Extreme Scaffolding – An Application of Blended Learning in Teaching Digital Landscape Architecture

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Abstract: The teaching of digital tools and techniques to landscape architects is a daunting task. This paper describes the combined use of two pedagogical interventions (scaffolding and blended learning) in the teaching of a range of digital techniques primarily through custom written scripts and associated software packages that are developed specific for landscape architectural use. The term "extreme scaffolding" here refers to the pre-preparation of an extensive list of scripts ready for use by students to accelerate their understanding and more importantly application of these tools into their design proposals. The interventions are especially important given the limitations in curricular space set aside for the teaching of such digital approaches and the results are demonstrated in the student work generated.

Keywords: Scaffolding, Blended Learning, Landscape Architecture Education

1 Introduction

It can be said that the birth of digital landscape architecture began with the development of digitally based Geographic Information System (GIS) tools and techniques, which are still very much in use today and serve as a foundational bedrock for landscape architectural education. However, in Singapore's context, projects are often of a much smaller scale and statutory requirements are pushing practitioners to embrace moving towards a Building Information Modelling (BIM) approach (BCA 2023). Unfortunately, BIM platforms which target the landscape architecture market specifically are few and far in-between and those that claim to do so are inflexible in allowing for custom analysis, modelling or scripting.

The result is often having to rely on a cocktail of different solutions for different purposes from mapping to analysis, modelling to visualisations. In light of this, some digital landscape educators have looked towards teaching their students parametric methods using Rhinoceros 3D and its inbuilt graphical scripting interface, Grasshopper, due to its flexible and relatively digestible graphical user interface (BELESKY 2018). In addition, Grasshopper itself is now able to interface with two major BIM authoring platforms (Autodesk's Revit and Graphisoft's Archicad) through plugins, thus allowing much more flexibility in the otherwise rigid BIM platforms. Yet with all its infinite flexibility, Grasshopper itself is neither designed specifically for landscape architects in mind nor is it easy for beginners to pick it up and use it specific to our discipline.

Grasshopper or otherwise, it is the opinion of similar minded scholars that such digital approaches, tools and techniques are not widely embraced in education by landscape architectural design schools, despite the potential benefits they provide (FRICKER et al. 2023). In response to this lack of digital rigour, this paper describes the teaching of landscape architecturally specific digital methods in a course titled "Digital Tools and Techniques for Landscape Architecture" delivered simultaneously to a mixture of 40+ Bachelor and Master of Landscape Architecture students at the National University of Singapore (2019 – 2023). Similar to many other schools of landscape architecture, an overview of the two programmes reveal a limitation in curricular space set aside for the teaching of digital tools, with the course

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in question not only offered only as an elective but also available only at an advanced level of study – perhaps at a point in which it would already been seen as being too late in the curriculum.

This limitation in the curricular introduction of digital approaches leads to necessity of finding means to accelerate not just an understanding of the complex nature of digital and parametric thinking via Grasshopper but also to provide a clear link to its application in our discipline. To that end, this paper focuses on a two-prong pedagogical intervention which leverages off scaffolding and blended learning. This was done in order to deliver a compact course which allows students to springboard themselves into application rather than being drowned in the complexities of building their own Grasshopper scripts.

2 Course Setup

The course was setup such that students were asked to form small groups to redesign an existing park based on 5 pre-prescribed scenarios (Tab. 1), each with an inherent underlying learning objective in mind.

This was done for two reasons, the first was to remove the burden of developing their own programmatic intervention for the site by pre-prescribing them with one. The second was to help students focus their efforts on a subset of the learning material so as not to be overburdened yet still be exposed to how other groups were using different techniques to resolve their own design problems.

The initial task for each group was to create a digital model of the park (Fig. 1) using the prepared site modelling scripts which created the topography, trees, buildings, roads and paths (Fig. 2).

