TRAVERSING UNKNOWN TERRITORIES: NOTES ON RESEARCHING THE LEARNERS' EXPERIENCE OF REAL-TIME VIRTUAL ENGINES IN THE ARCHITECTURAL DESIGN STUDIO

Notes on Researching the Learners' Experience of Real-Time Virtual Engines in the Architectural Design Studio

TANE MOLETA
[1] *Victoria University of Wellington*
[1] *tane.moleta@vuw.ac.nz*

Abstract. This paper explores the role of real-time-virtual-engines (RTVE) in contemporary architectural education. The research is a response to the increasing footprint virtual reality (VR) has begun to forge in the studios of architecture programmes. This paper stipulates that the use of RTVE in architecture is unique to CAAD research given the student motivation to 'create with' and 'for' VR. Presenting the results of two literature reviews that question: how does use of the Real-Time Virtual Engine shape the students learning experiences in the architectural design studio? The initial results are undertaken as a narrative literature review. This work uncovers the role of RTVE and ties it to a number of established educational frames. The subsequent search was undertaken using the systematic literature review framework. The knowledge generated from this piece of research locates that there is a substantial lack of empirical data exploring the experiences of student use of RTVE in the architectural design studio.

Keywords. RTVE; Education; Design Studio.

1. Background

As an academic, writing a paper in December, I am afforded the unique chance to take stock of the activities of the year, and in doing so, I wonder, as one does, 'why we do what we do', and also, why we often ask our students to 'do what we do' , 'do what we did' and sometimes, 'do what we wish we did'. As humans, many of our activities are ingrained. We have all been students prior to teaching. We have all received tutelage at one institution or another, and had some characteristics ingrained - and then at some point, we are allowed to teach. Then, to no fault of our own, quite a bit of time passes between the state of being a student and being an educator, and one could reasonably expect that the experience of the learner, as a learner, can be construed from experiences based on the educator. We can then question, do we genuinely have a vivid map of the experiences of our students?

To begin to understand how the learning experience of our students is constructed, it is valuable to look at the institutional structures of tutelage the

PROJECTIONS, Proceedings of the 26th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2021, Volume 2, 51-60. © 2021 and published by the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), Hong Kong.

student architects experience. One of the seminal studies and most frequently referenced studies that inform the education of an architect is authored by Donald Schon. His work, 'The Reflective Practitioner', has had a profound and sustained impact on how, 'architecture' as a course of study is delivered to students (Webster, 2008). Proposing that 'the learning environment is 'mapped to the activities of the profession' (Schon, 1983) the work of Schon is a guiding influence for many schools of architecture (Webster, 2008)(D. A. Schön, 1988). His notions that students are set with a 'brief' (Koper, 2005) undertake their daily study and receive tutelage in a 'design studio' (Davies, 1960) endure to this day (MacGilvray, 1992). Additionally, and central to this study, the stipulation that students are to be instructed and given 'tools typical to industry' (Attoe & Mugerauer, 1991) is equally a defining characteristic and experience for students who study in this field. Research on the role of the 'design brief' (Lutnæs, 2015) is well established, as is the purpose, configuration, inhabitants and changes to the design studio. Additionally, considerable effort has been invested in understanding the 'tools' (Gramazio, Kohler, & Oesterle, 2010) and 'processes' (Oosterhuis, Bouman, & Lénárd, 2002) undertaken by both 'professional architects' (Gero, Neill, & Science, 2006) and also 'student architects' (Moleta, 2016).

