Augmenting and Virtualising Landscape Architectural Teaching and Learning

Kenya Endo[1], Ervine Shengwei Lin[1], Chun Liang Tan[1]

[1]National University of Singapore, College of Design and Engineering, Department of Architecture/ Singapore · akike@nus.edu.sg

Abstract: The paper explores the potentials and challenges of integrating 3D digital technologies and platforms into landscape design studios to serve as the central medium for design communication and assessment. The paper qualitatively evaluates the efficacy of a technology-embedded design studio through 3 different points of views – learner, educator and expert centric – using questionnaires and structured observational studies. These findings will form a guideline to reinvigorate the teaching and learning experience in landscape architecture through the inclusion of such 3D technologies and platforms, especially in the post-COVID era, as well as increase our relevance with the practice.

Keywords: Teaching, learning, digital, landscape design studio

1 Introduction

Landscape architecture is a discipline that incorporates a number of interrelated parameters in the process of establishing a proper site analysis and eventually developing a spatial design. The most successful design solutions are able to traverse through the initial conceptual stages to the final detail drawings to address site-specific issues and reimagine spaces that are seamless, contextual, functional, buildable, and livable.

Compared to traditional small-scale garden designs, landscape architects nowadays are heavily involved in multi-disciplinary projects, which are larger and more complex than before. However, the tools of teaching design and representing design have resisted changes that match the current architecture, engineering and construction (AEC) industry's needs, for example Building Information Modeling, various hydraulic and micro-climatic simulations. Evolving away from 2D conventions, we envision a paradigm shift in adopting a 3D (or even 4D) way of thinking as a foundation for landscape education and design.

That is not to say that 3D solutions have not been utilized, but the work produced is always flattened back into a 2D graphical medium (in printed panels) thereby losing any potential of deeper appreciation of the spatial qualities of the design. In comparison, we are seeking solutions that are highly interactive in nature and facilitate deeper visual communication which move away from a static view of landscape architectural design and detailing.

As such, to explore the possibility of fundamentally changing the way tutors operate landscape design studios, we implemented a "technology-embedded design studio" which proposed a systematic testing of a paper-less approach in both design development and representation. In other words, no physical printed sheets or models were produced throughout the semester, instead, various digital platforms were explored for design ideation, form making, communication and visualization.

Owing to this pedagogical intervention, we seek to understand if this alters the paradigm in design education towards one which encourages 3D spatial communication of design ideas.

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To this end, the points of interest in our study include observing the efficacy of this method through three different lenses, expert-centric (KURILOVAS 2016), learner-centric as well as educator-centric point of views (TZIMA et al. 2019), in order to evaluate the efficacy of our pedagogical intervention:

- Expert-centric – Understanding changes to how student works are understood and accessed by external examiners
- Learner-centric – Uncovering potential changes to the level of spatial sensitivity in student design works, especially in the areas of detailing and narration, as well as peer-to-peer communication
- Educator-centric – Evaluating the effectiveness of knowledge transfer between tutor and student

The potential use of advanced 3D-centric technology in education has not gone unnoticed by scholars from a variety of different disciplines, but these have historically been leaning primarily towards the science and mathematics (MIKROPOULOS & NATSIS 2011). From early primary school education of mathematics (DEMITRIADOU et al. 2020) used to visualize 3D geometric shapes, to specialized fields like neurosurgery (CHAN et al. 2013) and dentistry (JODA et al. 2019) where there is little room for error in the real world, making the virtual environment a safer and more repeatable training, planning and learning environment.

More related to Landscape Architecture, digital technology, for instance Augmented Reality (AR) and Virtual Reality (VR), has been demonstrated to improve students understanding of fieldwork practices and techniques in geography (BOS et al. 2021) which includes an understanding of topography and hydraulics, both crucial to landscape architecture as well. Certainly, these more grounded areas are where AR/VR technology might prove useful but scholars have also noted its use in design education whereby VR has shown to greatly enhance problem solving activities in architectural design education as well as a higher level of student satisfaction compared to traditional design methods (ÖZGEN et al. 2021). The technology also allows landscape and planning educators to bring students into environments which are either inaccessible or non-existent realities, such as those of design proposals which are never realized (PORTMAN et al. 2015). Spatial understanding for landscape architects has also been shown to have benefits when including 3D environments in conjunction with 2D ones (CARBONELL-CARRERA et al. 2020) while communication through digital storytelling in AR is yet another area of potential interest (KERR & LAWSON 2020).

The implementation of our technology-embedded design studio is along the same trajectory, however, with the goal to identify its pedagogical pros and cons objectively and comprehensively, by implementing digital-centric learnings from the start till the end. We are interested to find out the potentials and challenges through qualitative evidence from each milestone, in order to make proper suggestions in what aspects, to what extent, and how landscape architects can or should elevate our technological literacy in the coming years so as to keep up with the AEC industry's technological innovations.

