Design Activity within Immersive Design Environments

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ABSTRACT: The introduction of digital design tools such as CAD Visualisations, Shared Virtual Spaces and Immersive Projection Systems, into the industrial design process has offered designers numerous benefits – primarily related to a reduction in development time and cost. However the use of digital design media changes both the kind of activities and interactions that produce the designs and those used to probe and further the designs in design reviews within an educational context. This paper presents research of user interactions and experiences in design review sessions. Reviews using both traditional media and digital (Virtual Reality) media are studied. The study examines design conversations, design reflections and the nature of the use of design media in both cases. The study has identified that the use of digital media for design reviews alters the nature of the design review process and its impact should be considered before adopting such an approach.

KEYWORDS: Industrial Design, Collocated interaction, Virtual Reality, Conceptual Design Reviews and Interaction Design.

INTRODUCTION

The term 'Industrial Design' describes the creation of products and systems that satisfy human needs and improve people's lives. As design is the process of communicating among various audiences, the design team must ensure that they create a shared understanding among the participants within the design process – typically done through creating artifacts that are accessible and comprehensible to all (Erickson, 1995).

Harrison and Minneman (1996), note that "while much has been made of the role of sketching in design activity, little has been done to shed light on the myriad of ways that solid objects play into design activity. How do artifacts function in the generative, performative processes of taking ideas to realities? What purposes do the artifacts serve? When do designers turn to the physical world?"

This paper provides an initial analysis of the impacts on

the design process through the use of the different prototyping mediums. A study of the interactions between designers and physical and virtual prototypes within the early stages of design development is provided, which has identified the roles the various mediums have on design thinking.

Artifacts And Design Thinking

Schon's (1990) reflection in action design paradigm provides a useful framework to identify the role of the artifact on design thinking. Schon describes the design process as an interactive process of (a) framing the design problem, (b) discovery mediated by the materials and (c) subsequent reframing of the problem in the light of the discoveries made during designing. In his initial description of the reflection in action paradigm (Schon 1983) he describes the sketch as talking back and revealing issues to the designer.

Brereton (2000) found through her study of multi-year engineering students and professional designers engaging in project work that engineers continually challenge the discrepancies between the physical representation and their conceptual understanding in order to advance both the design process and their conceptual understanding. She identified that: "design thinking is heavily dependant on physical objects; that designers are active and opportunistic in seeking out physical props; and that the interpretation of and use of an object depends heavily on the activity". She notes that the evolving physical prototype is a yet more active and evocative participant than the sketch as it responds through physical behaviour allowing the designer to obtain feedback through seeing, smelling and hearing the prototype.

If the physical model has been shown to be more evocative than the sketch, does the virtual model provide additional advances to design thinking?

Virtual Design Artifacts

During the past decade the tools used for product design development has changed significantly. Digital tools such as CAD Visualisations, Shared Virtual Spaces and Immersive Projection Systems have been made available to the Industrial Design community to assist in the communication and detail development aspects of the design process. Often such tools relate to the development of a 3-Dimensional model, allowing infinite viewing angles to be generated of the proposed concept and assisting in the detail design resolution of the final

design solution. Although the use of 3D virtual models is widely used for design and manufacturing, its role in assisting the creative design process is relatively unknown. Of the limited studies undertaken (Deisinger 2000 and Söderman 2002) on the role of virtual models for design, the impact on the nature of design conversation and subsequent design reflection resulting from the use of such media is often not considered. In order to address this issue one must come to understand the detailed interactions that constitute the design review experience.

Design reviews refer to the occasions when teams of designers come together to further develop the design concept. It is here where the team develops a shared understanding of the concept through group discussions and interaction with the many sketches and models. Design review sessions differ from design presentations, as the goal is not to 'present' the design concept for approval to the design team, but to discuss and further the design concept. The focus of this paper is on conceptual design reviews rather than development activity.