Current literature states, the contemporary architectural student inhabits an era where the range of digital tools is perpetually expanding (Iriti, Bickel, Schunn, & Stein, 2016). This shifting of poles has generated considerable academic discussion, especially in within CAAD research. The instruments that have been historically significant for architects such as sketching (Ekströmer & Wever, 2019), modelling (Shih, Sher, & Taylor, 2017) and scale drawing have seen less of an emphasis as students are encouraged to prepare for industry and gain increasing fluency in the use of digital tools (Beckmann, 1998; Carroll, 2010; Whyte & Nikolic, 2018). The pressures influencing this change come from a range of fields: professional (Architects Accreditation Council of Australia (AACA) and the Australian Institute of Architects (AIA), 2013; Wang, Wu, Wang, Chi, & Wang, 2018.), legislative (Ostwald & Williams, 2008) and constructional (Wang et al., 2018). The literature suggests that contemporary communication technologies will assist the design (Yuen, Yaoyuneyong, & Johnson, 2013), visualisation (Moleta, 2017), documentation and construction of buildings (Chen, Cui, & Hao, 2019). Educators (who are often largely Architects themselves) are accommodating of these influences, hoping that these skills will better prepare graduates for the contemporary (and increasingly competitive) workplace (Spaeth, Khali, Spaeth, & Khali, 2018). Consequently, as others have noted, the knowledge required of students to succeed is continually evolving (Burdick & Willis, 2011; Heller & Heller, 2014). Where each of these fields seems to delve into the broad term of 'digital tools', there is an essential joint component, and that is the necessity to use digital tools to communicate (Bates-Brkljac, 2012; Birt & Cowling, 2018; Lin, 2012; Whyte & Nikolic, 2018). Digital tools have been heralded as the means to understand both the complexity of the problem (Nováková, Achten, & Matějovská, 2010) and also the communicate the sophistication of the solution (Abdelhameed, 2013). The Real-Time Virtual Engine as a communication tool has seen an increasing focus in educational research. Studies cover the entire

gamut of scholarly research from medicine, to geography; however, for the student architect, The Real-Time Virtual Engine is reported to offer several compelling characteristics. The Real-Time Virtual Engine is inherently 'spatial' and possesses the capacity to communicate complex geometry in a manner that is not easily repeatable in other means (Chen et al., 2019; Ford & Ford, 2017). The Real-Time Virtual Engine also offers the ability for its inhabitants to better perceive proportion (Innes, Moleta, & Schnabel, 2018) and scale (Payette, 2012). The visual fidelity also allows users to better communicate types of material (Abdelhameed, 2012) and lighting qualities (Chen et al., 2019). It also affords its users the chance to produce the 'feeling' of a space, using the term 'atmosphere' and also locates the user within a 'temporal environment'. These affordances have seen the use of the Real-Time Virtual Engine achieve widespread employment in every school of architecture.

While this search uncovers a rich plethora of material and positions, what I find strikingly interesting, is that much of the material presented is from non-empirical studies. What is equally interesting is that in many cases, the studies are not constructed from the student perspective or have not included the student's voice.

2. Research motivation

The motivation for me as a design studio lecturer is that a defining characteristic of my daily tasks is that I spend time with my student cohort, converse and discuss their architectural design proposals. I listen, I offer suggestions, and I interpret their propositions. It is potentially an unsettling characteristic of a creative discipline that there is often no singularly correct answer; thus, it is often the role of the architectural educator to interpret the words of the student to understand their work and offer feedback. Communication is important and arriving at a common understanding is of considerable advantage for both parties, student and lecturer.

In my experience, in academia, the profession and in the student body each sector is keenly interested in the use of digital tools. I often discuss such matters with my colleagues. We debate the affordances of how we present, explore and experience the representation of an architectural design. We discuss what this means for our profession and as educators what this means for our students. It is often speculated that one of the intrinsically interesting components of the contemporary toolset is that we no longer review static projects on printed paper, but rather are enabled to inhabit and architectural design in ways not historically possible.