Fig. 1:
Data from drone photogrammetry as well as digital surface and terrain models obtained from the Singapore Land Authority (left) served as the baseline data for students to generate their digital site models (right)

Groups were then asked to redesign the park through 3 assignments based on the scenarios they were assigned to. The first assignment was due in the early part of the semester and served as point of comparison for both the author as well as the students themselves on how the tools and techniques being taught were able to augment the way they approach landscape design. The following two assignments were meant for students to incrementally apply the learning material presented over the course of the semester with a focus firstly on information

modelling and analysis followed by performative testing using simulations and other analytical techniques. See the results section for visual representations of these results.

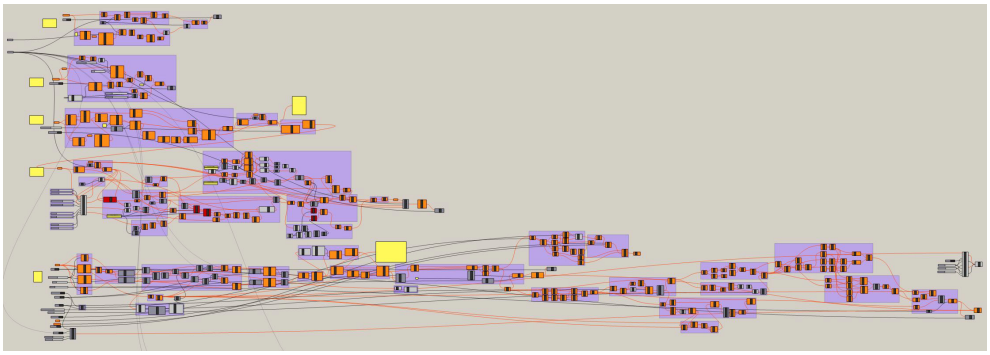

Fig. 2: Despite its graphical user interface, a Grasshopper script can still end up becoming an extremely complex web of components and nodes. The example above is a collection of pre-prepared scripts that allows students to create a 3D site model from the provided data.

Table 1: Five pre-prescribed scenarios were prepared for the students, each with its own underlying learning objectives

Pre-prescribed Scenarios	Underlying Learning Objectives
Liquid Cooled – Attempt to cool the park using bodies of water instead of just planting more trees.	To make use of surface run-off and micro-climatic simulations alongside topographical modification tools.
Biophilic Preschool – Allow the park to serve as an outdoor classroom for the educational institutions around it.	To make use of the BIM vegetation library alongside viewshed and other forms of analysis to enhance the exposure of natural elements to visitors.
Retirement Landscape – Redesign the park to be universally accessible considering its rather steep topography	To make use of topographical and infrastructural interventions alongside slope and shortest path analysis to create a universally designed park.
Rewilding Clementi – Increase the floral biodiversity while maintaining accessibility to the park	To make use of the BIM vegetation library and other forms of vegetation analysis to potentially increase the biodiversity of the park.
Fitness Fanatic – Utilise the steep topography to enhance fitness-based programmes.	To make use of topographical analysis alongside modifications and route planning analysis to identify and implement various interventions.

3 Pedagogical Interventions

3.1 Extreme Scaffolding

In design education, the typical tutor-student (or master-apprentice) dynamics can be seen as a form of scaffolding in that the tutor brings his own experience and expertise to elevate what otherwise would be impossible for the student to achieve alone (McDonnell 2016) such as in a typical design studio where the tutors' experience and knowledge accelerates what the student could otherwise achieve on their own. In a similar vein, owing to the steep learning

curve which Grasshopper presents, scaffolding can be seen as a method which provides the necessary support to students as they learn this new skills and concepts to extend their knowledge and surpass their existing skills and capabilities (STANIER 2015).

"Extreme scaffolding" here refers to an extension of this idea with a whole suite of custom developed Grasshopper scripts which cover a wide variety of topics from basic principles behind parametric modelling, reality capture techniques, topographical/site modelling and analysis, information modelling as well as performative assessments and simulations. The purpose of this "extreme scaffolding" was not only to provide ready to use scripts for students to leverage off but also to convert the author's own research back into end-user accessible scripts to be used by the students in their assignments, and hopefully to be filtered down organically into the industry.