RESEARCH STUDY
A study was undertaken of the interaction between designers and design artifacts (sketches and models) during a weekly design review session. The context for the study was a final year undergraduate industrial design exercise. The focus of the project was the redesign of a consumer white goods product. As is typical in such a process, the students communicated design details and their relationship to the original design brief through a series of sketches and form studies. Peers and experts then critiqued the design. The goal of the review was to obtain a shared understanding of the concept among the team whilst determining the suitability of the concept to meeting the original design brief. Figure 1 illustrates the studio setting and physical objects used throughout the traditional design review setting. The session was fairly informal, reviewers and designers engaged in considerable discussion and clarification throughout the process.

Figure 1: Design Review Studio Environment

This design review was then supplemented with another design review utilizing an immersive design environment

(Fakespace Immersadek R2) (Figure 2). Students were given the option of undertaking a design critique of their design concepts using a virtual representation of their concept only. To do this the students were required to create a low fidelity 3D CAD representation of their design concept. Students were not required to add any additional detail to their design and therefore the 3D CAD representations did not include texture representation or mechanical details and therefore were similar to the physical models used in the traditional design setting. The goal of the design review using this environment was identical to that of the traditional environment -- to develop a shared understanding of the concept among the team whilst determining the suitability of the concept to meeting the original design brief.
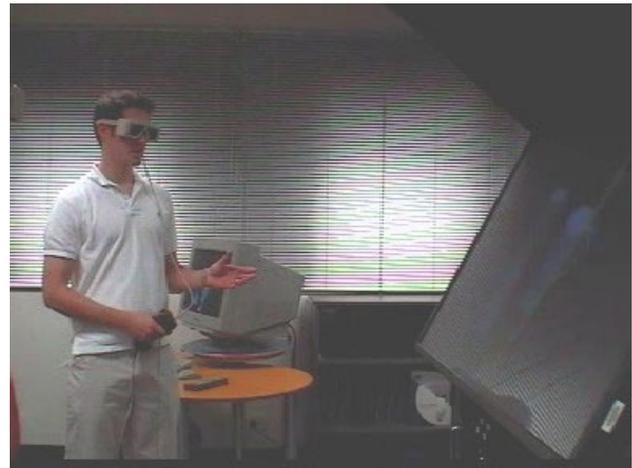

Figure 2: Virtual Design Review Studio Environment

Evaluating User Interaction
There are many methods that could be applied to evaluate user interaction and experiences. However as we were interested in understanding the moment-to-moment interactions with media, video was chosen to capture the interactions.

During the course of designing one is focused on the design discussion, which precludes paying attention to exactly how you are using and manipulating the media, so detailed interactions are not available for reflection. A video camera can capture the dynamics of the work setting and the complexity of interaction, albeit from a single viewpoint, rendering human activities such as talk, nonverbal interaction, the use of artifacts and technologies and the immediate workplace context available for repeated viewing and analysis, so that researchers can examine the consistency and generality of their observations.

Video Interaction Analysis (VIA) as described by Jordan and Henderson (1995) is an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment. Its roots lie in ethnomethodology. In VIA an interdisciplinary team of researchers views segments of

tapes selected by the primary investigator and identifies routine practices, routine problems and resources for their solution. VIA is an exploratory research technique. It supports formulation of our understanding of natural activity and assists us in generating explanatory frameworks and hypotheses grounded in verifiable observable empirical evidence. Were it even desirable, it is too early to define a controlled setting that affords comparison and statistical proof of types of interaction because types of interaction are not yet identified.

Seven final year undergraduate industrial design students were observed (using digital video recordings) during traditional and virtual design reviews (approximately 15 minutes each in duration each). Students were also asked to reflect on the virtual design experience on completion of the design review. The results for these studies are presented below and have been presented using a combination of patterns of activities identified and student reflections.

INITIAL OBSERVATIONS - USABILITY
It became clear from repeated viewing of the video data that usability issues related to the virtual environment setting were a major concern. Although undertaking usability studies of the virtual environment was not a primary aim of the study, its impact on the design review session became evident.

