MOTIVATIONAL AND PHYSICAL BENEFITS OF VIRTUAL REALITY ENHANCED HANDS-ON IDEATION WORKFLOW

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Imagine architecture and interior design students sketching in 3D space rather than a 2D piece of paper. Imagine these students sculpting forms intuitively with modifiable colour and scale. Imagine students moving around as they ideate as compared to doing it as prolonged unhealthy sedentary activity on a desk. These are some potential benefits offered by a virtual reality (VR) enhanced hands-on design ideation workflow that currently have not been widely realized. A workflow that this pilot study at a polytechnic built environment studies related course in Singapore wishes to explore.

Singapore is a relevant context that provides opportunity for a rigorous litmus test for this research. This is due to the increasingly mandatory use of Building Information Modelling (BIM). It is a prominent requirement in built environment studies education in Singapore. There are clear benefits that warrant the increased adoption of BIM in Singapore. The information inherent in the models created in BIM software would be able to be used for a range of analysis on the building. These benefits range from topics such as quantity surveying, structural integrity to environmental performance. However, there is currently a major difficulty in teaching the students the use of BIM in a creative and intuitive ways for even making the building's initial form. Currently, the complex procedural and parametric workflow of BIM software is very counter intuitive for the students. Exploring a workflow that introduces the use of VR created forms as input for BIM at the conceptual design stage of a project has the potential to make a breakthrough in overcoming this major obstacle.

This paper compared the students' conceptual designs using BIM software that were done using a conventional BIM workflow with results that are achieved when forms created in VR modelling were used as input for BIM. The comparison reveals that there are tangible improvements in terms of intuitive, enjoyable as well as healthier kinaesthetic creation processes. The VR modelling inputs also expanded the range of highly exploratory forms that are achievable. However, the current research identified some current limitations that the VR created forms on specific circumstances could not be made into specific building parts. There are also, some current additional requirements needed to enable effective transfer of data from the VR Modelling to the BIM software. Future research is planned to address these limitations.

Keywords: *Virtual Reality Modelling, Building Information Modelling, Kinaesthetic Design, Hands-on Intuitive Design*.

Introduction

In the current digital age, it has become increasingly difficult for built environment design courses to dedicate sufficient training of students on basic manual, hands on intuitive skills. These range from abilities to externalise ideas by sketching on a piece of paper to roughly sculpting forms. There is constant pressure to reduce teaching hours for these fundamental skills (Patron et al, 2021; Oxman, 2008; Ranscombe et al, 2017). In its place, an increased emphasis is given to digital means of production that are increasingly required to be used in the built environment industry. (Page, 2019; Bacus, 2020).

Singapore provides a tangible context in which this shift is very evident. This is especially seen in the increasing emphasis on promoting the use of Building Information Modelling (BIM). It has become increasingly mandatory to make digital submissions for planning approval of new buildings using the BIM format (Lin et al, 2016). This trend is related to the detailed building information that can be captured in this format. Information that have a multitude of uses such as for structural calculations, building material quantification and even environmental analysis (Kirby, et al. 2017).

There is a concern that increased use of BIM could potentially undermine the creative thinking ability of future designers of the built environment. The common nature of the BIM workflow that requires prolonged, elaborate initial setup, complex procedural and numeric input makes it very counter intuitive as seen in Figure 1.

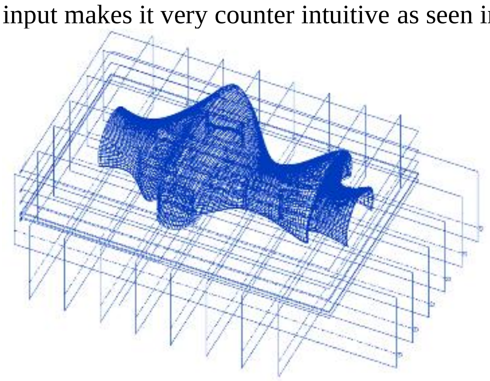

Figure 1. Example of elaborate floor level and grid reference planes arranged in initial setup before the form at the centre is created

In addition to this, Figure 2 shows an example of the various numeric inputs required in developing a common BIM model.

