a counter to modern-day standardisation". This has led *earthworld* Architects to explore a different organisational structure and new workflows, necessitated by the unique relationship with fabricators that the direct-to-fabrication process creates. By establishing a direct-to-fabrication division within the organisational structure of the practice, a circular design process is implemented. "This leads to "shortening the distance between design thinking and fabrication processes'' and "removing the divide between the architect and fabricator" (Overall et al. 2018, p. 174).

After establishing the practice in 2000, House Visser (2000) with its "use of a brick barrel vault and contrasting light steel window frame, signifies the beginning of the practice's unconventional tectonic experimentation with materials and structure" (Barker 2019, p. 24). The project also entrenched in the practitioners a way of working as *traditional* practitioners that are involved in the entire process. The architects state that "the project offered the opportunity to become intimately involved in the construction process, where detail development would only be complete on completion of the construction process" (earthworld Architects n.d.). Barker (2019, p. 25) writes that "it can be argued that their design process is organic, which allows for a multiplicity of inputs, not only from the client, but also from those making the buildings".

Over the years, the practice has experimented with a variety of materials, starting with brick, moving on to concrete, then steel, and most recently, timber. In the HEFF Quipaco Hunting Lodge (2010) in Mozambique, the practice began experimenting with prefabricated timber construction in a factory setting with transport to and installation on site. House Alto (2013) in the Cape "is an extension of these ideas using a combination of steel and timber frames made off-site and erected in situ" (Barker 2019, p. 26). Parallel to this material evolution, the practice also started experimenting with digital fabrication in the form of pre-manufactured CNC (computer numerical control) cut steel and plywood, first in interior furniture elements and then small building components.

These approaches culminated in the realisation of Future Africa Innovation Campus (2018). It is specifically in the Dining Hall that the "intention to challenge existing design and construction processes by combining high-level design processes with local resources and skills" (earthworld Architects n.d.) manifests. Through multidisciplinary partnerships with designers and manufacturers, a birch plywood portal frame was developed to carry the envelope. "Designed in detail and modelled 3-dimensionally in the architect's offices, then sent to CNC machines for cutting and manufacturing the off-site components, before finally being rapidly assembled on site" (earthworld Architects n.d.).

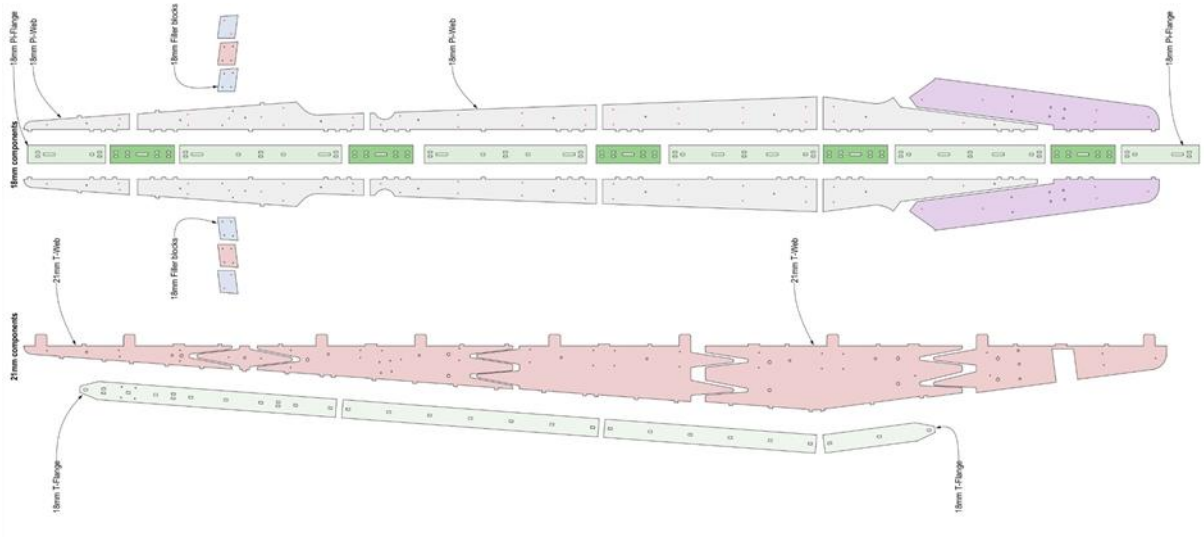

Figure 5: Cutting layout for a plywood rafter (earthworld Architects n.d.)