Examples of types of scaffolded scripts derived from past research include the use of point clouds in landscape architecture (LIN & GIROT 2014), parametric generation of 3D vegetation models (LIN et al. 2018) coupled with the use of a previously developed BIM vegetation library (GOBEAWAN et al. 2021), the use of these vegetation models in microclimatic simulations using ENVI-met (LIN et al. 2022), as well as the interfacing with flood modelling software for surface run-off simulations (LIN et al. 2016).

These scripts are always accompanied by a video (further described in Section 3.2) explaining the intricate steps in using the scripts for their intended purposes (Fig. 3).

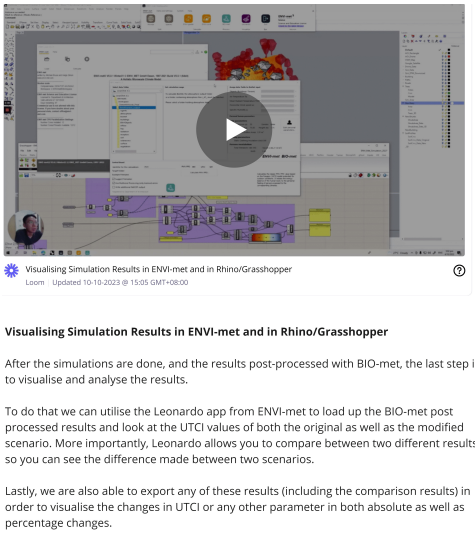

Fig. 3:
An example of a video showing students how to visualize results from microclimatic simulations done in ENVI-met back inside Rhinoceros

Certainly, another benefit of using Grasshopper is being able to leverage off an existing ecosystem of plugins made available by other scholars and the community alike. Of note include plugins such as *Docofossor* (HURKXKENS & BERNHARD 2019) which enabled the parametric modification of digital topography, *Groundhog* (BELESKY 2023) which enabled topographical analysis, *Human* (HEUMANN 2018) which was used to read and embed custom parameters enabling Rhinoceros to mimic a simple BIM software, *Morpho* (NUNZIO 2023) a plugin specifically to interface with ENVI-met, *Ladybug* (LADYBUG TOOLS LLC 2021) a suite of tools for analysing climatic data and analysis, and *Impala* (CASCAVAL 2018) a parallel computing focused tool used here specifically to enhance the speed of viewshed calculations. However,

since each of these plugins can be difficult to apply directly into a landscape related project, most were further adapted to fit the workflow prescribed by the course (Fig. 4).

While a substantial number of pre-developed scripts and videos were prepared for the students covering multiple broad topics which would cater for all groups, a final type of "extreme scaffolded" scripts included those specific to each group's requirements and requests which was discussed and prepared during consultations with the student groups. An example of such scripts includes requests by groups looking at viewshed analysis (e. g. the biophilic preschool group hoping to calculate the percentage of vegetation visible from a particular viewpoint) which might have multiple versions, some looking at a single viewpoint, others at multiple viewpoints (Fig. 5). Such student requested scripts were eventually made available for future iterations of the course, thereby further adding to the learning material.

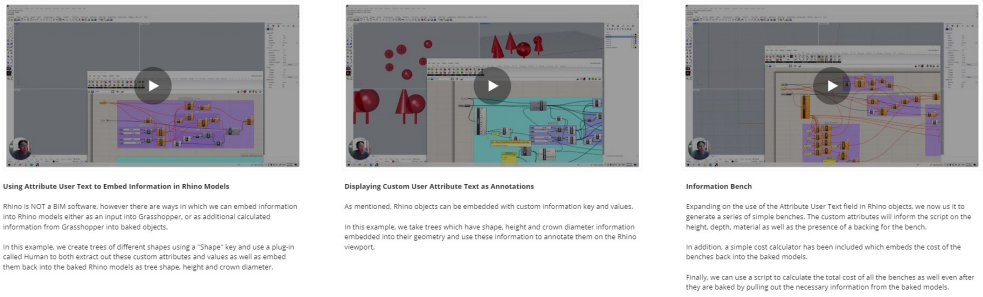

Fig. 4: Examples of scripts which make use of the *Human* plugin to mimic a simple information modelling workflow in which the user is able to read and write to custom attributes within objects inside of Rhinoceros.