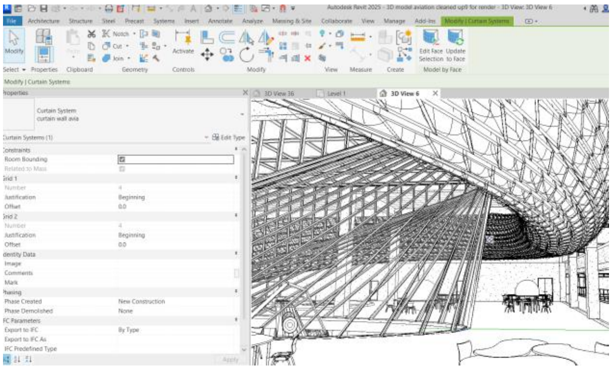

Figure 2. Example of numeric input interface for BIM

The paragraphs above show how BIM would especially be very complex to be used for the initial form ideation process at the conceptual stage of a project. A departure from creative processes traditionally focusing on the designer's agile externalisation of ideas into building forms through quick sketches and sculptures. The visual products in these traditional processes in return stimulate further creative possibilities in the designer's mind (Mc Kim, 1980).

An overview of the current conventional workflow that involves manual approaches and BIM can be summarised in Figure 3 below.

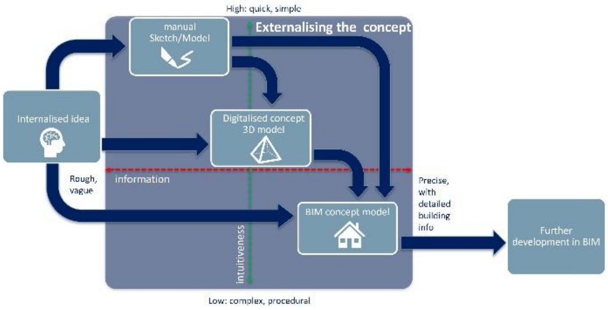

Figure 3. Overview diagram of the current conventional workflow

The diagram shows that the manual approach is extremely agile in externalising ideas and has little restraints in the forms that are possible. However, the products are limited to rough ideas that need to be digitalised in order to be further refined. There are many 3D modelling software which have varying degree of intuitiveness that could also be used to externalise the idea. As Singapore continues to promote BIM, these manual sketches or sculptures as well as products of digital modelling will in the end need to be exported into BIM software for further development.

There is a specific need to modify the current workflow to enable such an agile and creative thinking process to be incorporated in BIM. This would potentially transform the students' mindset to perceive digital modelling in BIM as part of a creative, intuitive and enjoyable ideation activity.

It is important to note that there is a generational trend that current built environment design students, born as digital natives, have higher affinity for digital means of sketching and modelling (Fakhry et al, 2021). At the same time alarming findings of negative health effects of prolonged sedentary work also highlights the importance of seeking digital means that promote rapid and kinaesthetic work activities (Gao et al, 2024). Therefore, modification of the BIM workflow should focus on enabling the students' digital preference to also become a more positively motivational and healthy endeavour.

This paper proposes this through the use of inputs of Virtual Reality (VR) modelling into the workflow. This builds on previous research that have shown the higher utility of VR modelling in comparison with other intuitive means available to digitalise sketching and modelling processes (Hadiatmadja, 2024). The research focuses on specific aspects that could enable VR modelling to support an improved workflow. Aspects that simultaneously support the health and motivational pursuits stated above. At the same time, aspects that may hinder these pursuits will also be examined.

Materials and Methods

This paper will focus on results of ongoing efforts in integrating VR modelling and BIM at a polytechnic level built environment course in Singapore. Focus was on year 3 students who have prior training in BIM using the conventional workflow. More recently, the students have been given training in VR modelling. Therefore, the student respondents would be well placed to give informed feedback to compare between the two modes. Overall, 21 students participated in this research.

