

Architecture on Digital Flatland

OPPORTUNITIES FOR PRESENTING ARCHITECTURAL PRECEDENTS

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The importance of precedent-based learning in architecture is well recognised by education researchers. Therefore, attention needs to be paid to the sources of building information and their presentation. This paper provides an overview of a research project that deals with the delivery of information of notable buildings specifically on computer screen for the purpose of accessibility to the wider public in general, and architectural students in particular. The paper highlights the critical need to reassess the effectiveness of current available publications. Apart from their traditional print format, architectural publications of design precedents are also swiftly advancing into the digital platform. This platform's potential to contribute to in-depth learning within the discipline has to be explored and exploited. This paper describes an illustrative prototype digital interactive system that explores the potential of visual content and digital capabilities to showcase and present architecture on digital 'flatland'. It adopts Murcutt, Lewin and Lark's, The Arthur and Yvonne Boyd Education Centre in New South Wales, Australia for the model, while outlining the aims, process, and considerations for its implementation. Finally, it reports on a general assessment of responses from a focus group.

INTRODUCTION

The publications of notable architectural works have often been relied upon as the one of the main sources of knowledge in precedent-based learning since physical buildings are less accessible. The effectiveness of these publications in their presentation and their degree of information rigour are assumed but not proven adequate in facilitating clear, in-depth learning. In their transitional phase to digitalisation, this regrettable trend continues unabated. In the digital realm, these architectural presentations take advantage only of the technology's provision for speed and ease of information retrieval. Little has been explored in the area of expanding its visualisation capabilities to leverage information clarity. Understanding the possibilities in the field of digital visualisation within and outside the architectural field, there is still much re-thinking and improvement for such architectural publications to recognise. What are the significant directions to consider in order to capitalise on the digital opportunities afforded within the limitations of the computer screen?

Already, works of architecture are often shrouded with mysteries of coded symbolism that is rarely decipherable and sometimes the language is not even clear to those who claim to truly understand it—the designers. Architecture in reality is not produced through definable, predictable 'aesthetic algorithms' as demonstrated by George Stiny's notion of shape grammar (Stiny 1975) and used in a current computer graphic visualisation to digitally mass-produce buildings (Mueller et al. 2006). In his "Architecture in the age of divided representation," Dalibor Vesely argues that Miesian structure "is sometimes situated in a broader sphere of meaning [which] may be available to the architect himself but to those who are not initiated or have their own critical understanding, the argument must appear hermetic and illusory" (Vesely 2004 33). Most publications supposedly aim at bridging the built form and its meaning, shedding some light on the unexplained world of the architecture they feature. However, often translations do not serve as an effective mediation but become enigmatic pieces themselves, with answers only available to the authors. How could architectural publications be entrusted to teach architectural works and the theories? On the other hand, how could they not attempt this role considering the alternatives are too limited?

Understanding and working with this limitation, this paper proposes a direction for architectural information visual delivery in a digital platform that addresses the overall improvement of media integration.

The aims of this research project are as follows:

- To shed light on relationships between current media and the construction of readers' understand-

ing about architectural projects, in order to investigate the opportunities for more effective delivery methods.

- To propose considerations in gathering information about notable architecture, particularly for use in precedent studies.
- To highlight advantages in using a digital platform to relay visual aspects of architectural information and possible areas or directions that could be explored.
- To propose a possible model for digital architectural publications.

METHODOLOGY

Firstly, in the absence of existing studies into the current performance of architectural publications, it has been found difficult to justify the research pursuit and address the needs of the audience for production of the prototype digital presentation about The Arthur and Yvonne Boyd Education Centre. The justification of the research is based on answering the question: Is there an opportunity to promote and improve architectural publications, especially in the digital format based on audience perception of the current situation? If so, which areas should attention be paid to?

Secondly, in order that the digital prototype be produced, detailed research seeking appropriate data and information about the building is needed. These data are further filtered and categorised based on their relevance to the prototype. The process of data collection necessitates immersion in and familiarity with the object of design. From this stance, informed assessment of the suitability of information can be made.

Thirdly, graphic and visualisation technologies and presentation techniques need to be researched for their potential use in delivery of information specific to the case study. What possible suitable applications or concepts could be adapted appropriate to the usage in the field?

When the above are completed and a prototype is produced, this prototype needs to be assessed by a group of initial users in a simulated setting of architectural learning.