In addition, the COVID-19 pandemic has challenged design education to be conducted in an agile manner, dynamically swapping between in-situ, hybrid and fully remote teaching has further imposed the necessity of optimizing digital technologies to aid 3D thinking, spatial recognition, and communication virtually. The research findings will provide insights on the process of digital transformation in landscape education, and the overall benefits that could bring to our profession.

2 Methodology

2.1 Technology-embedded Design Studio – Digital Playscapes

We have implemented this approach in a newly offered technology-embedded landscape design studio for year three students enrolled in Bachelor of Landscape Architecture (BLA) Programme at National University of Singapore (NUS), fall semester 2021. The studio titled "Digital Playscapes" focuses on an approximately six hectare site (~ 15 acres), which is an unused landscape close to NUS campus for twenty one students to explore ideas to populate the site with play related landscape programmes and designs. Few existing site elements are present to influence their design decisions (other than some clusters of tall trees and the undulating topography) and as a result requires students to be purposeful in their narrative as well as spatial design. In addition, the studio was purposefully set up to employ an open-ended style, allowing students freedom to explore the variety of digital tools and platforms made available to them while only prescribing the overarching programme.

Preparation works by tutors included digital scanning of the site, shared both as a 3D point cloud and simplified geometry in Rhinoceros3D (Rhino) to serve as students' base model throughout the course of the studio. This model was also presented to the students via two other formats to complement or potentially replace the physical site visit at the beginning of the semester. Firstly the models were shared on SketchFab (an online platform for the sharing and display of 3D models), and through AR via an app that was created using Unity3D and Vuforia (Figure 1). In addition, parametric methods of form-making and design thinking were

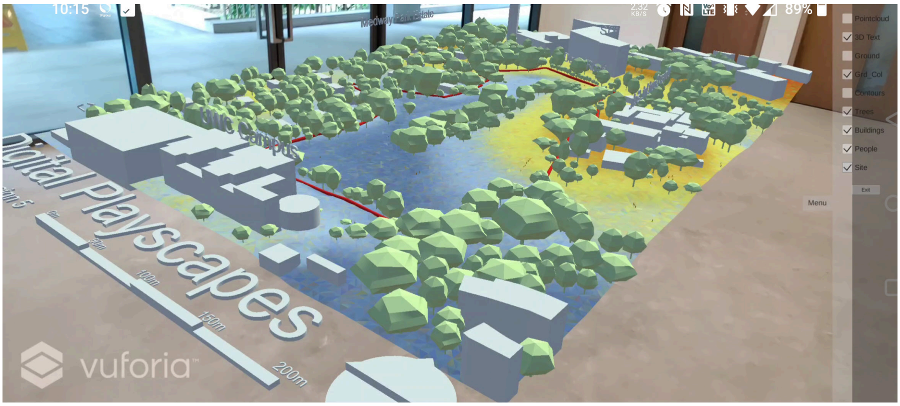

Fig. 1:
The base model was prepared and was presented to students prior to their physical site visit. Two versions were prepared, one via AR through compatible Android devices (above), and another hosted on SketchFab (below).

introduced to students through a series of Grasshopper (a plugin to Rhino) workshops serving as a portion of the technology that was embedded into the studio. To help with the expected steep learning curve (as well as in anticipation to create an agile hybrid environment during the pandemic), a total of 48 video tutorials (ranging from a few minutes to an hour each) were created to transfer knowledge ranging from topics including the handling of the various software, learning parametric modelling, and enabling other necessary workflows (e. g. preparing and uploading models to SketchFab). These videos were recorded on Loom (video recording and sharing platform) to demonstrate the capability of each software, including Rhino, Grasshopper, Unity3D, Vectorworks, SketchFab, Flood Modeller, Vuforia, Twin Motion, and ScreenToGIF.

Keeping in line with the policy of having no physical panels or models, almost all the material prepared both during weekly sessions as well as the final review were hosted and presented in a series of Miro boards – an online whiteboarding platform (Figure 2). This allowed for a variety of interactive materials to be hosted on the platform including images, short animations, videos and even interactive 3D models with SketchFab serving as an interface. Three types of Miro boards were produced during the semester. A main board which included all teaching material as well as intermediate material prepared by students, a series of personal boards or journals which individual students were to maintain and update on a weekly basis, and a consolidated board meant for the final review.