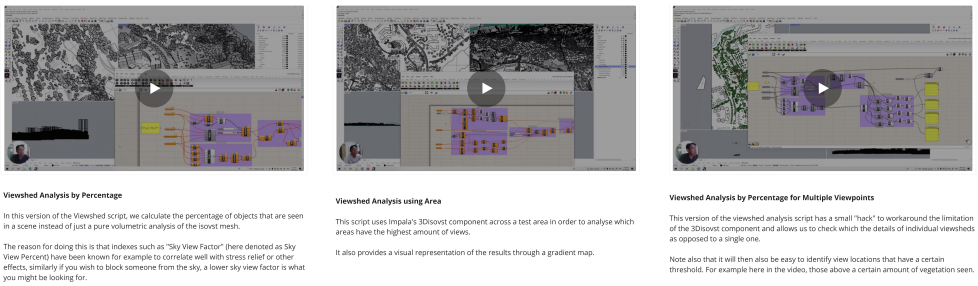

Fig. 5: Although a basic viewshed analysis script was created, students wanted to extend this capability to measure the percentage of landscape elements viewed from specific viewpoints. As such, multiple iterations of the script were prepared in consultations with the groups.

3.2 Blended Learning

While the paper has already shown how recoded videos are used in the delivery of learning material for the course, during the first iterations of the course in 2019, the delivery instructions on how to use these scaffolded scripts to students was done through annotated slides (Fig. 6) alongside synchronous face to face workshops. This proved to be not only extremely inefficient in the production of learning material but more importantly difficult for the students to follow and to revisit previously shared methods.

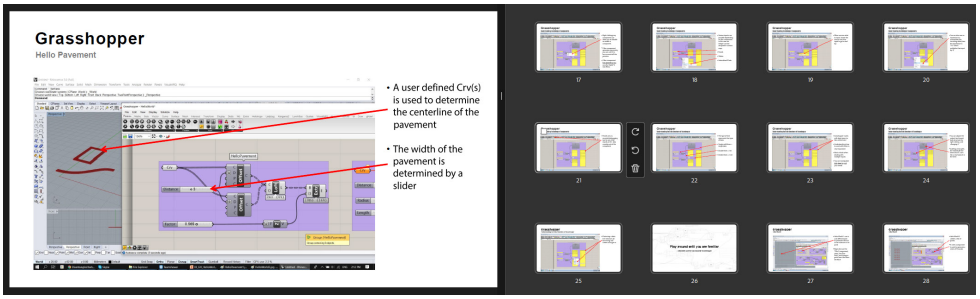

Fig. 6: An example of a stack of slides previously used to document step by step instructions for students

With the shadow of the pandemic almost dissipated, one silver lining that arose was the necessity to produce remote or online based learning material as a reaction to it. Incidentally, scaffolding has been found to lend well to such an online environment (DOO et al. 2020), although the implementation of these scaffolding techniques requires some consideration in order for them to be effective (SUWASTINI et al. 2021). To that end, blended learning was seen as one possible pedagogical intervention in design education which could deal with this predicament while possibly improving the learning outcomes by leveraging off an asynchronous approach to delivering teaching material (AFACAN 2016). Outside of the pandemic, this often presents itself as the provision of offline learning material in unison with face to face contact time with students with the two reinforcing one another, although the exact understanding of how to carry out blended learning presents itself with a variety of different approaches (ALAMMARY et al. 2014).

By the 5th iteration of the course in question, blended learning has been well implemented resulting in the primary learning material for the course comprising of a series of video tutorials pre-recorded on Loom – totalling up to 115 (Tab. 2) – with accompanying pre-prepared scripts hosted visually on Miro, an interactive whiteboarding platform, which is subsequently delivered in an asynchronously blended fashion to our students (Fig. 7).