The students provided feedback on the effects of VR modelling input for BIM at the conceptual design stage. The students' feedback were mostly obtained through open ended questions in an online anonymous survey. The mostly open-ended nature of the response was meant to enable students to extensively express their feedback.

In line with the research objectives to promote the students' health and motivation, a range of preparations were done. These will be further explained below.

First of this was that the lecturer provided computer hardware with specifications that had been previously proven to be effective in previous research that compared various options for intuitive modelling (Hadiatmadja, 2024). The hardware was positioned in the year 3 student's studio. This would enable easy physical access and motivate the students to use it frequently.

The research area set up, seen in Figure 4, shows an initial 3 metre by 3 metre barrier free work area. During the research it will be observed if this needs to be modified to achieve a sufficient working space.

Figure 4. Initial work area size relative to a polytechnic student.

An important hardware used for this research was a wireless VR headset that would prevent students from tripping on cables when using the headset. The wireless equipment also enables students to freely move around in developing the intended building forms in VR modelling software. This can be seen in Figure 5 below.

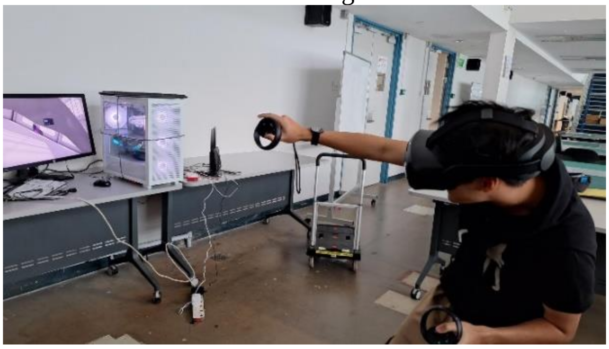

Figure 5. A student using VR modelling equipment in the research space provided.

A further safety precaution is the choice for the students to use of the 'pass through mode' feature of the VR headset. This enables the student to still see the surrounding studio environment even when they are wearing the headset. An example of a passthrough mode can be seen in figure 6 below.

Figure 6. Passthrough mode showing coloured VR modelled forms and the grey scale physical surrounding area.

The planned use of the passthrough mode also enabled students to see the position of various buttons on the actual physical VR hand controllers near its digital representation. This can be seen in the part of the view shown at the bottom right of Figure 6. The coloured digital representation of the hand controller is seen in front of the grey scale pass-through view of the actual physical hand controller. This could help students to see the effect of clicking various buttons on the model they are creating. This is a useful visual support feature for the students, especially when they are initially still getting familiar with the equipment.

As can be seen in Figure 7, there are a range of buttons that the students need to become familiar with. Being able to see the actual physical placement of the buttons in the pass-through mode will help aid the student's initial orientation of the locations of various buttons. Alternatively, the students who chose not to use the pass-through mode would have to use the sense of touch to orientate the location of the buttons.

Figure 7. Zoomed in view of the hand controllers used in this research.

The lecturer planned a system to help maintain good cleanliness and hygiene. After a student uses the headset and hand controllers, the student would have to clean the items with an antiseptic wipe. This prepares the items as a clean set ready for use by the next user. It is hoped that such a system would reduce hesitation of hygiene sensitive students to use a shared headset. During the actual research, feedback is requested from students on possible additional measures that the student feel would further help in this regard.

The study also planned for the lecturer to be able to observe the students' actions through a feature of the VR software that enables the VR view to be casted (screened) on an external monitor. This view enabled the lecturer to provide further guidance while the student is creating the model in VR space. This casted view can be seen in in the left side of Figure 5.

At the start of the research, it was established that the polytechnic has access to two VR modelling software. These are Adobe Substance Modeller and Gravity sketch (Adobe, 2024; Gravity Sketch, 2025). Comparison was done between the two options in terms of the software's compatibility as input into BIM.