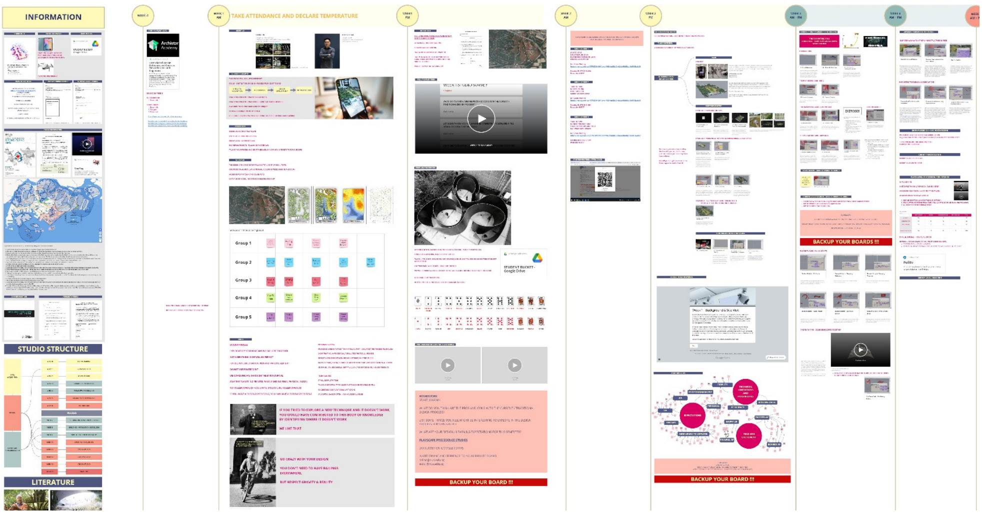

Fig. 2: Miro was used as a communication medium across the duration of the studio, this included design ideation via students' individual boards to official crits via the group's main board

2.2 Framework for Pedagogical Assessment

To test our pedagogical intervention, we attempted to evaluate our introduced methodology through 3 different lenses as each was expected to reveal different pedagogical findings.

Expert-centric Assessment

Design studios are often capped off by a presentation at the end of the semester to a panel of examiners who will then evaluate the project based on the student's ability to convey their ideas both visually and orally. Unfortunately, spatial communication of a designed project is not always immediately understandable based on traditional 2D drawings (plan, sections, elevations, perspectives, etc.). This happens not only during the weekly design studio sessions but is especially obvious when students are given only a very short time during the final oral examination. As such, we introduced various means of presenting their projects in an interactive 3D format during the final review in anticipation that this would improve both the conveying of student's ideas to experts correctly and immediately, and subsequently for experts to assess student's performance accurately. Both oral and written feedback was recorded from experts after the review to reflect their views in our findings.

Learner-centric Assessment

The semester-long studio is essentially a self-directive process of problem-based learning. Thus, feedback from the students' point of view of the new learning environment are essential for our analysis. In addition, since half of the semester was conducted in groups, we were also interested in evaluating the effectiveness of digital technologies in peer-to-peer communication and collaboration, an important aspect of learning in design studios. Questionnaires were distributed to students at the beginning, mid-point, and at the end of the semester to evaluate; 1) changes in their views on the approach to design studios using the various technologies introduced, 2) pros & cons of introducing them in a studio environment, 3) potentials and possibilities for future usage.

Educator-centric Assessment

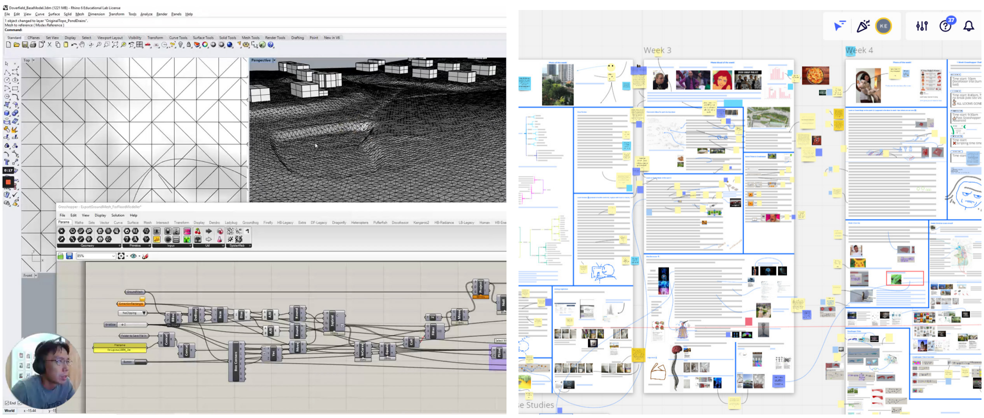

Fig 3: Snapshot of student's weekly journal (left) and Loom tutorials (right: Rhino and Grasshopper) recorded by educators

Weekly discussions between students and tutors formed the bulk of our educator-centric assessment. In order to better capture the evidence of how technologies influence student's decision making process at each phase of the studio, we introduced online Miro hosted individual journals for students to record their struggles and achievements on a weekly basis (Figure 3). In the end, this journal serves to clarify whether knowledge transfer was done properly, and to ensure technical hurdles have not affected student's creativity. In other words, this journal will help to differentiate the effectiveness of digital technologies; whether during the process of design or its final outcome.

3 Results and Discussion

Table 1 summarizes the overall process of the studio, seen from three different perspectives; key tasks, milestones, and interaction points. We found that each phase came along with different sets of pros and cons, but our interest was to understand how the negative factors of introducing digital techniques in a studio environment can be transformed into positive ones from a pedagogical point of view.