Table 2: A breakdown of the topics and number of pre-recorded videos made available to students in the latest iteration of the course in 2023

Topic	**No. of Videos**
Pre-recorded Lectures & Guest Lectures	6
Basic Introduction to Grasshopper	14
Understanding Parametric Modelling	14
Reality Capture, Point Clouds & Interfacing with Rhinoceros	6
Site Modelling of Landscape Specific Objects (e. g. topography, paths, vegetation)	5
Topographical Modifications and Analysis	4
Building Information Modelling and Vegetation Library	8
Solar/Thermal Simulations with Ladybug	6
Interfacing with Flood Modeller for Runoff Simulations	10
Interfacing with ENVI-met for Thermal Comfort Simulations	4
Other videos based on student consultations specific to their assignments	38
Total	**115**

Fig. 7: An example of the Miro board in which the not only is primary learning material presented (left) but also serves as a visual method for students to ask questions outside of contact time in class (right).

4 Results from Students

As mentioned in section 2, the first assignment made students come up with designs using whatever existing methods they had specific to their respective scenarios. This was a deliberate attempt to qualitatively evidence the changes in design approach – and seeing if the learning objective have been met – by the time all the learning material was delivered and the final assignment was presented. By visually comparing the two, it is obvious that across multiple groups, students were able to apply the scaffolded scripts in their revised designs and were able to prove more definitively that their designs would perform as intended (Fig. 8, 9 & 10).

In addition to visually comparing the students' outputs through their assignments, student feedback gathered anonymously at the end of each semester (Fig. 11) also indicated that, not only were the scaffolded scripts highly appreciated, the accompanying blended instructional videos were instrumental in enabling students to learn at their own pace and to revisit topics in previous weeks when it came to working on their assignments.

Fig. 8: For assignment 1 (top), students would fall back on existing methods to present their design proposals such as using collages, sections and typological axonometric diagrams, however by assignment 3 (bottom) with an extended range of tools and techniques, students are able to not only model their sites in full 3D but also to find various means of testing them from a variety of different perspectives.

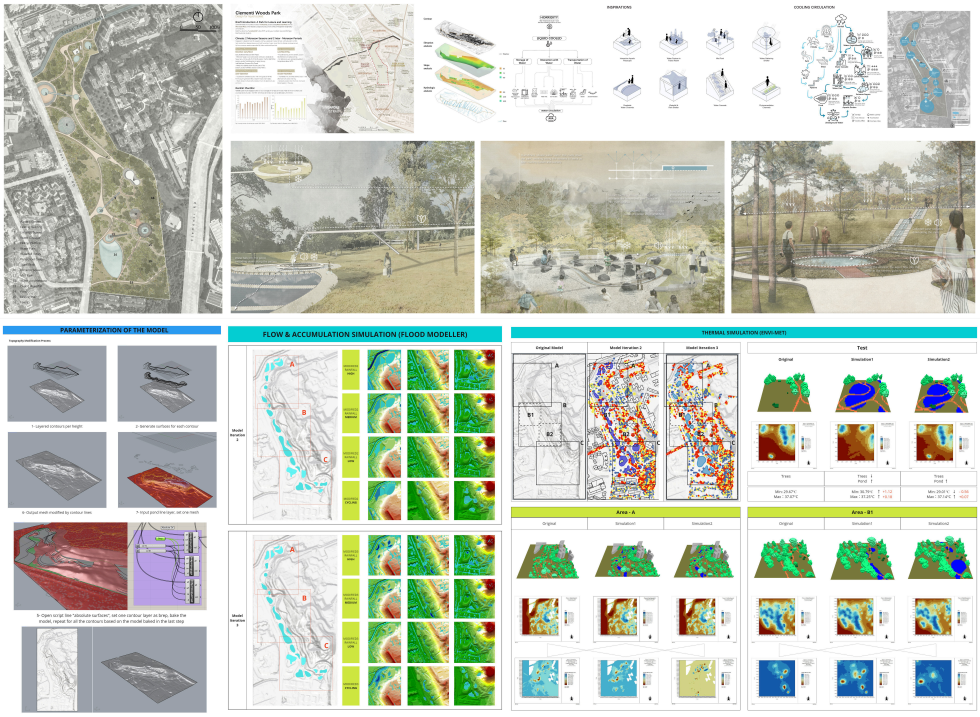

Fig. 9: Another example in which collages in assignment 1 (top) give way to flood and thermal simulations in assignment 3 (bottom) specifically for the "Liquid Cooled" scenario