As noted the environment used as part of the study was a commercial system designed specifically as a tool primarily for small group discussions such as design reviews. The system included 6DOF-tracked wand to allow for interaction of the model by using a "skewering" metaphor (VRSCAPE). Head tracking was also included with the other participants required to wear LCD shutter glasses to be able to view the active stereo projection.

Although such a system is considered state of the art usability issues were observed in all groups studied. Further student reflection on their experience within the virtual environment referred heavily to the usability difficulties that they had encountered. Typical issues identified related to: the weight of the stereo glasses, which became uncomfortable after short periods of use; the skewer metaphor to rotate the object required unnecessary hand rotation; and the need for team members to stand behind the person wearing tracked glasses in order to obtain the 'one' correct view generated due to the head tracking (Figure 3).

Although such issues could be considered minor, their indirect impact on design activity during the design review was observed. To illustrate this relationship the following extracts from the student reflections have been provided:

Figure 3: Ensuring 'Correct' View is Seen By Group

...I also found it was hard to talk about the design because I would be trying to move a part of the blender while I was being asked questions. Because I was concentrating so hard in navigating the objects I wasn't answering the questions very well. I think if I had a physical model it would have been a lot easier in explaining the usability of the jug handle and the pouring action ... (V-002)

...I was also limited due to the undesirable usability problems of the ImmersaDesk, such as the glasses cord problems and the hand device problems with navigation and object manipulation. I personally find it quite hard to use the hand device and easily move objects around as I desire to explain details of the design. (V-002)

... I believe physical models are a better aid for a design critique, it is something tactile and is excellent for looking at the form, scale, proportions, usability, semantics and ergonomics. I also personally feel a lot more comfortable talking about a design with a model. This is because I do not need to concentrate about holding glasses on, on trying to navigate my product with a user unfriendly hand control. With a foam model I can concentrate on what is important, communicating the design... (V-002)

As the students have indicated, traditional artifacts are intuitive to use within the context of a design review. This allows them to focus on the design discussion rather than diverting their attention to the control of an interface device. The difference between traditional artifacts and the virtual interface are explored further below.

INITIAL OBSERVATIONS – DESIGN ACTIVITY
It was noted that in both the traditional and virtual environment settings a number of similar activities, and interactions styles were common to both approaches. These observations are summarized in the following table.

Design Activity	Design Context	Interaction Styles
Presenting Querying Discussion Resolving	Usability Market Technical Aesthetics	Referring to model or sketch directly Interacting with the model Simulating action

Further significant querying and discussion of the design concept leading to a shared understanding by the group was observed in both environments. It had initially appeared that Schon's (1990) interactive process of (a) framing the design problem, (b) discovery mediated by the materials and (c) subsequent reframing of the problem in the light of the discoveries made during designing was evident in both situations. However a more detailed analysis of the interaction revealed that although the groups did develop a shared understanding in both environments the approaches to how this was achieved were significantly different. These differences relate to the level of abstraction between the virtual and physical artifacts and how the students compensate for this using a variety of interaction styles during the design review.

Artifacts Representing Abstract Knowledge
Within the traditional environment, students made use of a large variety of artifacts such as sketches (technical representations and rendered form perspectives) and foam form models. Although the design concept was not a final design solution, the prototype artifacts contained a significant level of detail. Students were able to refer to technical details such as wall sections and engineering components. Further the tactile qualities of the foam model, allowed students to directly interact with the model, furthering their understanding of the design concept. Students would focus their conversation on the actual artifacts, as the necessary information was available in an appropriate form. They touched, pointed at, manipulated and gestured with the artifacts. This approach followed Schon's reflective conversation with the materials of the situation. An issue was raised (see), and they would manipulate the device in order to explore the issue (move), resulting in better understanding of the issue (see).