When employing the use of Real-Time Virtual Engine we can now make decisions on 'how' and 'where' we will 'inhabit' a representation of a project which ultimately and perhaps problematically, allows the creation of individual and unique readings of a given project. Dwelling on these notes, I postulate, the tools we use to communicate now shift from being didactic to being speculative, instructional to experiential, specific to in-specific. We can consider then, in the contemporary design studio, today's students are invested in creation in a way that is different from the way in which their predecessors ever did, or ever could. We

could also speculate, given the unique readings contemporary tools offer, that our students are now faced with communicative hurdles that are undeniably divergent and undeniably significant. We will not know however unless we engaging in understanding these matters from their perspective.

3. Review of literature

In an attempt to answer 'how does use of the Real-Time Virtual Engine as a communication tool shape the students learning experiences in the architectural design studio?' The following literature reviewed is presented in four sections that trace the development of communication issues in the context of architectural education. It begins with the central issue of how abstract architectural ideas can be communicated. Changes to the field include the tool of virtual reality and its importance to architectural studies

4. Abstraction to the real

As with many professionally accredited programmes of study, students of architecture are quick to align themselves to the activities, aspirations and concerns of professional architects. Within a year of their education, students are largely equipped to read the same professional journals, enter competitions and participate in the many events of the professional world (Askland, Williams, Ostwald, & Australia. Department of Industry, 2012) A contributing factor to this culture occurs due to the fact that most academics in schools of architecture are, by in large, either former or current architectural professional themselves (Schön, 1988). This close relation to the profession is a strongly held tradition and one that is unlikely to change. These sentiments are supported in a number of key texts citing a desire in architectural studies to achieve the 'real activities of an architect' (Webster, 2008). Webster argues that "design studio learning simulated real professional action" (p. 63). There is, however, one considerable and frequently overlooked difference between the modes of practice between the aspiring student architect and the professional. This is a matter of knowledge gained from the experience of reviewing one's work; a difference that can be seen in the 'output' that centres on notions of 'media' (Roudavski, 2011). Where the architect gains an understanding of their work through 1 to 1 review of the built outcome, the student, however, gains architectural understanding through communication with their lecturer. Considerable effort has been imparted in understanding and defining architectural education, Table 1 provides an overview of approximately six decades of theoretical literature and accreditation reports, organised according to key principles and aspects (or focus) of these studies.

Table 1. Table 1: Overview of theoretical literature.

Key Principle	Key aspects of architectural education	Literature
What	Research centred on defining what are the key principles for architectural education	Davies (1960); McEwen (2003); Varnelis (1998); Carlhian (1979)
Where	Works that define the studio experience	Caruso (2008); Gül (2012); Deamer (2005); Lyndon (1978); Attoe & Mugerauer (1991)
Creativity	Creativity as an educational goal	Herbert (2010); Wang & Huang (2018); Kilicaslana & Ziyrek (2012)
Technology	Research centred on the role of technology in architectural education	Nováková, Achten & Matějovská (2010); Westfall (2008)
Pedagogy	Research centred on pedagogical systems	MacGilvray (1992); Dutton (1987); Askland, Williams, Ostwald… (2012)
Qualification	Research defining the registry characteristics of professional degrees	Architects Accreditation Council of Australia (AACA) and the Australian Institute of Architects (AIA). (2013); Orr (2015)

Table 1 defines this body of literature within the categories of What, Where Creativity and Technology. The compelling finding from this literature is that the professionally-oriented educators in architecture have a tendency to refer to research centred on reviewing the work of professionals (Schön, 1988) and not students. This important characteristic, and point of difference from this proposed study is that architectural educators or professionals (Gero et al., 2006) are likely to be able to articulate their views on their experiences in greater detail (Shih et al., 2017).