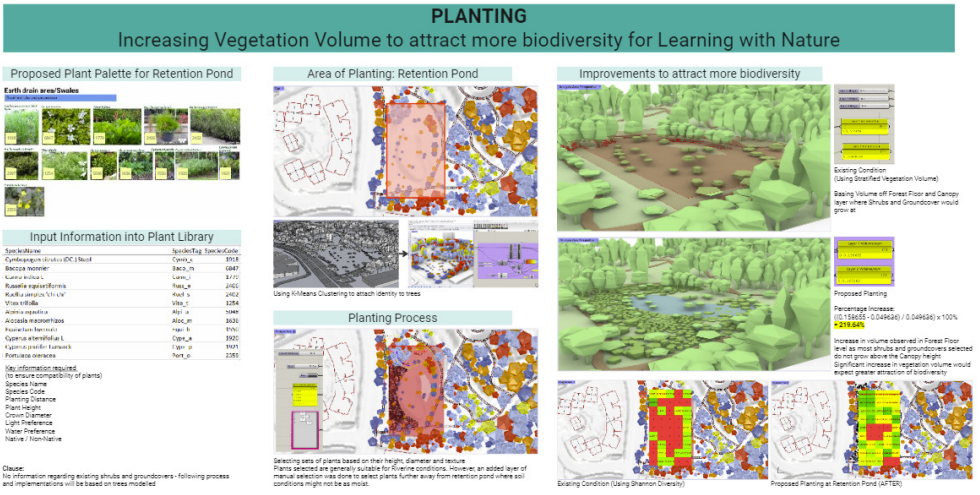

Fig. 10: A final example of student output from the course utilising a developed BIM vegetation library in the generation of 3D vegetation models while simultaneously analysing biodiversity indexes

What I liked about the module:

Comments
Refresh knowledge on grasshopper. Opportunity to practice rhino
Learning new software that enables me to test and simulate my design against the weather
It could be tough but it is an enjoyable challenge because the students are not left in the dark most of the time as consultations are consistent and sufficient. Online miro board problem solving helps save time too! Though it could be an intimidating script writing session, i think i enjoyed the thinking process and exploring the different ways in achieving the endpoint even though it might be painful.. and definitely it would be useful in the built environment industry.
This module provides us a good exposure to digital techniques that aid in the analysis of the landscape, evaluation of design outcomes, and modification of design outputs.
this module is actually very enjoyable albeit having a steep learning curve. what we have learned does not just stop here, we were able to apply those skills to other modules eg. studio 3d modeling, which have been effective and saved a lot of time.
I liked how the module taught us something new that has yet to be learned in poly years. Coding or writing a script is hard for some of us, but the professor ensures that we are kept in the loop and makes sure that we understand how the logic behind the script works.
– more confident in my grasshopper skills now – pace of the lessons were appropriate
Very applicable to the current industry and very valuable skillset
It challenges the norm of landscape architecture and opens up a new path in design thinking
it was all group work and there weren't many drastic changes from submission to submission, so it was easy to follow along and plan how and what to show

Fig. 11: An example of the student feedback obtained with students referencing the usefulness of the prepared videos and scripts despite the otherwise steep learning curve

The above has demonstrated the students' ability to perform the tasks required of them through the prepared scripts, however another important consideration is to consider if such an approach of "extreme scaffolding" enables students to create or at least modify such complex scripts. Certainly, the creation of complex scripts from scratch by the students themselves is highly unlikely given their brief introduction to Grasshopper, however, in some instances it was observed that students extended provided scripts or adapted workflows in order to achieve an additional desired outcome that was specific to their design scenarios (Fig. 12). However, this was often an exception rather than the norm and perhaps the assignments need to be altered to further encourage such explorations.