However within the virtual setting, the students did not have access to such detailed information and therefore had to rely on a level of abstraction to convey their design concept. This resulted in the students compensating for the level of abstraction through the use of interaction techniques such as pantomimes of intended user interactions and through verbal descriptions of the concept which relied heavily on their prior experiences. This often occurred away from the 3D virtual representation. This observation is explained further in the following visual narration of how the designer utilizes each of the artifacts within a traditional and virtual review session.

The sketch is used to explain the details of the proposed concept. The designer refers to known details to best communicate the concept.

The foam model is used to simulate assembly and component details. The model is also commonly used to describe the intended user activity. Further, the group uses the artifact directly to query the design with discussion being made using the artifact.

When this is compared to the interaction style and use of the medium within a virtual setting a different pattern of activity was observed.

As noted within the virtual environment, the designer only had the virtual representation to assist in communicating their design. Unlike a typical detailed 3D CAD representation, which contains significant design detail, the virtual representation used during this review was similar in detail to an early stage physical foam model. As this was the only artifact which they had available to them during the review, the designer could not rely on the variety of artifacts to prompt discussion as in a traditional setting and was required to rely on external resources such as metaphors, hand simulations and detailed verbal descriptions to assist them in communicating their concept.

The following demonstrates the interaction styles and role of the medium within the virtual setting.

As the designer is unable to directly interact with the model, they are often required to simulate the user action and provide a rich verbal description to describe the intended interaction to the group.

Often the design conversation occurs away from the screen and the virtual representation. Often a richer discussion occurred away from the virtual environment, when the designers could remove their stereo glasses and discuss the details using a combination of rich language, simulating action through pantomimes and metaphors to communicate the concept and resolve a particular design detail.

This point is further elaborated in the designer's reflection on the experience of using the virtual environment

...I had quite a few unresolved areas, which I tried to explain what I intended to do to the group. These included the base section and power activation area that would have a foot-button. However this was very difficult to explain with the use of the model on screen, I felt like I needed to draw interactively on screen to get my point across. In the end, I found I didn't really use the model so

much as I explained to the group about my future intentions. (V-003)

The technology is such that everyone has the same view of the product and a person pointing at one item he sees, appears to be indicating something completely different or even not in the scene to other participants. This forces you to fall back on verbal communication during the interaction or conventional methods thereafter. The technology has its benefits in the interaction and manipulation of the product by the individual to create a feeling of ownership (not fiscal, but in terms of interaction) (V-007)

To further illustrate these differences the following transcript of a particular design review is provided.

Traditional Setting Design Review

Time	Transcript (T-0304) (Student comments in italics)
0.03	*This is our original kettle, the (product name). (Referring to actual product) As you can see it is very tall very awkward looking. It has a lot of usability issues the first one was just actually pouring was uncomfortable (simulating pouring action with actual product) especially when it was full of two liters of water. The lid also (opening up product lid) when you poured out the water basically split everywhere ... that was just the first little things from a usability issue and also manufacturing wise (referring to technical sketch) it had large assembly time (referring to actual product) a lot of part processing cost, they have painted, they have tried to put the silver into some of these polypropylene parts and they have ended up seeing they it has not worked they have painted the tops of it and it is really poor quality finishes and in generally a pretty poor quality product but it was in the (high price bracket noted) kettle market range so ... manual assembly on everything – seventeen screws and two springs ...*
0.55	*I can start with my design first, that is the section (referring to concept sketch). First I will talk you through the usability issues (holding form model) – I have changed the lid design (referring to concept sketch and simulating intended user action) I personally thought that a one button lid release was probably sufficient not the two, that also cut down part sizes – so I went from this is what the original part assembly was for the lid (referring to concept sketch) and I have now limited it to this (referring to a concept sketch detail) so instead of having the originally have the two buttons which were had to be put in with a*

	spring and a jig and it had another section which came in here which required a jig and a spring and you had to screw the two section together so I made it now instead of two buttons a one button release (referring to a concept sketch detail) and this comes into this gap the spring sits in here and the that sit over the rib (searches for a new concept sketch) – is that technical detail (referring to a concept sketch) yep - it will snap into this section here (referring to another concept detail) ...
1.54 -	Additional technical discussion continues making reference to both the concept sketches, actual product and form model
3.39	It looks very complex? *To use it?* No just the button *Well originally I was considering not actually having a button release to use it (referring to foam model and simulating lifting of lid), you just pull it up but that was taking away a feature so that button release gave it a bit more of a prestige, our kettle was low on features as it is ... (*Design reviews continues for another seven minutes)