Thus the research methodology is comprised of three main components that investigate:

- 1) The strengths and weaknesses presented by current publications in delivering information about specific architectural works. This is approached through studying the current media performance in explaining and educating students and the wider public about particular notable buildings. An online survey is carried out in order to achieve this objective (Component I, Figure 1). Its outcome is used to inform the overall

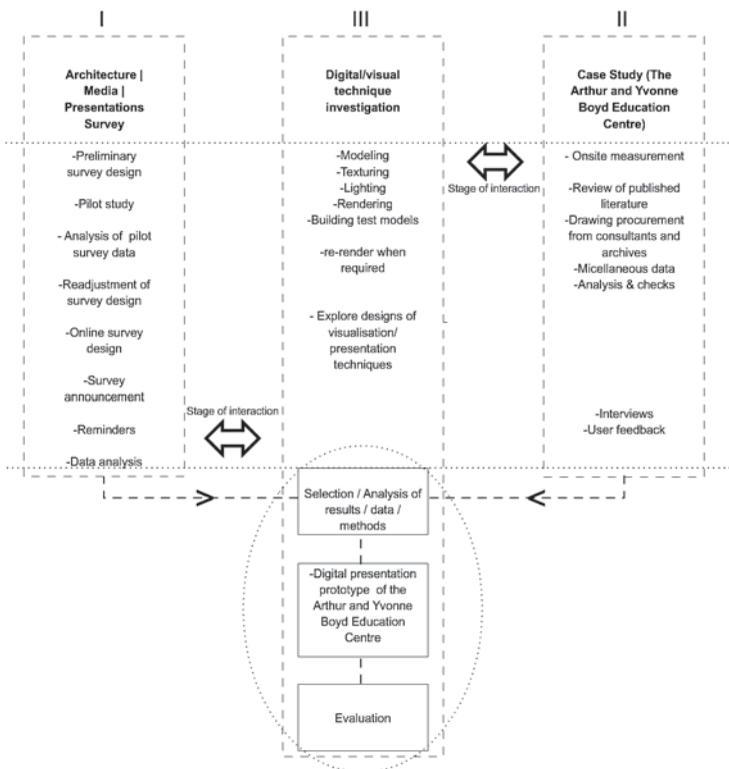


FIGURE 1 An Overview of Methodology

- research project.
- 2) A case study: *The Arthur and Yvonne Boyd Education Centre* by Australian architects Glenn Murcutt, Wendy Lewin and Reg Lark. (Component II, Figure 1). The process includes:
 - project selection criteria;
 - a research into the project background;
 - collection of onsite/offsite information;
 - interviews with the relevant parties involved in the realisation of the building;
 - user feedback.
 - 3) Visual digital presentation techniques (Component III - Figure 1). This entails an investigation of means for delivering architectural information specifically for educational purposes and assesses what the current technologies could facilitate and add to the dimensions necessary to address the requirements for the production of educative material. A digital reconstruction of the building is used in most of this exploration process.

The process of designing an architectural presen-

tation is similar to the conventional design process of analysis-synthesis-evaluation (Lawson 1980). This necessitates that the above components be carried out almost concurrently. As such, the proposal for the building visualisation has to undergo a myriad of transformations to include the new findings of the research components above. And like any design process it shall never be complete, i.e. any solution could be revisited, redesigned, and re-evaluated all over again.

FINDINGS

The following findings have been derived from the above research components:

- The survey has been designed to study the performance of media in architectural publications and how they contribute to the understanding of architectural works from the perspective of the audience (raw data is available for download: Kwee 2006). The results have provided insights into the varying presence of architectural media within existing publications and how they have been commonly executed. The high frequency of certain media types is apparent and there appears to be lower-than-desired performance in overall media quality. The assessment has also shown that there is still a vast opportunity to use and integrate various media to provide a better platform for the study of architecture (for detailed analysis, please refer to Kwee et al. 2006a). It is strongly suggested that architectural publications need to steer themselves in a direction which is more audience-centred.
- A set of comprehensive information about the building is obtained. It includes a collection of existing documentations as well as a compilation of recorded interviews which are later transcribed, outlining the design and development process. The data is further classified according to information type (for more details, please refer to Kwee et al. 2006b). A selection of information is extracted as an illustrative example of the building’s possible digital presentation.
- The combination of visualisation techniques for use in detailed architectural studies, analyses, and records in digital platform may be enhanced through the re-interpretation and hybridisation of technological strengths, concepts, and strategies found in other fields, traditional or otherwise. Not one particular technique would be able to show the full object of architecture through the computer screen. Since each technique, including every medium within it, possesses unique strengths, combinations of them need to be considered.

ILLUSTRATIVE PROTOTYPE

From the findings and compilations of data above, it is clear that coherence, apart from the depth of information, is imperative to help augment the understanding of a presented architectural work. The following illustrations are based on the concept of seamless integration of media to present architectural information through the concept of layering.

Figure 2: An animation sequence is selected as the central medium to which other related media are anchored. It is thus placed in the highest position on the hierarchical structure of media used. A second layer of information in the form of an animated directional compass is attached to this architectural animation to specify the bearing of the view direction.

As in most digital movies, standard navigations are provided. Unlike them, however, additional modifiers are added. These include the zooming and panning buttons and transparency sliders. The magnification here is restricted due to the resolution of the original movie clip which had to be relatively low to allow for speed of display.