Their approach of "making as a means of generating design knowledge in the process" (Loh, Burry & Wagenfeld 2016, p. 187) has meant that the exploration of digital fabrication processes is ongoing (Figure 5). Collaborating with York Timbers the practice has been able to construct some plywood elements with local SAP (South African Pine) plywood instead of imported Birch plywood. This has led the practice to develop a complete plywood structural system, manufactured through a direct-to-fabrication process, and constructed on site using only basic tools and minimal labour. This system was tested in the *Kospaza* (2021) project, a small plywood spaza shop, constructed in just a few days (Figure 6).

earthworld s Architects' engaged material consciousness and fascination with material craft means that they are able to merge their ideas with new forms of digital technology and fabrication processes. They have found ways of realising these experimentations by following a circular design process facilitated through digital manufacturing.

Figure 6: Rapid assembly of prefabrication components for *Kospaza* (earthworld Architects n.d)

Peter Rich and collaboration

On the formation of the *Bauhaus*, Bannon and Ehn (2012, p. 38) write that "early modern design was, if not explicitly participatory, at least programmatically collaborative". They highlight the importance of the *Bauhaus* workshops as forming the foundation for collaborative building activities. "It was collaborative and interdisciplinary, joining the different design competences of art, craft, architecture and technology – in order to build a genuinely collaborative design work (Bannon & Ehn 2012, p. 38).

It is a process through which the open-ended approach encourages participatory practice in its design, construction, and everyday use. Tim Brown (Bannon & Ehn 2012, p. 55) argues that "design should be viewed as a collaborative effort where the design process is spread among diverse participating stakeholders and competences; ideas have to be envisioned, 'prototyped' and explored hands-on, tried out early on in the design process, in a process characterised by human-centredness, empathy and optimism". When referring to participatory processes, Low (2014, pp. 324, 326) writes that by embedding local skill and community effort it is possible to effect contemporary architectures, which appear to be capable of providing stronger direction for an African Architecture. In addition to social innovation, it is a design process that also has the potential to lead to inclusion of indigenous building technologies through the exploration of materials, construction techniques, and structural systems.

Figure 7: Peter Rich and Senthil Kumar Doss (SKUD) collaborating on workshops in Bangalore, India (Rich 2023)

In the practice's community work prior to 1994, "Rich took an unconventional path, engaging with communities, acting as architects and also as a facilitator" (Hall 2011, p. 12). This participatory design process, long periods of community engagement and consultation, led to the completion of a series of small community buildings, Tembisa Medical Clinic (1988), Tembisa Sports Centre (1988), and Elim Shopping Centre (1986). After 1994, Rich was involved in a series of important cultural heritage projects. During this time, a number of community consultation projects were completed by the practice, Bwanari community-owned lodge (2000), Lekgophung brick-making cooperative (1999) and the Bopitikelo Community and Cultural Centre (2002). Parallel to this, he was appointed as the co-director of the UNESCO project Growing up in Cities, where he helped to facilitate participatory projects in Canaanland, an informal settlement in central Johannesburg. By making use of indigenous construction knowledge and skills, "gum poles for structure, thatch for the roof covering, and locally gathered stone and soil bricks for walls" (Hall 2011, p. 17), the architectural interventions engaged and empowered local communities. Cooke (2011, p. 1) states that "in community projects, he works directly with members, learning from their skills and helping to give them current valency".

The most ambitious of these was the Alexandra Interpretive Center (2002-2018), initiated in 2000 by the government. At the start of the project, Rich formed part of the Heritage Agency team that mapped the oral heritage of the area, which includes Mande's Yard, home to Nelson Mandela in 1942. A team of local residents were trained to complete this process. Due to irregular funding, the project was restarted multiple times with different stakeholders involved, leading to a programmatic hybridisation. Not only did this mean that the participatory process was ongoing but as Hall (2011, p. 23) states "serves to accentuate the notion of building as process".

Focussing on the multidisciplinary characteristics embedded in participatory design processes, Rich challenged the typical linear way of working by evolving a multidisciplinary team from the first stages of a project (Figure 8). At the Mapungubwe Interpretive Center (2009), a chance encounter with Issay Benjamin led to an introduction to John Ochendorf (Massachusetts Institute of Technology) and Michael Ramage (Cambridge University), both leading world experts on timbrel-vaulted structures (Noble 2020, p. 138). The involvement of the engineering team from the inception of the project, together with Anne Fitchett (Wits) research into the production of stabilised hand-pressed soil tiles, led to the completion of this innovative project, despite a highly unique set of constraints regarding materials and labour (Noble 2020, p. 139).