Table 1: Flow of design studio and summary of activities relating to experts, learners and educators in each studio phase

	Expert-centric	Learner-centric	Educator-centric
Phase 0: Pre-studio			**Preparation** Studio brief, base 3D files, basic tutorials
Phase 1: Introduction and Group Work		**Exposure** ⟵ Interaction ⟶ To new digital tools and new ways of thinking	**Mass tutorials** Introducing digital tools to all students
Phase 2: Individual Design Development		**Customizing** ⟵ Interaction ⟶ Applying digital tools for individual designs	**Individual tutorials** Providing personalized support on both design and technical development
Phase 3: Final Review	**Q&A, Assessment** ⟵ Interaction ⟶	**Storytelling**	
Phase 4: Post-studio	**Realization**	**Reflection**	**Reflection & Planning**

3.1 Expert-centric Insights in Assessment

The final review for the semester was carried out in person with students using the Miro board as the main vessel for communicating visual elements (Figure 4). Interactive material on the boards was projected but the same boards were accessible by all in the class including the review panel which meant that reviewers could access the interactive material concurrently during the oral presentation (15mins per student).

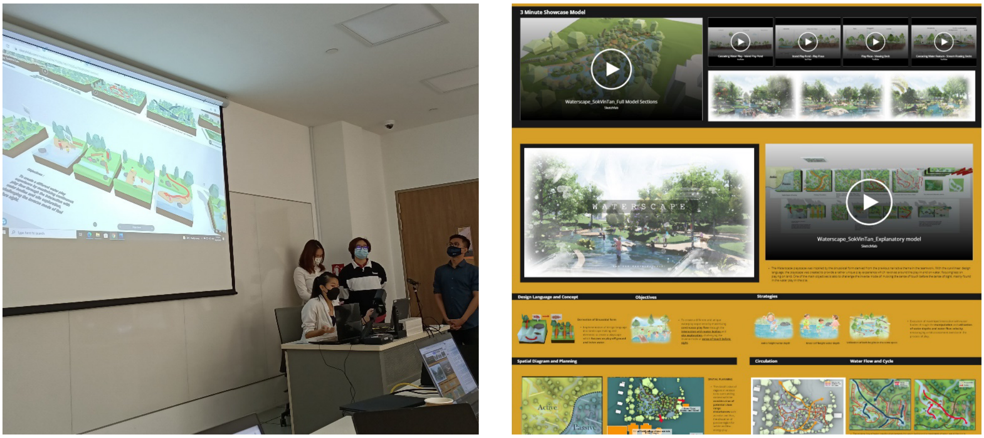

Fig 4: Overview of final review in which embedded SketchFab links allowed for an interactive 3D navigation of uploaded models (left). Student's final work on Miro included various forms of static and interactive graphics such as embedded 3D models, pre-recorded animations or shorter graphics interchange format (GIF) animations (right).

Fig. 5: Applying parametric scoring to create 3D spaces with different levels of "solitude". This design exemplified the active use of Grasshopper for space making with clear illustration of steps taken (Illustrations by Siew Yi Hia).

3.1.1 Findings from Comments by Experts

The oral and written comments from the review panel who served as our "experts" during the final design review were mostly positive. Experts noted that they were able to discern the nuances of student projects within a short period of time. In particular, students who were able to integrate various digital tools to demonstrate their design intent and decision making processes transparently (Figure 5) fared better than those who used the digital tools mainly for a visually attractive representation (often in the form of animated fly throughs). In addition, most of the Q&A session emphasised more on the design process and clarifying the robustness of the underlying design logic as opposed to attempting to grasp the spatial quality of the design proposal.

Another aspect that enhanced the assessment was the seamless transition between 2D to 3D, static image to dynamic graphics, human-scale to aerial view, by using the interactivity offered by the digital whiteboard as a means for final presentation. In fact, some students presented more than half of their content in a 3D format, and some going so far as to explain their entire narrative through the SketchFab interface. Because of this process, the space created by each student became more engaging and less distractive, which enhanced the clarity of the design, including scale, proximity, orientation, and atmosphere with some even including audio as an important component of their design (e. g. the sound of gravel as one walked over it).

3.1.2 Discussion on Expert-centric Aspect

While all 3D material was presented through the projected SketchFab links, a couple of experts requested to see overall site's "before and after" condition viewable through AR with their tablets by overlaying design proposals on the original AR site model to better evaluate the design proposals. While this was an initial goal in the studio, technical and time limitations prevented us from doing so as this would have required the students to individually prepare their projects in Unity3D and Vuforia and have them prepared as individual applications installed in each tablet. In place of that, it was decided that the students could host their models in SketchFab to which the mobile application could view their models in AR. Unfortunately, limitations with the application prevented most models from being loaded in AR and this was skipped entirely in place of a simpler interactive 3D projection on screen controlled by the student or the expert.