Figure 3: The sequence of animation permits adjustable transparency, revealing a separate layer of corresponding animation below that indicates the roof constructions of the building and how these construction elements relate to the whole.

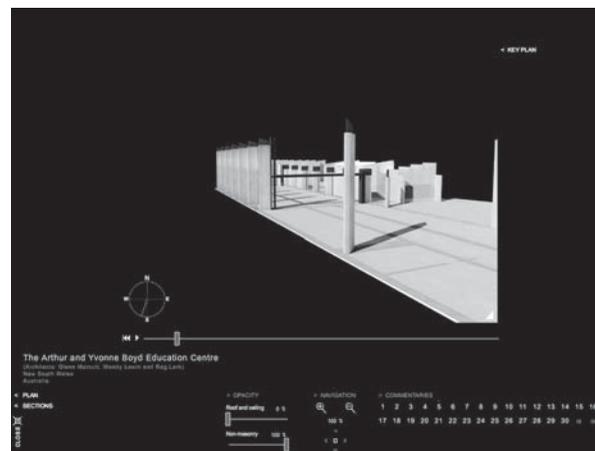
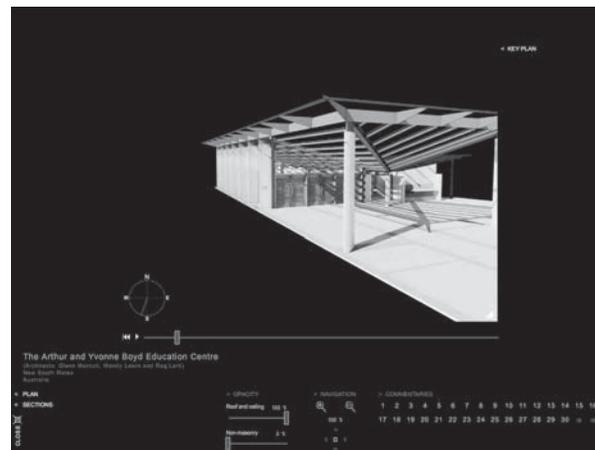
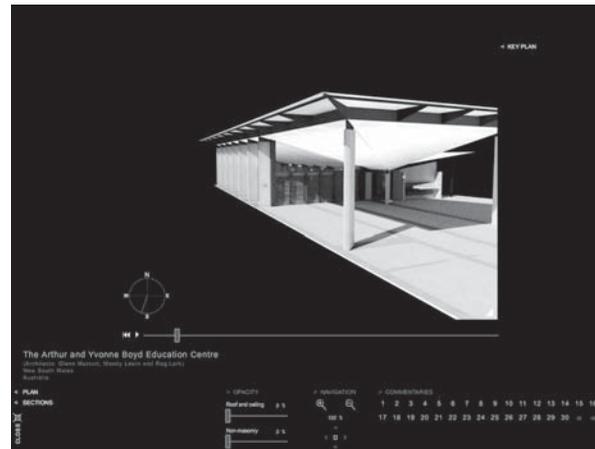
Figure 4: In order to understand the structural components of the building, another layer of animation is located beneath the other two layers of animations. All layers of animation run concurrently and with uniform sequence. Adjusting the transparency of the middle layer may affect the transparency of the top layer.

Figure 5: Another layer of animation that indicates the position of the camera in relation to the building plan may also be revealed. Adjustable transparency is significant in allowing the visual connection between the various animations with each carrying its own particular information.

Figure 6: A non-visual, textual layer may be evoked to add to the information content. This medium is contextualised in relation to its visual counterpart and line indicators are attached wherever applicable to increase the explicitness of the textual referents.

Figure 7: In some instances, where the level of legibility from the visual component is inadequate, additional media are introduced. In Figure 7, within the layer of non-visual information, an additional medium of line graphics/sketches are used to clarify the textual explanation.

Figure 8: Reflecting the versatility of the text medium which often tends to reference external ideas, the embedding of visual components within the texts to illustrate



From top to bottom
FIGURE 2 Digital Presentation–Screenshot
FIGURE 3 Digital Presentation–Screenshot
FIGURE 4 Digital Presentation–Screenshot