Within this traditional design review, the student is able to make sufficient time to use the available artifacts to describe the necessary detail of his concept. The student makes use of the knowledge gained during the experimentation with the physical artifacts which occurred external to the review, however the findings are embodied in the artifacts brought to the design review. Whereas in the virtual review, the nature of the conversation and the use of the artifacts was significantly different.

Virtual Design Review

Time	Transcript (V-014)
0.01	*Our original product was a (product name) that had a lot of aesthetic issues, manufacturing issues, it was meant to be an expensive kettle but overall was a poor quality product* (rotating virtual object on screen)
0.12	*So what we aimed to do in this one was to increase the product quality and also fix some of the issues the other one had such as it was sort of sitting back on an arch like that (referring to virtual object) so basically it basically looked like it should knock forward*

	and the handle was very comfortable to pour ... it was also a two litre jug which made it very heavy and very hard to pour and we did some research into that and most people didn't want that anyway.
0.35	*So we actually made it smaller – it looks tall? That's it there (referring to form study and then back to the virtual model) Its tall because our element is actually quite small and to make it that water capacity you have to make it that big*
0.50	I think your also pushing these very fine lines (referring to virtual model) going straight up and there is nothing in the middle to break it up and it looks very long – *there is actually a line here where the element is (detail is not shown but still point to virtual model) 40mm from the base and there is also a window that comes in here that follows the curve back there which is one of the nicest things that people thought about the product* - if you want to bring that window out …that is going to make it look smaller – *originally that window went around the back (tracing an outline on the virtual product where the window would be) so it was one window into the jug – that said it made it look too wide and people did not like that and they preferred it to the to small windows on the side* … (design review continued for another eight minutes)

Here the students also make use of the prior knowledge gained during the experimentation with the physical artifacts which occurred external to the review, however this knowledge gained could not be integrated into the artifacts developed for the design review and therefore the students rely on verbal communication to describe this knowledge. When directly relating to the virtual representation the conversation is directed to the level of detail afforded on screen. Typically this conversation related to aesthetic or form issues.

The contrast in the differences between the two mediums is illustrated in the following schematic. Within the traditional setting (Figure 4a), the artifact affords direct interaction by the design group and therefore allows for a shared understanding to be developed through this interaction, supported by the prior knowledge brought by participants of the design review. Within this setting Schon's reflective conversation with the materials of the situation is clearly identifiable.
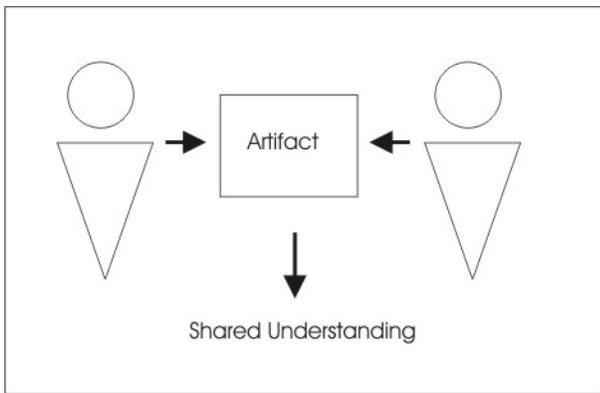
Figure 4a: Traditional Setting Schematic