The BIM software used in this research was Autodesk Revit. It was chosen because the students have been previously trained using this software. It is commonly used in Singapore (Kaneta et al, 2016).

Before involving students to participate in the research, the class lecturer conducted initial studies to enable the smooth running of VR modelling and transfer of data into BIM. First of this was a comparison between the two available VR modelling software. Both software were intuitive to use for VR modelling. However, currently only the models produced in Gravity Sketch could be exported as a format that is suitable for effective development in BIM.

Gravity Sketch files could be exported in an IGES format, which stands for Initial Graphics Exchange Specification format (Gravity Sketch 2025a). This format has a useful feature that it retains definition of curvature (Joko Engineeringhelp, 2020). A visual comparison between the surface of a model that was saved in an IGES format and a model that was not (in this example an OBJ format) is shown in Figure 8.

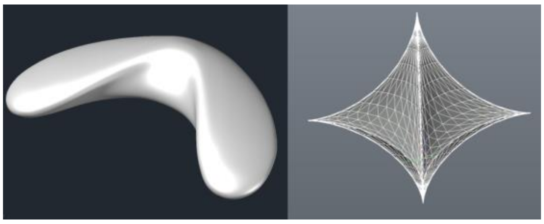

Figure 8. Comparison of IGES (left) & OBJ surfaces (right)

The model saved in IGES format will result in one or a manageable number of large smooth surfaces that can be efficiently modified in BIM. In comparison, the alternative file format (in this example an OBJ format) resulted in a large amount of small, triangulated surfaces that would require the very tedious process of individual modification. Therefore, Gravity Sketch and the IGES format were decided to be used for this research.

The class lecturer also had to overcome an additional problem that currently Autodesk Revit (as the BIM software used) cannot directly import the IGES file. As a solution, a few intermediary software that could import IGES and save it into a format that can be imported into Autodesk Revit were explored. At the end it was found that AutoCAD and Fusion 360 software had specific tools that could be used for such a purpose. Within the intermediary software, the IGES files were able to be saved as a DWG format that is importable to Autodesk Revit. The intermediary software were also useful in converting the surfaces of the IGES file to become solid forms. An important benefit of a solid form is that in Autodesk Revit the unique floor plate shape of each floor level could be automatically generated. An example is shown in Figure 9.

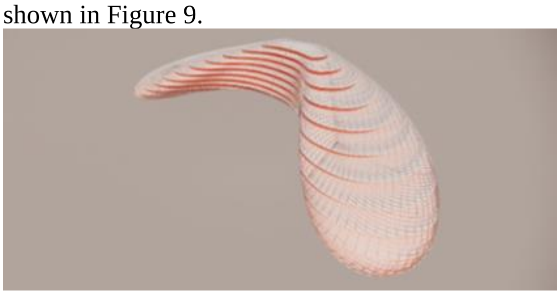

Figure 9. Example of floor levels generated from a VR model that was imported into the BIM software.

Results and Discussion

From the preparations done to incorporate VR modelling, there is an opportunity for a more efficient workflow to emerge. In place of the processes in Figure 3 a new streamlined workflow that incorporates the use of VR modelling emerges as seen in Figure 10 below.

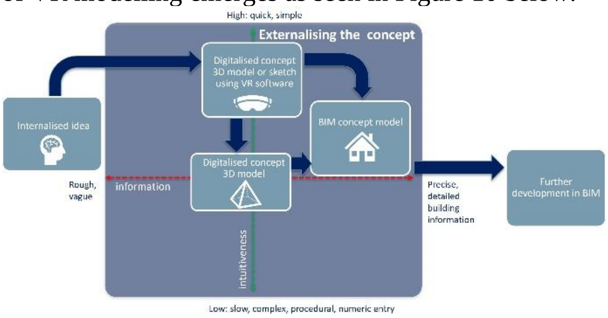

Figure 10. New workflow incorporating VR modelling

Figure 10 shows that traditional manual intuitive sketching can be digitally replicated by the similarly intuitive sketching and modelling that can be done in VR modelling software. This also automatically produces a precise digital form. The time-consuming step needed in the previous workflow to convert from manual to digital is no longer required. The VR produced digital line sketches have additional benefit of being 3D line sketches. After processed through intermediary 3D modelling software, the data is importable to BIM software for further development into building parts.