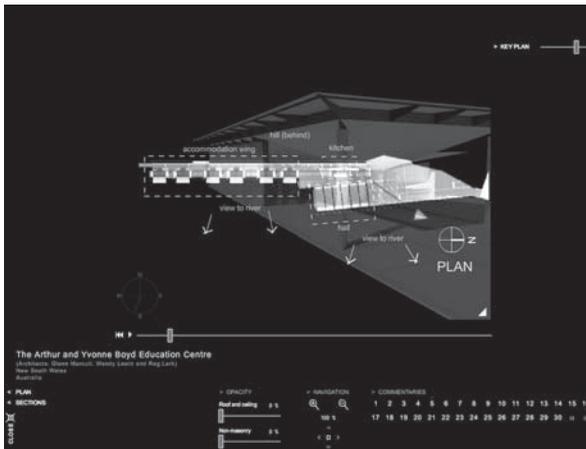


FIGURE 5 (top) Digital Presentation—Screenshot

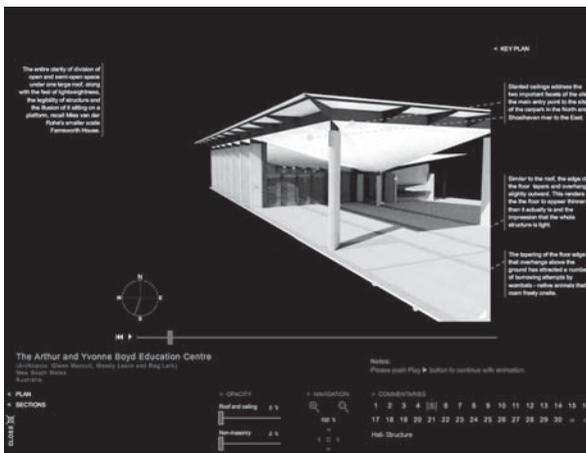


FIGURE 6 (bottom) Digital Presentation—Screenshot

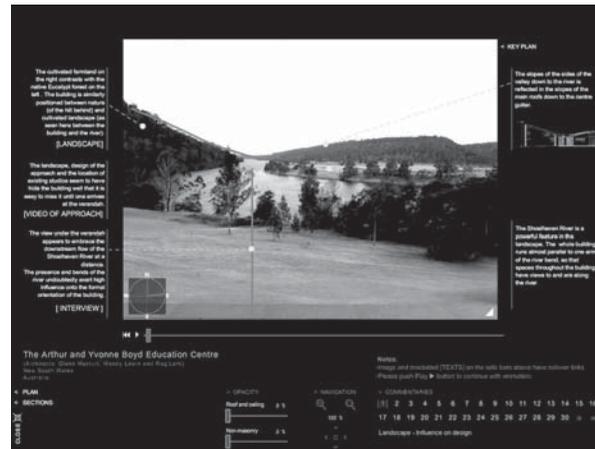


FIGURE 7 (top) Digital Presentation—Screenshot

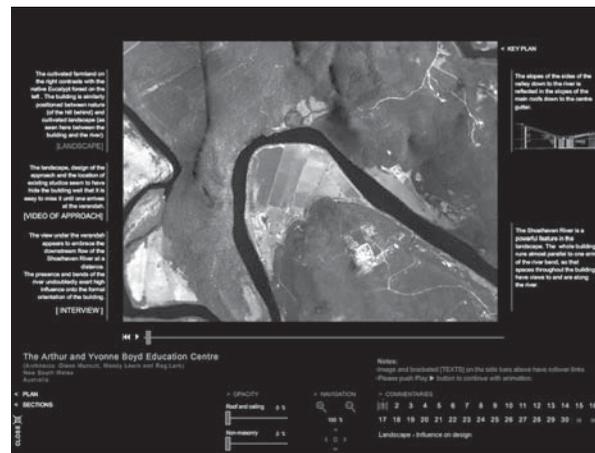


FIGURE 8 (bottom) Digital Presentation—Screenshot

the message becomes necessary to increase legibility. Figure 8 exemplifies the necessity of a site animation to narrate the condition of the surrounding landscape. Satellite images used in the animation above have been obtained through screenshots procured through Google Earth which are later mapped onto a three-dimensional model of the landscape. A three-dimensional model of the building is rendered according to the similar camera path and layered upon the final animation of the landscape through image compositing.

Figure 9: Understanding the strengths of each medium is imperative in the choice of narrative vehicle. Figure 9 illustrates the use of digital video recording to provide the impression of the winding journey from the gate of the property to the building compound. There is no compelling advantage in using an animated model.

Figure 10: When textual references are made to particular details of the building that may not be obvious through onsite photographs, animations or video record-

ing, the architects' drawings become the only reliable source of dependable illustration.

Figure 11: Direct explanations from the designers may be desired at certain junctures. This not only validates the textual explanations, but also addresses the needs for affirmation required by the audience as indicated in the survey.

Figure 12: Two-dimensional animations are also another medium type that might be necessary to best illustrate the textual content. This figure shows the portion of roof that receives rainwater that is channelled to the underground storage tank, while indicating the estimated locations of the components in relation to the elongated facade.