Despite these technical issues faced, experts still expressed a positive impression of the digital techniques, realizing the effectiveness in different phases of landscape design. However, they were keen to understand if there was a wider breadth of their usage, namely beyond form-making or representation, but also in site analysis and quantification which could be of more use in practice (although these were actively neither taught nor required during the studio due to a focus on exploration of tools and techniques as opposed to practical considerations).

Perhaps the most important realisation raised by the experts was the fundamental importance of a clear narrative and good communication skills. The significance of these skills remains unchanged whether it's a digital-centric studio or not. Similar to how students need to lay out their graphics on a traditional 2D printed panel in a legible manner, this new digital format also required students to rethink the options made available and the sequencing of their oral presentation. Successful students actively leveraged off the digital platforms provided (SketchFab, Unity3D, Roblox, etc.) as part of the presentation flow producing an effective curated narrative. Less coherent students fared worse regardless of their design qualities, some were perhaps even hindered by the new digital format rather than helped by it.

Yet, the final review serves only as a polished snapshot of the studio's learning points. The following section explores how the studio was perceived by the students themselves.

3.2 Learner-centric Insights in Spatial Sensitivity and Communication

A series of questionnaires were given to students at various points in the semester to track their opinions on the new digital tools and platforms being introduced. Below are the summarised findings from these questionnaires.

3.2.1 Findings from Questionnaires Answered by Students

According to their responses, technical hurdles were a significant issue raised by almost all students. These were exacerbated by the fact that none of them were introduced to the use of Rhino and Grasshopper prior to the studio thus resulting in an extremely steep learning curve over the course of the semester. Students who overcame these initial challenges soon realised the advantages of working both parametrically as well as directly within a 3D environment as it allowed them to explore and ultimately demonstrate their elevated spatial sensitivity and encouraged them to be mindful of the spaces they have created.

Fig 6:
Curated 3D experiential walk-through with rendered materials and synchronized sound effects. This outcome required a high understanding of scale, proximity, materiality, atmosphere and how they impact a visitor's sensory experience (Image by Wen Zhang using Lumion).

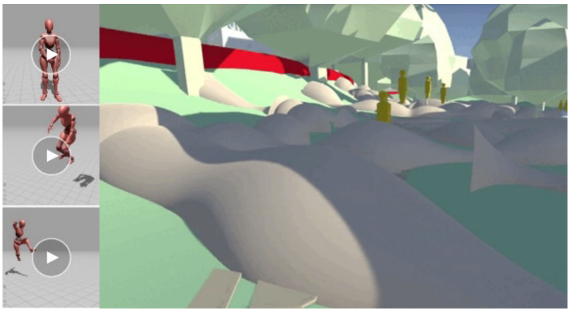

Fig 7:
An interactive first person perspective (FPS) walk-through demonstrated how designed obstacles encouraged visitors to jump over them – the motion of jumping being the thematic underpinning of the student's project (Illustration by Chester Lee using Unity3D).

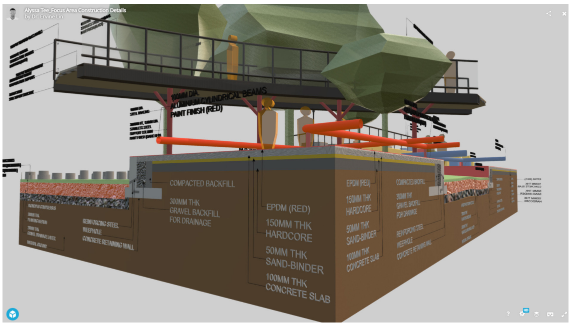

Fig 8:
An annotated detail design demonstrated in 3D illustrated the ability of the student to consider the spatial, practical and construction processes involved (Illustration by Alyssa Tee, 3D model hosted in SketchFab).

It should be noted that the technical difficulties raised pertained mainly to the parametric modelling, few students noted issues using Miro or any of the embedded interactive formats. In general, students found the digital modelling and studies to be a positive experience as it enabled them to save time (and money) which would otherwise have been spent purely on physical production. In fact, many students demonstrated an ability to leverage off a variety of representational modes from curated 3D walkthroughs (Figure 6) to interactive first person experiences (Figure 7) to fully 3D construction models (Figure 8). Some of these innovative approaches toward design have influenced and guided other students as well although it was raised that not all students were able to tap on these options due to a lack of peer-to-peer learning.

Although the semester started with a series of class level workshops, the fragmentation into groups and eventually individuals (as well as the strengthened study-from-home policy due to the pandemic especially from phase 2 onwards) meant that the availability of peer-to-peer learning was highly compromised. Even though sessions were held to share each other's progress, reflections by students included comments indicating that they were unaware of certain technical solutions, modes of modelling or representation which their peers had demonstrated in the final review.