Students were invited to create forms using Gravity Sketch software and subsequently develop it further in Autodesk Revit. The students were trained on the spot to use the Gravity Sketch software as well as the processes needed to import the VR models as input to subsequently produce BIM models in Autodesk Revit. An example is shown in Figure 11. The students were also briefed on specific commands in the intermediary software for converting surfaces of an IGES file to be solid forms that can be saved as a DWG file.

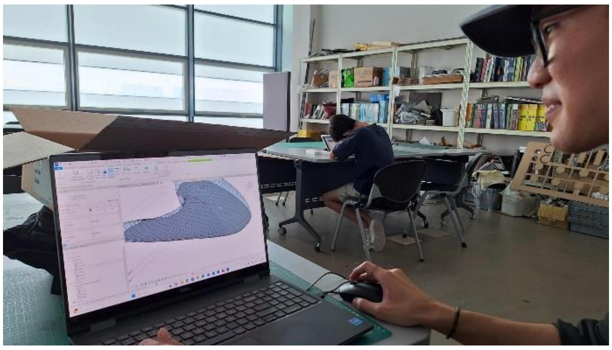

Figure 11. A student further developing a VR model form that was imported into the BIM software.

The paragraphs below will focus on the more positive results of the research that the students gave feedback on. In the online survey, some students expressed appreciation for some highly tangible physical benefits. The students contrasted the new workflow processes with their previous experience of using a mouse to rotate the view of a model on a monitor screen. Some students' feedback also revealed their awareness that the immersive VR view encouraged their entire body to frequently move around the model to view it from various angles. They also gave feedback that they were aware of the positive health implications involved.

Other students gave feedback that when using VR modelling, they focused more on creatively making the form and have less need to constantly figure out the settings of the software itself. Their previous experience in BIM software such as Autodesk Revit necessitated many presets and parameters as previously shown in Figure 1 and Figure 2. Previously, this took the students' focus away from the creative ideation process itself that is of high importance in the concept design stage.

The students provided feedback that VR modelling resulted in very dynamic forms that would have been harder to model directly in BIM software. Some students provided positive comments that the VR modelling process enabled higher freedom and flexibility. The vast majority of students gave feedback that VR modelling was more intuitive in nature compared to BIM.

In terms of the perceived time needed to make the overall conceptual form of the building in the VR modelling software, students gave feedback that it took between 5 to 20 minutes to create a form that they feel satisfied with to be further developed in BIM software. Most students finished their model in about 10 minutes. This is very encouraging that despite the complexities of a range of buttons that the student needs to familiarize themselves with, it took a relatively short period of time for them to be up and running to start making forms in VR space.

It was also observed that a student would be able to be trained on the spot and produce VR forms that were importable to the BIM software within one day. The students were able to achieve models with all external surfaces of building components (e.g. roof, wall or curtain wall). In comparison, the time needed by the same students in their year 2 studies to develop a similar building using BIM software in a conventional workflow was more than two weeks. This represents a significant improvement in time efficiency.

This research also revealed some notable negative feedback. These will be elaborated in the following paragraphs. There seems to be some limitations in terms of importing and exporting of the VR model. These limitations also continued in the latter process of transforming surfaces into building parts in the BIM software. Not all surfaces were able to be transformed into the intended building part. For instance, some surfaces that the students wanted to transform to become a roof or wall was only possible to be transformed into curtain systems which had less potential for further modifications.