Figure 13: By applying dynamic layering of a working drawing with adjustable transparency over the sectional model and relating the two-dimensional coded architectural symbolism to its corresponding three-dimensional illustration, an interactive overlay provides richer information to each medium. Apart from

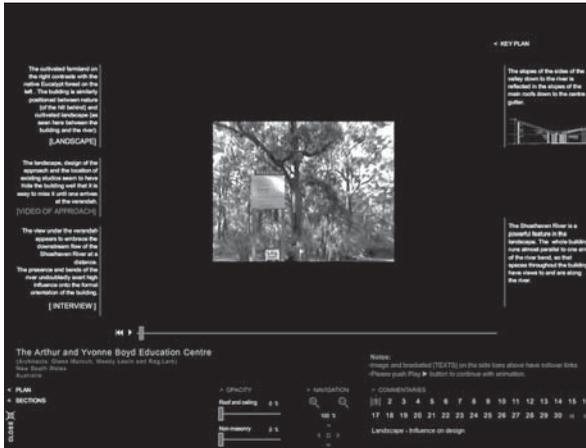


FIGURE 9 (top) Digital Presentation—Screenshot
FIGURE 10 (bottom) Digital Presentation—Screenshot

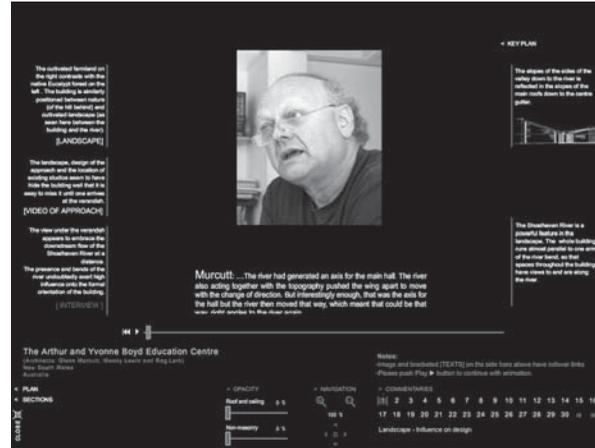
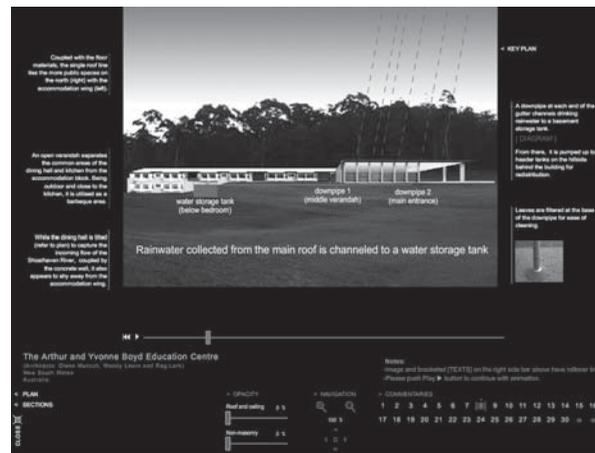


FIGURE 11 (top) Digital Presentation—Screenshot
FIGURE 12 (bottom) Digital Presentation—Screenshot



the ability to understand the component, their sizes, finishing and materials within each of the rooms and spaces through the architectural labels of the working drawing, reciprocally, the technique adds visual qualities to the more abstract descriptions of the drawings. In addition, similar to some CAD applications, a key plan is added at the bottom of the screen to situate the viewed portion within the overall scheme.

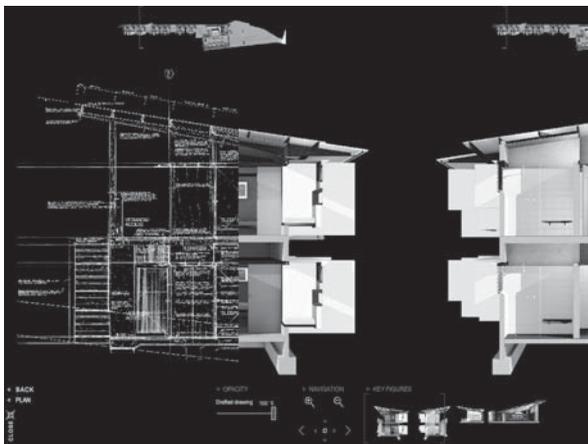
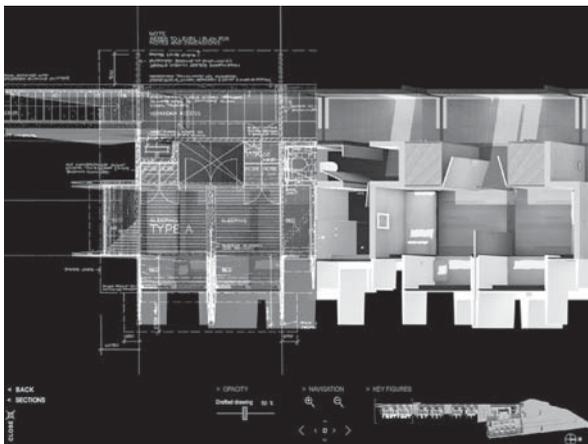
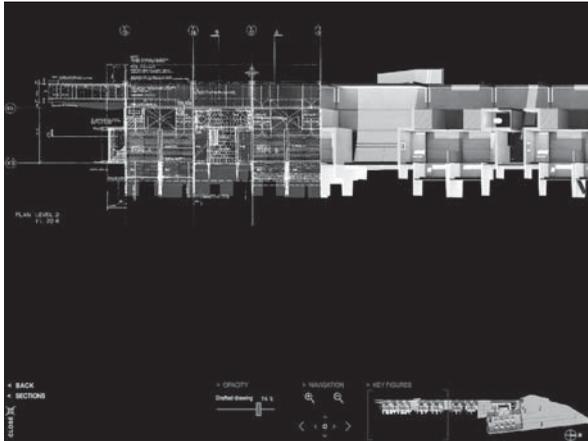
Overall, this visualisation technique shifts a degree of responsibility to the reader in exploring the materials closely and forming their own analysis without relying on the author's interpretation. More texts, of course, could be added to offer this interpretation, if required.