3.2.2 Discussion on Learner-centric Aspect

We note this lack of peer-to-peer communication, specifically when solving technical issues as most of these were solved at an individual level through their personal journals, oblivious to the rest of the class. Efforts were made to share certain repetitive issues on the main Miro board, but perhaps in future a different approach could be taken, for example a shared technical portal or platform in which all common technical issues could be resolved in unison. A forum, message board or just a portion of the shared Miro board discussing technical issues might have been used instead.

Perhaps the largest hurdle for students was understanding that the mastering of digital tools and applying them to materialize ideas are separate processes. Some students streamlined both processes quickly and were ultimately successful, others focused too much attention on one process, neglecting the other. These cases which unsuccessfully fused tools and design ended up at final review in one of two ways; little usage of digital tools and techniques in the design process (those who prioritized design over technical aspect), or a heavily diluted and thinned design exploration (those who prioritized technical aspects over design).

It was also observed that the technical challenges not only caused frustration in student’s day-to-day life, but also potentially narrowed the design exploration process. Technical hurdles unresolved in phase 1 result in the inability of students to fully exploit rapid testing of form making through parametric processes. This disadvantage is further worsened in phase 2 as the lack of the knowledge of tools taught earlier prevent any significant progress but instead end up as an ever increasing hurdle for students to cross leading to further frustration and resentment.

This gap between students seems to stem from previous exposure level to digital technologies. The less exposed ones required more time to digest the key principals, and think what can be done thereafter. The need to assist these weaker students highlights the importance of proper scaffolding by educators. Here, there was often a need to prepare scripts for students to use directly or to springboard them into creating their own. Yet this treads the thin line between spoon-feeding, which would cripple students' progress and guidance, which would allow students to stand on their own two feet eventually. One negative example of this was a particular script prepared by the tutors to parametrically create an elevated undulating structure along with columns beneath it. This ended up in several students' final designs (Figure 9) with little modification to the scripts (even though all of their design intentions were different). As such, where should educators draw a line when it comes to scaffolding is discussed in the next section.

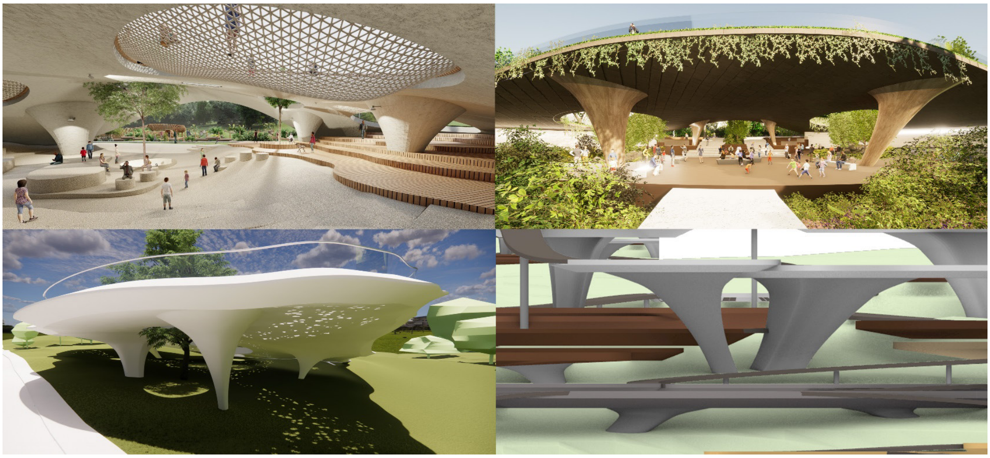

Fig 9: Despite having different design intentions, several students ended up creating very similar forms possibly owing to the fact that the scripts to create the roof and column were provided by the tutors (Graphics by Amber Yong, Brina Choo, Julia Tong and Yulin Teo).

3.3 Educator-centric Insights in Knowledge Transfer

The shared as well as individual Miro boards served as a critical conduit between educator and student by enabling knowledge transfer through a unified platform to teach tools and processes which would otherwise have been much more challenging to do.

3.3.1 Findings from Observations by Educators

As mentioned, 48 video tutorials were prepared to aid students in their learning journey, these were shared as links on the group Miro board at the appropriate time in phase 1. The majority of these videos were also explained in class but the videos served as a key repository of knowledge for students to learn at their own pace as few would be able to fully grasp them during the class itself. This video tutorial library was especially valuable since the majority of online sources (e. g. Youtube channels) do not have much landscape related content.

In addition to the video tutorials, the AR-based site model was also pre-prepared to enable students to preview as well as to work with the site remotely considering group based site visits were disallowed due to the COVID-19 pandemic. Students appreciated the ability to virtually visit the site repeatedly and to view it in relation to the larger context, however they noted that certain site-specific experiences were not apparent until they actually visited the sites in smaller individual groups (for example the pond that was not visible in the scan). That said, after their initial visit, none of the students revisited the site in person, perhaps owing to the fact that the digital model was sufficient for their design purposes.