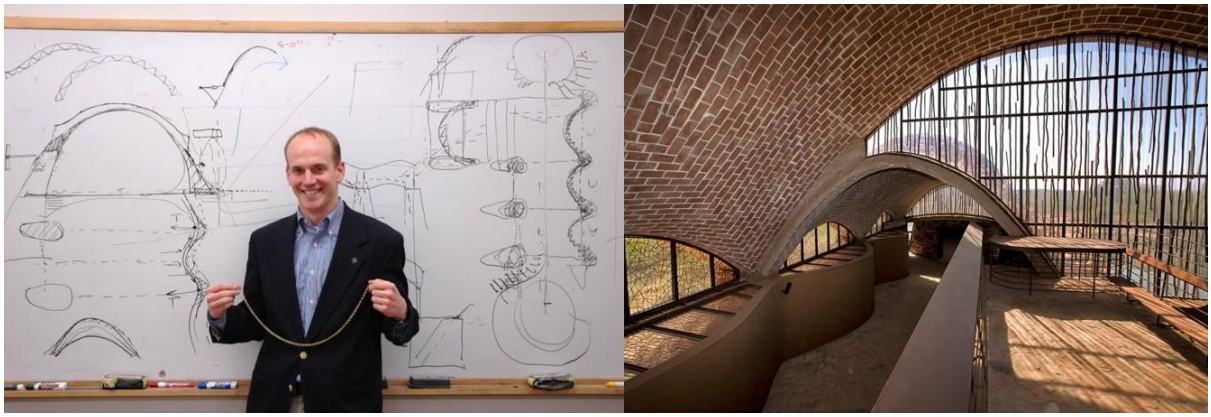

Figure 8: Peter Rich and John Ochendorf collaborating on the Mapungubwe Interpretive Center (Rich 2023)

This explorative way of working contributed to the project winning World Building of the year in 2009. The project demonstrates innovation on fours fronts; building materials used, the application of geometry, the unique construction methods, and structural calculations.

Conclusion

The silo effect in higher education has meant that students are often tasked only with small questions of design, leading to fine-grain answers. If a continuous overlap of knowledge fields does not occur it has the potential to lead to students graduating with only siloed design thinking skills. The multifaceted structure of higher education is in many ways similar to the linear and phased way of working, found in practice. The circular design processes of craft mode, digital fabrication and participatory design, have allowed Kate Otten, *earthworld* Architects and Peter Rich to work in a way that fully integrates different skill sets into fully synthesised built works.

By embracing circular design processes, the selected practitioners have been able to introduce the *concept of risk* in their way of working, overcoming constraints imposed by the South African built environment, to produce experimental and innovative projects. These practitioners are dedicated to experimenting with how the architecture is made. By being involved in the entire design and construction process, through a circular design process, consistent intersections between design and construction transpire. The completed projects highlight the importance of working collaboratively and transdisciplinary, prototyping and learning through making, a material consciousness where material has the potential to become a generator of form, and a focus on building technology to encourage the development of innovative fabrication solutions.

An understanding of how practitioners, through the implementation of circular design processes, have been able to establish these moments of intersection between design and construction earlier, and continuously throughout the design and construction process, can assist educators in transferring this approach to the classroom. Finding ways to emulate these circular design processes in the studio, can lead to the introduction of the *concept of risk*, in what has often become, largely due to the multifaceted structure of higher education, a typical linear design process with predictable outcomes.

The studio has the greatest potential for distinct knowledge fields to become smudged and muddled, leading to synthetic design thinking and making. It is the role of the studio instructor to find ways of disrupting *workmanship of certainty* by introducing risk or variables. Attempts at reconfiguring the design studio to align it more with the ideal of the *tectonic laboratory* have been made, most notably through the design/built project run by *Rural Studio* at the College of Architecture, Design and Construction's (CADC) in Newbern, Alabama, and locally by the *Unit for Urban Citizenship* (UUC) at the University of Pretoria, with a focus on new forms of participation and engagement. These studios reflect the value of working with mock-ups and prototypes in the design process, as well as the fundamental practice of experimentation and learning-by-doing.

The value of an improved intersection between design and construction will be improved pedagogy that limits the silo effect, forefronting building technology as a design generator, and creating better and more adaptable designers that can cope with new futures.

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