Figure 14: Due to the limited space of the screen, a zooming technique is applied while still maintaining the overlay capability. This helps increase the readability of the texts within the high-resolution digital architectural documentation. By clicking and dragging the display area, the images may be panned. This is in addition to the panning buttons provided.

Figure 15: A similar mode of presentation as illustrated for the plan above is applied to view the various sections throughout the building. Apart from providing a spatial depth appreciation to the two-dimensional sections, it is aimed to give a clear insight into the vertical arrangements of the building components.

DISCUSSION

The suggestion of the findings is clear: there are needs and ways for improvements in architectural publications to be accomplished in the digital platform. However, we cannot dismiss the counter argument that the level of quality found in current publications is sufficient for its value in evoking our imagination for what their discussed buildings could be instead of what they are. To a stratum of audience and for some purposes, that may be justifiable. Therefore, the coffee-table publications likened to fictitious novels are neither challenged nor replaced. However, if we were to embrace the belief that these publications are sufficiently designed for students



From top to bottom:

FIGURE 13 Digital Presentation—Screenshot

FIGURE 14 Digital Presentation—Screenshot

FIGURE 15 Digital Presentation—Screenshot

to easily gain deeper understanding of an architectural project, we are dismissing the bigger opportunities that the digital platform could provide—to teach and possibly to inspire with clearer message and with more appropriate “massage,” to borrow Marshall McLuhan’s term (McLuhan and Fiore 1967).

In order that an indication of the quality of, as well as interest in, this delivery mode may be gathered, a focus group assessment has been implemented. Because the system is only an illustrative prototype and the current absence of comparable work to benchmark it against in terms of content and delivery techniques, this small group assessment should only be considered preliminary. However, the results provide an indicative response to this digital approach.

The participants of the focus group were recruited based on their background. Most of the 12 participants were fulltime undergraduate and postgraduate students predominantly in the discipline of architecture. This helps in acquiring answers from samples with some prior exposures to popular architectural publications.

The initial 7 participants were given time to explore the digital information after a brief overview of the navigation system. They were regrouped, and questions were asked face-to-face. Finally, in order to capture more responses from participants, particularly from those who were less participative in the interview, they were asked to fill out a set of questionnaires. The remaining 5 participants were separated into two groups due to their unavailability to join a larger group. Exploration time was provided. Face-to-face responses were less formal in nature in the smaller groups, but written questionnaires were still prescribed.

As a summary, almost all of the group members agreed that they understood the building better after exploring the digital material. Despite this, some had stronger preference for books or the traditional media. This was reflected in the earlier survey of public perception of the current architectural publications. It is interesting to note that preference does not necessarily translate to practice as there are more people who source architectural information from the internet than from books (Kwee et al. 2006a).

When asked to describe what existing publications that they had strong preference for, similar to the media survey, one respondent indicated fictions with immersive storylines attached to descriptions of buildings. There appeared to be an element of ‘experiencing through a character’ that was valued. A couple of respondents with an architectural education background had raised the issue of blue prints being an easy static object to look at. Could this preference have been shaped by habits? Will the presence of more digital educational materials

like this alter the perception of end-users? Learning from the introduction of a digital drafting system, for instance, the pattern of apprehension in embracing a new system was clear. During those initial phases, many professionals and academics alike had strong unwavering preference for manually produced working drawings. This view had almost become a non-issue as far as the delivery of information aspect is concerned. Readers tend to look past the medium now and concentrate on the message or content.

Overall, there was a positive interest in similar digital resources for other buildings if they were made readily available in the future. Although this figure may be encouraging, this response may exhibit merely an interest to learn more about notable buildings or indeed the preference for the system for delivering the rich visual content. This may have to be ascertained in future evaluations.

A participant remarked that the digital platform would not be able to convey the 'poetics' of the building design which could only be experienced onsite. This is understandable. Experiences onsite can not be totally replaced by its representations and the poetics of the referent are dissimilar to the poetics of its representation(s).