This observation of the literature advances a case for the value of a study that explores the experience of the design studio from a student perspective. In schools of architecture students read about design, they talk about design and inevitably engage in the act of design. However, these 'designs' they speak of can only ever be articulated through 'abstraction' (Koper, 2005). Also, students will never gain experience of their design as a real building. Therefore, they will only ever be able to imagine and subsequently communicate their designs through sketches, measured drawings or physical models. This 'problem of abstraction' has been cited as a limitation to the study of architecture (Iordanova, 2007, p. 687). Students, in contrast to professionals, are unlikely able to achieve the experience of inhabiting their designed buildings. The important act of reflecting on a structure is not possible to the student architect. The journey through the spaces or exploration of a structure is only ever imagined in the minds of the student and speculated in the minds of their teacher. Peter Downton (2016) argues this position in 'Design Research' noting that, "In the case of projects, the referents for images or mock-ups are yet to be possible to experience and the project may never come to fruition and never exist beyond this modelling of it" (2016, p. 118). For the student, the 'imagined building' through communicative tools is the only possible outcome from the established design studio learning experience.

5. What is the Real-Time Virtual Engine?

In the past decade, the Real-Time Virtual Engine has arrived to power interactive computer graphics. The current generation of learners have been exposed to gaming, and more recently, virtual reality gaming from a young age. The equipment is not only more affordable, it is easier to use. The increased volume of feedback from consumers has produced increasingly more accessible user interfaces, and presently, the use of the Real-Time Virtual Engine has found its way into professional architecture as a communication tool that offers exceptional visual fidelity, and a novel means to allow clients to experience buildings prior to construction. The compelling characteristic is that inhabitants are often able to 'walk' freely in the Real-Time Virtual Engine, simulating the experience of 'being there' and making decisions of what to 'do', whilst there (Segard, Moloney, & Moleta, 2013; Vaai, Moloney, & Moleta, 2014). The experience of 'being there' has been seen as an answer to some of the criticisms of physical architectural communication tools. A user is able to experience the volumetric, material, and spatial characteristics of a design, without the 'difficult to acquire' intellectual translation required of sketches, scale drawings and models. This is however the established view recorded from practice and not a recorded experience of students who use it.

Architecture, as a field of professional tertiary education, relies extensively on the use of architectural communications such as: representation, simulation, and visualisation. Abstractions are an understandable requirement. The complexity, legal obligation and monetary cost associated with the act of constructing a building render the process of learning architectural design by planning, manufacturing, and then the important aspect of reviewing the completed building prohibitive to the extreme. To bridge this gap, the educators in schools of architecture set exercises for students to hone their communication skills. Tasks are designed to allow students to develop their designs and develop the skills to communicate their designs to others. Physical representational tools such as sketches, scale drawings and models have historically been routinely employed. In most prospectus's drawing is listed as a high priority for students of architecture, and additionally, many schools will offer numerous courses focussing on these and related skills. Drawing is also considered as an important 'expressive' and as unique in the way that it allows the designer to think through problems as they develop on the page (Lowe & Lowe, 1972; Webster, 2008). It is, therefore, considered an important arrow to develop in a very large quiver. Conversely, physical tools, such as sketching, however, have been criticised as focussing on a skillset that is removed from the act of design, postulating, that students of architecture become expert in the art of communication, at the expense of an intrinsic understanding of the spatial and constructional requirements of designing architecture. These voices report it is possible through physical media to misrepresent knowledge of a building through the manipulation of materials and space.

6. Why is the Real-Time Virtual Engine important for architectural studies?

Architecture as a field of study engages its students in design-based problems to facilitate learning the skills required for the design of buildings and structures (Wang et al., 2018.; Whyte & Nikolic, 2018). This field of education has historically required the learner to develop the ability to interpret two-dimensional drawings into three-dimensional relationships (Ascher, 2015; Varnelis, 1998). Examples of these skills may be found in the placement of a building on a complex sloping site, ensuring that a building envelope does not intrude into a neighbouring properties access to sun or a junction of three or more structural members. The spatial and geometric complexity required of the discipline are known stumbling blocks for the developing architect (Caruso, 2008; McEwen, 2003).