Potentially related to the of lingering problems above, there were a sizeable minority (around 35%) of student respondents who still felt that for them working fully in Autodesk Revit would still be more effective. This could be related to the longer-term comfort and familiarity with Autodesk Revit. It could also be related to the negative feedback some students provided that their initial VR forms are too abstract to be perceived as a building right away. BIM software would directly provide information related to building parts. Some students also gave negative feedback that it was harder to find the exact dimensions using the VR modelling software.

Some students felt some discomfort when using the headset. The students stated that the area of contact between their face and the headset rapidly becomes sweaty. This occurred even though they were using it in an air-conditioned studio space. Some students also expressed that the VR headset felt heavy on their head. Some students also felt that the VR screen often became blurry and they felt the screen position was too close to their eyes.

Some students gave feedback in the form of improvement suggestions for the headset related problems. For instance, one suggested the alternative use of light weight and less enclosed augmented reality (AR) glasses in the future when it can be compatible with the modelling software.

There was specific input given by students who opted out of using the pass-through mode in order to have a more focused view of the model. The students commented on the uneasiness of being in VR space while totally visually disconnected from the physical surrounding space.

This research also revealed findings related to parameters of hygiene, time and space requirements. These are useful to note for planning future VR modelling sessions. These will be elaborated in the following paragraphs.

The students appreciated the procedures put in place to sanitize the equipment with antiseptic wipes. It was also encouraging that early in the research, some students proactively suggested the option to use gloves as an extra precaution that a user can utilise.

Currently only one lecturer in the course has experience in using VR modelling software. During this research, the lecturer trained one student at a time. Although as previously stated some students claimed that with the current guidance given, they could be up and running even in 5 minutes, accumulatively it will take a relatively long time in order to train the whole class. As an illustration, for an average size class of 24 students it would take at least 2 hours for the lecturer to initially train the whole class. As not all students are fast learners, this process could be even longer.

The students gave feedback that they appreciated the care given to train students in the detailed use of the controllers on a one-to-one basis. However, the current one to one session could be made more efficient. Some students declined to wait their turn to participate. The overall session was exhausting for the single lecturer to conduct. It is planned that some 'train the trainer' session for other lecturers may be required. This would enable other lecturers to shoulder some of the training responsibilities. Possible video materials would also be useful to be developed as an alternative for students to train with while waiting to use the VR equipment.

Some students also expressed that there was a maximum amount of time that the students could tolerate in using the VR headset. The student feedback showed that 30 minutes was the maximum time that a student would like to continuously be using a VR headset. Most students preferred to use it for about 20 to 30 minutes at a time. A common 2-hour session should potentially be planned to involve stretches of time where the student intermittently engages with other medium. This could be used for further development of the VR model in CAD, 3D and BIM software as planned in the new workflow shown in Figure 10.

It was noticed that the initially planned work area boundary of about 3 metres by 3 metres previously shown in Figure 4 was sufficient. It was observed that such an area enabled the student to stretch their limbs maximally without obstruction. This is bigger than the area utilised by a single student who in the past were deskbound when they did 3D modelling tasks. Overall, a larger studio space would be needed for future VR modelling classes. The current individual area could potentially be useful as a standard module that can be used as part of the planning of this larger studio.

Conclusions

The student respondents stated that the use of processes and equipment as part of the new workflow shown in Figure 10 have many positive impacts that they appreciated. Overall it is a more streamlined, and enjoyably intuitive arrangement. The students were able to quickly familiarise with the use of the VR equipment and software. They were able to create unique conceptual forms more rapidly, intuitively while healthily moving around throughout the process.

Some notable negative feedback are mainly related to the enclosed nature of the VR headset which causes discomfort for some students. There are also current lingering limitations in the software used. The researcher plans to conduct further research on possible emerging alternatives that could overcome these problems.

There are findings on time and space considerations as well as training needs that were important to note from this research. These will be useful for planning future larger scale implementations. Aside from this, it is also important to note that even small gestures of promoting hygene and safety considerations that the lecturer put in place seems to also positively motivate the students. It even encouraged them to be active partners who contribute useful input for further improvement.

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