More work on the visualisation of architectural information and rigorous research-analysis of notable architecture will need to be produced to be able to justifiably evaluate applicable systems in tandem. Projects like 'Aalto on the Internet' (Madrazo and Andreas 2001) are excellent platforms for research into design and analysis, but the component of presenting the findings in ways easily digested by a larger audience who may be of different backgrounds appears to be overlooked. As more techniques and systems are developed and made available, presentation patterns specifically for the presentation of architectural knowledge should emerge.

To produce resources like the illustrated prototype and to take advantage of the internet as a popular means to access digital information, several considerations need to be further studied:

- *The availability of user-friendly technologies* to facilitate authoring of these digital resources. The lack of such a system is apparent and has been a considered a hindrance to the production of similar work for publication.
- *The 'standardisation' of content depth or rigour.* A set of guidelines will need to be in place to monitor the quality of the content. Beacham, Richard, Hugh Denard, and Franco Niccoucci, for example, are proposing visualisation standard for heritage work presentation (Beacham et al. 2006). A similar character should be set up to guide this type of educational

materials within the architectural field to ensure a certain depth and quality of information.

- *User accessibility*, which may translate to the standardisation of user interface, among many other aspects. Rigorous research into user interfaces within the architectural field and their effects on learning seems to be lacking. Other factors involve technical issues such as the access speed, transmission of data, system platform, etc., which may affect the facilitation of speedier communication and accessibility.

CONCLUSION AND FUTURE WORK

It has been more than a decade since Bermudez raised a similar stance in the use of technology in architectural design and practice: "Thus an essential issue before us today is *how the representational techniques and technologies of the information age do and will affect architecture*. Eluding this question means to fall trap in an uncritical utilization of the new tools of depiction" (Bermudez 1995 140). It is now overdue that we should critically assess the approach of delivery techniques, media and technologies in relation to architectural education, specifically in the presentation of architectural information. The stakes and implications may be higher than they first appear.

Visual media have too long been used as a secondary support to educational architectural writing that attempts to explain buildings. Within the current period of digital transition, visual representations may and should take a more active, primary role. As Jeff Kowalski in his presentation at Autodesk World Press Day notes, "it's easy to see how extending the visual representation of a design extends the reach of understanding" (Kowalski 2007). CAD manufacturers have been largely active in investigating ways to present designs which will help designers show their products to customers. Much of the technologies available now could be applied to foster a larger role that will link designers and their designs with design students in their educational pursuits. This opportunity is currently still untapped. Could an architect, for example, insert a simple video or audio track explaining the rationale for using a certain material for the façade cladding of his building, and attach this to his digital drawing which is readily layered with a three dimensional representation and animation of it? It is certainly possible. As such, visual architectural documentation will take on a role not only as a construction document and graphical presentation in isolation from other related information as it is now, but it could also be forwarded to students to assist them in understanding the process and thoughts of the designers in an integrated media format.

If we understand the position of representations, contrary to the fear that some may attempt to instil, we should understand too that the media will not lead to the demise of architecture. The proliferation of efficient delivery methods for architectural information will not only result in the unveiling of many architectural mysteries, but they will also further heighten architectural interest and true appreciation. This has been historically proven by the traditional media. However, a substantially improved presentation of architectural knowledge in visual clarity may further prove a long-awaited revelation to the field—in education and thus practice.

There is some immediate further work that might stem from this research project:

1. Extending the dimensions of digital presentation of architectural works could be made at several levels:
 - Adding a timeline or frame number would facilitate the referencing and communication of extra information by readers through a web log. Facilitating the addition of commentaries to visuals is also a sub-area to investigate.
 - Linking this type of educational material to popular public applications such as Google Earth, where it is currently possible to add only three-dimensional models without detailed explanations.
 - A system of presentation may also be derived that could directly extract information from CAD models to facilitate speedier authoring instruments. This will consequently lead to faster and more effective dissemination of information.
 - Tunçer, et al. note that “the study of important historical precedents or designs plays an important role in design instruction and in the students’ design processes. While there is no doubt that the most effective outcome of such a study would be achieved when the student does the entire study him-/herself, students also benefit from a collaboration with peers, where they form groups to do an analysis of various aspects of a same building or over a group of buildings” (Tunçer et al. 2001a 114). The benefit of collaborative learning in enhancing individual learning is also highlighted by David Nicol and Simon Piling (Nicol and Piling 2000). In the development of future educational materials, peer-assisted learning could also be investigated. Taking digital architectural publications further, they could include, for example, online live forums and chat rooms where users could share findings, opinions, and knowledge.
 - In line with the above, considering a viewer’s experience might be enhanced through an onsite tour, it might pose a separate opportunity to investigate the possibility for integrating real onsite visitors and those behind the screen equipped with such digital presentation of the building. It may allow a distant learning of experiences through a site viewed from another person’s perspective as an added dimension.
2. Akin to the notion of a pattern language in design, as presentation methods or vocabularies of architectural information and analysis delivery develop and are used, there could be observable syntax and patterns and thus grammar to digital delivery and its techniques as well. As explorations continue, we are inadvertently involved in the process of constructing vocabularies of digital presentation methods through which architectural designs could unfold.
3. The educational value of digital presentation works requires a further study, especially in its effect or contribution to the field of architectural education. Assessment of this approach can only be done well when criteria guidelines—which may include content depth or rigour and delivery modes—are clearly established.
4. E-learning of architectural precedents has largely been confined to the ‘traditional’ modes of text and static images. The popular Blackboard application used by educational institutions to post lecture notes, etc. could be extended to cater to full-fledged visual presentations. Although visual, graphic-intensive content at present may not be widely accessible through the internet, there is still the possibility of incorporating such materials through e-learning within specific institutions.
5. Traditional architectural concept presentations and documentations could be revamped to take advantage of digital presentation possibilities. This would not only assist in ensuring that built structures adhere to the intentions of the designers as much as possible during construction, but it would also facilitate the ready availability of educational materials for learning use.
6. More in-depth study of graphic user interfaces in the field and their impact on learning could be explored. Such study could possibly be based on those implemented in available graphic applications within the field (e.g. CAD applications), in other graphic disciplines or in games. Should a new set of interfaces be established specifically for learning architectural precedents?