A number of reports note that the skills of 'spatial understanding' are difficult to muster because traditional means for depicting design situations are located in the orthographic drawing tradition (Abdelhameed, 2013; Aflatoony, Wakkary, & Neustaedter, 2018). It is common practice that two-dimensional drawings are used to communicate a three-dimensional structure. A series of pages are far easier to transport than a physical model, and if a model were used, it would need to be so complex that the utility of its role as a 'communication tool' would be debatable. The orthographic drawings system contains a view from above, a view from the front, a view from the side and potentially a section view. While this system of communicating is historically significant (Lowe & Lowe, 1972), rising criticism of the system is evident (Bilda, Gero, & Purcell, 2006) in conjunction with the rise of computationally-aided design (Ekströmer & Wever, 2019; Jonson, 2005; Poelman & Keyson, 2008.; Shih et al., 2017).

The rise of computational design is reported as offering significant change (Ekströmer & Wever, 2019). Ekströmer and Wever note virtual reality enables a shift from working primarily in two dimensions to working on a 'virtual model' in three dimensions. The field of CAD is a highly contested and the volume of research (see Table 2) and commentary is generated by architects, technologists and software developers actively promoting virtual reality. Five international conference circuits and two highly regarded journals support the peer-reviewed dissemination of this research.

Table 2. Table 2: Sub-fields of architectural education.

Sub-fields of architectural education	Literature
Educational Studies in Architecture	Cocchiarella (2015); Poelman & Keyson (2008)
Computational architecture	Abdelfattah, H. K. and A. A. R. (2004);
Technology in Architectural Education	Chieh (2005); Vecchia, da Silva & Pereira (2009); Liang (2006); Radford (2000)
Virtualisation as an educational tool	Nitsche (2008); Bogost (2007)

There have been many studies exploring the use of the Real-Time Virtual

Engine. A review of the literature using the search terms Game Engine, Virtual Engine, Real-Time, Technology, Education yielded a high number of results (Bozalek, 2014; Foot, 2014; Koszalka & Wu, 2004; Nussbaumer, 2012). In many of these studies, a complex system of recording the activities of the learners and their engagement with technology is employed. A high number of studies employed informal interviews or open-ended questionnaires. A number of researchers have referred to an 'interview checklist'. However, this is an incidence frequently found in the field of Human-Computer-Interaction and Interface Design. Yael Kali (2011) discusses the role of technology in creative contexts in 'Learning, Media and Technology'. She states, 'We believe that future progress in learning R&D will require more and better research on users, their needs, contexts of use and the affordances of the various tools and resources that are meant to improve their design activity..." (p. 130). This is a valid claim, the field needs more reporting to better our understanding of the impacts of technology on future learners. Propositions such as this indicate the need to undertake study; however, how do we study the experiences of those who employ virtual reality in the architectural design studio? Table 3 traces seven key principles important in architectural education and maps each principle to studies undertaken using a Real-Time Virtual Engine.

Table 3. Table 3: Architectural studies in virtual reality.

Key Principle	What aspects of Architecutre have been explored in VR	Literature
Atmosphere	The abilty to describe space in high fidelity to evoke an emotional response	Moleta (2015); Moleta (2017); Debono & Moleta (2016); Vasylevska, K., Podkosova, I., & Kaufmann, H. (2015).;
Construction	Constructability, project management and construction pratices are central to Architecure	Moleta, Vaai & Moloney (2014); Joch (2005) Beckmann (1998). Mitchell & McCullough (1991); Morgan & Zampi (1995); Livingston (2008); Kuliga, Thrash, Dalton & Hölscher(2015)
Collaboration	Architecture as a profession requires its students to develop skills in collaboration and sharing	Lo, Schnabel & Moleta(2018); Moleta, Walker & Schnabel (2018); Lo, Schnabel & Moleta(2016); Moleta (2016); Segard, Moleta & Moloney (2013);
Creative expression	Creative expression and speculation on design activity	Rogers, Schnabel & Moleta (2019); Voss & Moleta (2016); Dean (2008)
Geometry, Scale, Proportion	How architects use geometry scale and proportion	Holth, Meekings, Moleta & Schnabel (2019); Innes, Schnabel & Moleta (2017)
Culture	How architecture contributes to a culture through design of social spaces	Qureshi, Schnabel & Moleta (2019); Silcock, Rushton, Moleta & Schnabel (2018); Qureshi, Schnabel & Moleta (2018); Aydin, Schnabel & Moleta(2017); Duddumpudi, Moleta & Moloney (2013)
Design systems	How architects go about the activity of design	Wang & Moleta(2019), Wang, Moleta & Schnabel (2018); Nguyen, Moleta & Schnabel (2019) Dorta, Aydin, Schnabel & Moleta (2017); Chen & Wang (2017); Weibel, Schmutz, Pahud & Wissmath (2015)