Once the studio commenced, weekly consultations were supplemented by individual Miro journals for educators to keep track of the student's progress. During this time the journals greatly increased the transparency between educator and student; such as design intent, technical (and occasionally personal) struggles. It helped educators to know upfront on what technical advice was critical for each student in between the weekly consultation sessions and meant that more important design related matters could be attended to during face to face sessions. Successful students required minimum touch-points for technical support and were able to develop their ideas independently (Figure 10). However, many others were unable to move forward due to technical roadblocks.

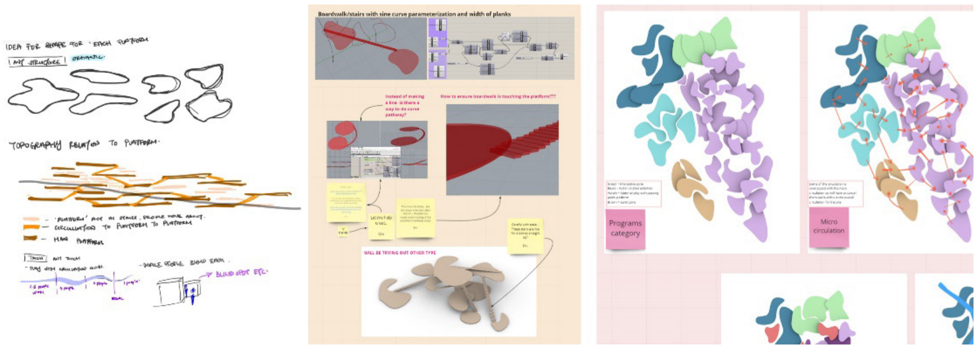

Fig 10: Example of design intent being materialized from a sketch, Grasshopper exploration, and finally to a spatial design that configured platforms and circulation patterns (from left to right) (Snapshot of the Journal by Brina Choo).

To address these issues, a further 45 more video tutorials were created in the course of the semester to solve specific problems by different groups/students, most of these were raised and answered through the online Miro journals between planned studio sessions. While this engagement was highly appreciated by the students, the high dependency on the educators' support resulted in a rather unsustainable amount of time and effort to respond to individual queries on an ad-hoc basis.

3.3.2 Discussion on Educator-centric Aspect

One notable observation was that in spite of access to preparatory videos, most students still felt that more time was needed to learn the required modelling skills. Even with the additional effort made by the educators, some students still commented on the need for more one-on-one interactions, since the Loom videos were largely a one-way communication device. This additional individual interaction was something which would be impossible given the limited time we are allocated with them each week.

To make matters worse, the deliberate open-endedness of the studio by not specifying exactly what digital tools to use – instead preferring to expose them to several options for them to pick the appropriate one – proved to be a challenge to both students and educators. On one hand, students expressed enthusiasm to explore even more tools which were briefly introduced (e. g. Vectorworks, 3D laser scanning, drone mapping) seemingly contradicting their opinion on being overburdened by technical hurdles during the semester. On the other hand, it would be impossible for educators to cover all grounds in a single semester which might end up either diluting the main content or simply overburdening the students. The question then would be how to curate the array of digital tools and techniques for the next studio to be more fruitful with less hurdles for educators and students alike, resulting in an even more fluid transfer of knowledge.

Another recurring issue that was not resolved was the inherent differences between the ability as well as active participation of individual students. Students have differing abilities as well as attitudes and some obviously leveraged more on the digital platforms provided than others both in their learning journey throughout the semester as well as communications in the final review. This holds true regardless if the studio is digitally focused or not and we are uncertain if the digital tools helped to close the gap between these students, if anything it might have inadvertently gouged a deeper one instead.

The positive outlook for all this effort is that we can bring forward the tutorials and scripts to the next studio. Even the past students could serve either as official teaching assistants or a more ground-up student support group (something which was already implemented organically). We are also exploring the possibility of conducting technical workshops before the semester starts to unload most of the technical learnings prior to the design phase of the studio in order to delink the technical and design related challenges for a more effective learning experience.

4 Conclusion and Outlook – Significance of Study

In an era of uncertainty in how best to conduct design studios due to the ongoing pandemic, the paper firstly introduces mediums which if required could be converted to a virtualized learning experience on the fly due to their digital nature. Even beyond the confines of the pandemic, the findings are expected to provide an alternative format for which design studios are run by releasing students from the constraints of producing their work in a static physical format and instead embracing digital, virtual and augmented means of working with and the communication of their design ideas. Table 2 provides a detailed explanation of the main digital platforms, tools and equipment that we have introduced in the studio, along with some of the learnings as well as technical issues we have encountered.