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REFERENCES

- Beacham, R., H. Denard, and F. Niccoucci. 2006. An Introduction to London Charter. In *The e-volution of Information Communication Technology in Cultural Heritage. Where Hi-Tech Touches the Past: Risks and Challenges for the 21st Century*, ed. M. Ioannides, D. Arnold, F. Niccolucci, 263-269. Nicosia, Cyprus: EPOCH.
- Bermudez, J. 1995. Designing Architectural Experiences: Using Computers to Construct Temporal 3D Narratives. In *ACADIA Conference - Computing in Design - Enabling, Capturing and Sharing Ideas, 19-22 October 1995*, ed. Loukas Nickolas Kalisperis, and Branko Kolarevic, 139-149. United States: ACADIA.
- Kowalski, J. 2007. *Autodesk World Press Day: Experience The Possibilities Now!*, Video: WMV/3:43. http://www.pacificcommerce.com.au/autodesk/newsletters_archive/ASEANCustomerNewsletter_Issue14.html
- Kwee, V. 2006. Architecture | Media | Representations: Survey Data 2006. <http://cumincad.scix.net/cgi-bin/works/Show?id=8d88>
- Kwee, V., A. Radford, and D. Bruton. 2006a. Architecture | Media | Representations Survey - Exigencies at a Media Crossroad. In *ANZAScA 40th Annual Conference of the Architectural Science Association, Nov 2006, at Adelaide (Australia)*, ed. S. Susan, V. Soebarto and T. Williamson, 225-232. The University of Adelaide, Australia: Architectural Science Association.
- Kwee, V., A. Radford, and D. Bruton. 2006b. Educative Visuals - Digital Delivery of Architectural Information for (potential) Heritage Buildings. In *VAST 2006, Oct 2006, at Nicosia (Cyprus)*, ed. M. Ioannides, D. Arnold, F. Niccolucci and K. Mania, 91-99. Nicosia, Cyprus: Eurographics.
- Lawson, B. 1980. *How designers think*. London: Architectural Press, Eastview Editions.
- Madrazo, L., and W. Andreas. 2001. Aalto on the Internet: architectural analysis and concept representation with computer media. *Automation in Construction* 10(5): 561-575.
- McLuhan, M., and Q. Fiore. 1967. *The medium is the message*. New York: Random House.
- Mueller, P., P. Wonka, S. Haegler, A. Ulmer, and L. V. Gool. 2006. Procedural Modelling of Buildings. In *Proceedings of ACM SIGGRAPH 2006, Boston, MA, 614-623*. New York, NY: Association for Computing Machinery.
- Nicol, D., and S. Piling. 2000. Architectural Education and the Profession—Preparing for the Future. In *Changing Architectural Education*, ed. D. Nicol and S. Piling, 1-26. New York: Spon Press.
- Oxman, R. 2004. Think-maps: teaching design thinking in design education. *Design Studies* 25(1):63-91.
- Stiny, G. 1975. *Pictorial and Formal Aspects of Shape and Shape Grammars*. Basel: Birkhauser.
- Tunçer, B., R. Stouffs, and S. Sariyildiz. 2001. Facilitating the complexity of architectural analyses. In *AVOCAAAD - Third International Conference - Added Value of Computer Aided Architectural Design, 4 June 2001*, ed. N. Koenraad, P. Tom, V. Johan and V. Johan, 114-121. *Brussel, Belgium: Departement Architectuur Sint-Lucas*.
- Vesely, D. 2004. *Architecture in the age of divided representation : the question of creativity in the shadow of production*. Cambridge, MA: MIT Press.