7. Conclusion

Despite this amassed pool of knowledge, there are aspects of the Real-Time Virtual Engine's deployment in the contemporary design studio that do not appear to have been observed and documented. The literature review uncovers some striking findings the most telling being Mavers (1995) claim about CAD research pre-1995 cited a need for empirical evidence. I am therefore reporting that few papers contradict his postulation and furthermore, even fewer of these are from the perspective of the student.

References

Abdelfattah, H.K. and Raouf, A.A.: 2004, No more fear or doubt: Electronica Architecture in Architectural Education, *Proceedings of ASCAAD 'e-Design in Architecture'*, 155-176.

Askland, H.H., Ostwald, M.J. and Williams, A.: 2012, *Assessing creativity□: supporting learning in architecture and design. Office for Learning and Teaching*, Australian Govenment Office for Learning and Teaching (OLT), Sydney.

Attoe, W. and Mugerauer, R.: 1991, Excellent studio teaching in architecture, *Studies in Higher Education,*, **16(1)**, 41-50.

Beckman, J.: 1998, *Virtual Dimension: Architecture, Representation, and Crash Culture*, Princeton Architectural Press.

Bogost, I.: 2007, *Persuasive games: the expressive power of videogames*, MIT Press.

de Bono, J. and Moleta, T.: 2016, Sentimentality and the Digital Expanse An Exploration of Virtual Environments and their Emotive Impact on Virtual Inhabitants, *SIGraDi 2016, XX Congress of the Iberoamerican Society of Digital Graphics*, Buenos Aires, 668-676.

Carlhian, J.P.: 1979, The Ecole Des Beaux-Arts: Modes and Manners, *Journal of Architectural Education*, **33**, 7-17.

Caruso, A.: 2019, Studio Culture: learning from the American experience, *The Oxford Conference□: A Re-Evaluation of Education in Architecture*, Oxford.

Chen, Y.H. and Wang, C.H.: 2017, Learner presence, perception, and learning achievements in augmented–reality–mediated learning environments, *Interactive Learning Environments*, **1**, 1-14.

Chieh, J.L.: 2005, Space layout game: An Interactive Game of Space Layout for Teaching and Representing Design Knowledge, *CAADRIA 2005 [Proceedings of the 10th International Conference on Computer Aided Architectural Design Research in Asia*, New Delhi.

Cocchiarella, L.: 2015, *Working with the Image: Description Processing Prediction*, Springer.

Davies, R.L.: 1960, The Education Of an Architect, *The Education Of an Architect*, **50**, 1-14.

Deamer, P.: 2005, First Year: The Fictions of Studio Design, *Perspecta*, **36**, 10-16.

Dutton, T.A.: 1987, Design and Studio Pedagogy, *Journal of Architectural Education*, **41**(1), 16-25.

Gül, L.F.: 2012, Educating new generation of architects, *Proceedings of eCAADe 2012, Digital Physcality*, Prague, 77-85.

Herbert, A.: 2010, *The pedagogy of creativity*, Routledge.