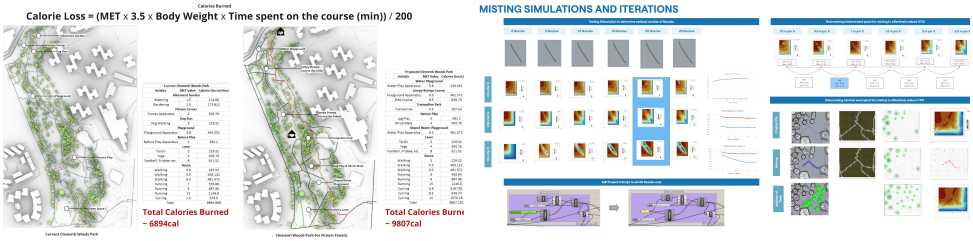

Fig. 12: Towards the end of the semester some students were able to demonstrate an ability to adapt provided scripts and workflows to suit their specific requirements. This includes examples such as a calorie expenditure calculator (left) which compares the potential change in physical activity levels after implementing their design changes or the testing of the number of misting nozzles needed (right) to affect thermal comfort.

5 Discussion

It is evident from the above that the combined interventions of scaffolding and blended learning have been serving the students well. In particular the use of pre-recorded videos explaining the development and demonstrating the use of each scaffolded script seems to be highly effective in allowing students to effectively apply their newly found knowledge into their assignments. This is not only well received by the students but also clearly demonstrated when comparing their assignments back to back.

However, there are limitations to this method of delivery. The first is that this is likely going to be more applicable to technical courses, such as the one described in the paper, whereby the successful completion of assignments relies heavily on watching and following the videos. I would assume the same is unlikely to be said for less technical courses (such as history and theory courses) where the videos are merely a replacement of face to face lectures.

Secondly, while the "extreme scaffolding" described here was meant to help students, one wonders if it is actually to the detriment of students in that they become reliant on the tutor's expertise and cannot operate within this level of depth in their absence. While a number of students managed to combine and alter the prepared scripts and workflows by themselves, the majority simply used them to deliver the minimum required for the course. This lack of an ability to extend their new-found knowledge beyond the assistance of their tutor is especially evident. Anecdotally, it has been noticed that little of the learning materials taught have made it beyond the confines of the course in question (e. g. in the students design studios).

Finally, the amount of effort required to exercise this combination of scaffolding and blended learning in order not only to produce but also to maintain the library of learning material, is a substantial investment on the tutor's end. Digital methods are constantly evolving often requiring revisions the moment new software versions are launched or methods become obsolete. Student requested scripts can also sometime seem to be a bottomless pit and would quickly become unsustainable if the class size were to be increased. That said, these are precisely why the two interventions were introduced in the first place, as a means of building up a library of learning material that can help service more students simultaneously.

6 Conclusion and Outlook

The paper has outlined the successful use of two pedagogical interventions, scaffolding and blended learning, in the difficult task of teaching not only the use of Grasshopper itself but more importantly putting together a coherent stack of learning material on the use of Grasshopper across multiple landscape architectural purposes. While it might seem like it, the goal is not to develop our students into "Grasshopper gurus" but rather to entice them to incorporate more advanced digital techniques into their existing repertoire of tools and to raise the overall digital literacy of our landscape industry to meet the digital demands facing us. Considering how fast the digital frontier is moving, it's more important that students understand and develop a certain degree of digital agility and the course described here merely introduces them to these future possibilities.

Supplementary Link

As the format of a journal paper is not ideal for sharing of the material described above, please visit the following Miro page which shows examples of both a portion of the blended learning videos prepared as well as examples of student assignment outputs – https://miro.com/app/board/uXjVNpizqZw=/?share_link_id=567129716123.

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