Table 2: A list of main digital platforms, tools and equipment that enabled the digital studio, including detailed suggestions, advantages, and disadvantages

Tools	Description	Pros	Limitations & Issues
Miro	The online whiteboard platform Miro was used extensively as the main source of two-way communication throughout the studio, including final review. Miro allowed the inclusion of not only static images and text but also animations and embedded 3D models.	• Extremely intuitive for users, used across several modules within the BLA programme • Very visual oriented • Easier to add various file types, comments, at various times	• Loading time for data-heavy boards can be long, with the occasional crashing of the entire website • Because the boards are editable by all, objects tend to be accidentally moved around

Tools	Description	Pros	Limitations & Issues
SketchFab	SketchFab allows for 3D models to be hosted and viewed interactively on its web portal. 3D objects created via Rhino must be saved in OBJ format to be imported into SketchFab. Uploaded file can be viewed by an embedded link on Miro.	• Simple and intuitive interface • Materials, lighting effects, and other environmental settings can be adjusted easily within SketchFab	• Care has to be taken to reduce 3D file size to shorten uploading time • Not easy to create realistic rendered effect • Not suitable for adding audio and animations • AR option via mobile app was not stable
Vuforia	A purpose built engine required to run and built AR interface through Unity 3D. Vuforia was used to create the AR site model experience.	• Very stable viewing experience in AR • Viewers can turn-on & off certain layers while viewing the model (if these are programmed into the GUI)	• Software's academic license is expensive • Setting up the AR framework in Unity 3D along with building the GUIs was too complex a task for students to undertake.
Loom	Loom allowed tutors to capture and record the computer screen while speaking and moving the mouse. Suitable to record technical tutorials and share the outcome with students via a link almost immediately. Embedded link to video also viewable in Miro.	• Videos recorded are uploaded directly to Loom without needing any further uploading, editing or encoding. • Extremely quick processing times, video is almost immediately available after recording	• Editing function of the videos are limited. • Due to the lack of editing tools, most videos have to be completed in a single take.
Laser Scanner	A Riegl VZ-400i was loaned via a separate research project to scan the site. Further edits (cleaning the errors, creating mesh surface etc.) were done by Rhino and Grasshopper. After optimization, six hectare site became a data of ~30 million points with a file size of 1.2GB including the mesh data.	• Fast and long-distance scanning; six hectare site required approximately 6 hours to complete by a single person. • Millimeter accuracy	• Equipment is expensive and is not readily available in future studios • Scanner is extremely heavy and bulky making it unsuitable for students to handle directly, thus limiting their appreciation of the technology.
Tablets and Mobile devices	Any commercially available hardware is capable for viewing AR models prepared via Vuforia and Unity 3D, including tablet computers and hand phones. (Although typically installed) gyroscope sensor is recommended for smooth viewing. For loading heavy models, e. g. point cloud model, 4GB RAM size and above is recommended.	• Viewing the prepared site model via AR was intuitive for students and experts • Tablets size made it easier to view the model	• Other than viewing the site model, limited use was observed beyond that initial exploration. • AR experience while interactive, is a one way communication option no means of engaging multiple parties in the same virtual space.

This paper's uniqueness lies in analysing the potentials and challenges of introducing various digital tools in a studio setting through the vantage points of experts, learners, and educators. Above all, we clarified the advantage of them in enhancing the transparency of the learner's thinking and design processes to be legible and traceable, which would be extremely difficult with conventional 2D-based learning. We have also found that the virtual whiteboard environment along with the ability to append both static as well as interactive content have facilitated a smoother knowledge transfer between educators and learners at weekly consultations, as well as experts and learners at final review. However, steps should be taken to allow for greater peer-to-peer learning, something which individualised boards were unable to do.

The studio's open-ended style allowed each student to take initiative in deciding not only a design direction but also defining how/what digital tools to be used in order to achieve this. This procedure, on one hand, greatly increased the variety of outcomes in the end – which was valued by experts, however, on the other hand, brought about a fair number of challenges to both students and educators due to technical hurdles associated and the time constraints imposed upon the studio. It is interesting to note the differences in the opinion with regards to how open and flexible the studio should be. The hinge point may rely on educator's standpoint who is eventually in charge of maximizing the quality of both studio outcome and all student's learning process.

In summary, we highly recommend that various digital tools be taught to students alongside corresponding digital platforms to evolve our profession away from its two dimensional constraints. In practice, we have already experienced the transition from printed panels to Powerpoint presentations as a means of communicating with clients. As we enter an era of where augmenting and virtualizing design ideas becomes the new norm, the application of such digital tools should grow exponentially within our discipline; in classrooms, client meetings, construction sites, community workshops, and so on (e. g. GILL & LANGE 2015, CAMPBELL-ARVAI & LINDQUIST 2021). Inevitably, there is a need to thoroughly analyse the Plan-Do-Check-Act cycle of fusing landscape and digital technologies in each scenario, in order to make ourselves relevant and responsible to the society. The COVID-19 pandemic has indeed accelerated the arrival of the new norm and challenged us all to think deeply on how future design education should be carried out. The key debate here is not about adapting to remote teaching and learning, but much more on how best we are able to actively incorporate digital platforms into our design education process even years after the pandemic ends. We look forward to more action-based cases to be tested and shared within our community to better facilitate a smoother integration of digital technologies into our industry.

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