Joch, A.: 2005, Design embraces the machine age: Digital fabrication of architecture, *Architectural Record*, **193**(12), 1-20.

Khrystyna, K., Podkosova, I. and Kaufman, H.: 2015, Walking in Virtual Reality: Flexible Spaces and Other Techniques, *The Visual Language of Technique*, **7**(7), 81-97.

Kilicaslan, J. and Ziyrek, B.E.: 2012, A research about creativity in design education, *Procedia -Social and Behavioral Sciences*, **46**, 1461-1464.

Kuliga, S.F., Thrash, T., Dalton, R.C. and Hölscher, C.: 2015, Virtual reality as an empirical research tool — Exploring user experience in a real building and a corresponding virtual model, *Computers, Environment and Urban Systems*, **54**, 363-375.

Liang, C.H. and Chang, T.W.: 2006, TOWARD A PLAYFUL DESIGN ENVIRONMENT - DIGAME, *Rhythm and Harmony in Digital Space in Proceedings of CAADRIA 2006*, Kumamoto, 187-196.

Lyndon, D.: 1978, Architectural Education Here, *Journal of Architectural Education*, **31**, 2.

MacGilvray, D.F.: 1992, The Proper Education of Musicians and Architects, *Journal of Architectural Education*, **46**(2), 87.

McEwen, I.K.: 2003, *Vitruvius: Writing the Body of Architecture*, MIT Press.

Mitchell, W.J. and McCollough, M.: 1991, *Digital design media□: a handbook for architects and design professionals*, Van Nostrand Reinhold.

Moleta, T.: 2016, Game on: Exploring constructive design behaviors through the use of real-time virtual engines in architectural education, *International Journal of Architectural Computing*, **14**(3), 212-218.

Moleta, T.: 2017, Digital Ephemera - Autonomous Real-Time Events in Virtual Environments, *CAADRIA 2017 - 22nd International Conference on Computer-Aided Architectural Design Research in Asia: Protocols, Flows and Glitches*, Suzhou, China, 14-22.

Nitsche, M.: 2008, *Video game spaces: image, play, and structure in 3D game worlds*, MIT Press.

Nováková, K., Achten, H. and Matějovská, D.: 2010, Design Studio Pedagogy for Experiments with Unusual Material, Collaboration and Web Communication, *International Journal of Architectural Computing*, **8**(4), 557-572.

Poleman, W. and Keyson, D.: 2008, What Architects & Industrial Designers can teach eachother about managing the design process, *Technology diffusions and design. The metabolism of knowledge*, **1**, 90-107.

Qureshi, C., Moleta, T. and Schnabel, M.A.: 2019, BEYOND THE PORTAL: A Study of the Tangible and Intangible Rituals within Sacred Spaces, *Intelligent & Informed, Proceedings of the 24thInternational Conference of the Association forComputer-Aided Architectural Design Research in Asia*, Wellington.

Radford, A.: 2000, Games and Learning about Form in Architecture, *Automation in Construction*, **9**(4), 379-385.

Vaai, J., Moleta, T. and Moloney, J.: 2014, Integrating project management and mobile augmented reality, *Rethinking Comprehensive Design: Speculative Counterculture - Proceedings of the 19th International Conference on Computer-Aided Architectural Design Research in Asia*, Kyoto.

Varnelis, K.: 1998, The Education of the Innocent Eye, *Journal of Architectural Education*, **51**, 212-223.

Vecchia, L., Pereira, A. and ds Silva, A.: 2009, Teaching/learning Architectural Design based on a Virtual Learning Environment, *International Journal of Architectural Computing*, **7**(2), 255-266.

Wang, T.J. and Huang, K.H.: 2018, Pedagogy, philosophy, and the question of creativity, *Teaching in Higher Education*, **23**(2), 261-273.

Westfall, C.W.: 2008, Why the Orders Belong in Studio, *Journal of Architectural Education*, **61**(4), 95-107.