In contrast in the Virtual setting (Figure 4b), the virtual representation acts as a prompt for conversations but is not incorporated directly into conversations. The prior knowledge and experience brought to the design review by the participants dominates the conversations. The shared understanding is generated from this prior knowledge and through the use of detailed gestural pantomiming and verbal discussion. These interactions are required because the virtual representation has little detail and therefore are unable to interact with it directly. Within this setting Schon's description of the design process would not relate to the reflective conversation with the materials but to the design language, prior knowledge brought to the design review and pantomime interaction used to describe a particular concept during the design review.
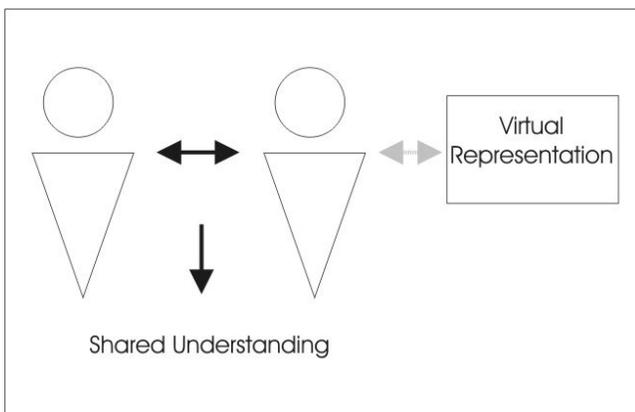

Figure 4b: Virtual Setting Schematic

The following reflection from a student designer on their experience in using the virtual environment offers a fitting summary of this observation.

Overall the virtual environment is relatively quick to prepare and is a great way of presenting a design concept onscreen. However, more traditional methods such as physical 3D models have always been an excellent communication tool because it is something that communicates straight away design issues that may not be

so obvious onscreen, such as the size of the product. I think a combination of physical 3d models together with computer-generated images such as those created in VR is ideal for presenting a design concept. This is because both elements offer something unique, which the other doesn't. So a combination of both traditional and new design tools such as a virtual environment would be ideal for a design presentation. (V-017)

SIGNIFICANCE OF FINDINGS

The authors believe that the difference in interaction style and role of the medium is significant when considering a design review activity within a virtual or traditional design setting.

The difference in interaction styles observed in both settings raises two questions which directly relate to the use of such a tool within an educational setting.

First, the reliance on prior experience to assist in the communication of the designer's concept within the virtual setting indicates that such a tool may only be beneficial to latter year or experienced designers who are capable of working with abstract concepts and without the need for artifacts to communicate this abstraction. It would be expected that if this study was repeated with early year design students, the level of conversation observed within the virtual setting would have been reduced, as these student would not have the necessary experience to work with such abstract concepts.

Secondly, within this study the design students were able to utilize their knowledge gained during the physical experimentation with the form studies which occurred external to the design review. In both the traditional and virtual settings, this knowledge was referred to during the design review. However, had students only been able to use virtual tools in order to develop their designs, they would have had to draw on physical knowledge from prior projects and not from any direct prototyping experience on this specific design problem. It is unclear how provocative the virtual prototype would have been in this case in raising design, usability and manufacturing issues. Therefore the benefit of virtual only tools within an education environment for design development draws into sharp focus the question of where students obtain the necessary physical knowledge in order to design.

CONCLUSION AND FUTURE RESEARCH
As the use of virtual tools within educational design institutions increases, an understanding of the impacts of such tools is required. Designed products are the result of designers interactions and design tools have the effect of changing those interactions.

This research has provided an insight into the role of virtual environments within the context of a conceptual design review. It has compared the interaction styles

between designers and traditional artifacts and designers and virtual representations. The focus of the study was comparing the two environments in order to determine how the medium influenced the ability to engage design conversation and develop a shared understanding among the members of the design group. Using the method of Video Interaction analysis certain interaction styles and patterns of activities with the traditional and virtual environments have been identified.

Future research will extend the studies reported within this paper.   A more detailed analysis of the differences in the design language during each of the review environments identified will be undertaken in order to further characterize the qualities of the design discussions and interactions taking place in both kinds of environments.

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