CP500031

Adventures in Convergence: Sustainable Design, Data & Procedural Modelling

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Learning Objectives

- Discover the value of Procedural Modeling (a technology borrowed from Media and Entertainment) as it applies to Product/Industrial Design
- Evaluate how academic and industry leaders are experimenting with this technology in Product/Industrial Design (including a perspective on sustainability)
- Identify critical factors during the design process (and material lifecycle) that can affect a products ability to be "sustainable"
- Experience how the opportunity to converge workflows and tools exists in the Autodesk Technology Centers Outsight Network

Description

What are new emerging methods for tackling large and complex challenges such as sustainable design? More specifically, what might happen when we combine technology from one industry and apply it to another? Further, how can designers leverage these experiments in "convergence" to push the future of design-and-make innovation?

Informed by the work of an Autodesk Technology Center resident, this case study explores the sustainable implications of converging industrial design tasks with "procedural modeling" tools (a Media and Entertainment technology). This talk shares the results of both practical hands-on experiments from the resident and conceptual-thinking on how procedural modeling tools can influence design decisions applied to product-design and manufacturing.

At a broad scale, this talk highlights how the practice of converging tools can become a method to designing with enhanced performance requirements.

Speaker(s)

Tyson Fogel – Workshop Supvisor

Autodesk Technology Centre Toronto

Linkedin

A passionate maker and champion of sustainable product design. Tyson works directly with innovation communities to provide technical expertise and fabrication through the Autodesk Technology Centers Outsight Network. With extensive experience in additive manufacturing, prototyping and bespoke wood fabrication, Tyson challenges others to design for a circular economy by combining converging or emerging tools and technology.

Matthew Spremulli – Development Manager

Autodesk Technology Centre Toronto

Linkedin

A design-technology enthusiast and trans-disciplinary experimenter at heart, Matthew scouts for organizations to join the Autodesk Technology Centers Outsight Network and helps shape their projects. Matthew has a diverse background ranging from Architecture, Manufatcuring, Storytelling, and Education – which he leverages in guiding others to be experimental in their design-research.

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0.0 Introduction (Design Intent)

What is convergence? Why should you care? And, what does this have to do with procedural modelling or sustainable design?

To answer these questions we thought it best to start from the perspective of 'design intent' and reflect back on what is good design and what may not be good design. More importantly, our 'design intention' helps frame the impact our design choices have on our surrounding environment. For instance, looking at both popular news and scientific reports, an argument can be made that pollution and overconsumption are one of the byproducts of poor design.

As an example, here are a few snapshots of what our poor design is costing us:

- If Americans could repair their broken electronics, they could save approx. **40 billion dollars**. Instead electronics are tossed and new ones purchased, equating to over 153,000 passenger airplanes worth of e-waste per year.
- Currently **8.6% of the world is operating as a circular economy** meaning remainder is operating under the assumption that we can continue to take, make and waste.
- **20 cents of every dollar** spent on manufacturing is wasted due to inefficiences. This is economic waste, e.g. redundancies in prototyping or design and manufacturing changes that cause downstream effects.
- The average adult makes approx. **35,000 decisions daily**. If 1% of this is spent on the consumer products we use, then that's 3500 opportunities to make an environmental difference as individuals.

1.0 The Need For Better Design

The cross-cutting theme from the statistics mentioned above is that there is a sense of urgency and inherent responsibility. We need to design the objects around us better, smarter and more efficiently. And what better way to initiate this shift in our design intent, than to ***change our mindset***?

1.1 The Mindset of Convergence

Convergence could be one path forward. At it's most broad sense, convergence is a mindset to gain an entirely new perspective on how to solve problems. It means leveraging best practices/tools from other industries and domains. It also means deliberately encouraging designers/makers to lean on trans-disciplinary workflows to achieve better outcomes—whether that be optimizing the use of energy and materials, increasing resilience of infrastructure and supply chains, or learning new skills to adapt and thrive.

At Autodesk, we see this concept of convergence manifesting in four ways:

- **Workflow coordination**: By using digital tools to coordinate work processes across teams and systems and across supply chains and ecosystems, innovators can automate tasks and discover data insights that reveal outcomes they never thought possible.
- **On-demand customization**: Customers are experiencing—and expecting—greater choice and customization than ever. Innovators are tapping into this demand by taking advantage of mass assembly of tailored products and by precision crafting unique components.
- **Virtual creation**: By building rich information models, innovators are increasingly able to embody their creativity, surface insights, and build immersive experiences.
- **Continuous reshaping**: Innovative owners and operators of existing things can continue reshaping their products and projects beyond the construction site, factory floor, or production studio based on ongoing performance, customer experience, and changing needs

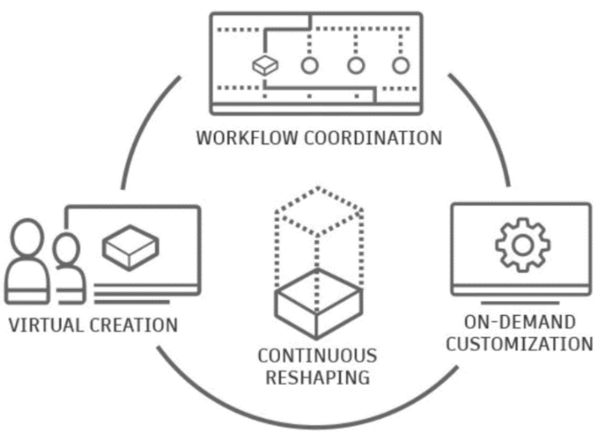


Figure 1 – Types of Convergence

What people are making today is now being reshaped by data, automation, and insights, which will create better outcomes for their customers, their businesses, and the world.

To support the emerging era of convergence, we at Autodesk are committed to making our customers' data more interoperable, accessible, and open. We're doing that by providing tools that connect workflows and services that help customers optimize and innovate. We're connecting disciplines for more seamless collaboration, and we're cross-pollinating best practices among all industries we serve, such as leveraging media-creation workflow-coordination tools for manufacturing and using manufacturing tools to improve outcomes in industrialized construction

To learn more about how autodesk is enabling convergence, please visit: www.autodesk.com/industry/convergence

1.2 Sustainable Design + Procedural Modelling

Since a convergence mindset lends itselt to the experimental mixing of tools, workflows, and personas – technologies themslves can be reimagined as they are applied to new industries.

An example of this (which we have focused on for this talk) is the use of procedural modelling. Traditionally, procedural modelling has been used within the Media and Entertainment industries – but, has also been recently leveraged in other design sectors (such as Industrial Design) to investigate topics including: sustainability, added design behaviour, and formal complexity.

2.0 Exploring Convergence through a Case Study

2.1 Hypothesis

To understand the nuances and impetus for this procedural modelling convergence, we set out to explore the interplay between design, sustainability and procedural modelling. More specifically we asked: ***Can procedural modelling (from Media and Entertainment) be used to make industrial design more sustainable?***

2.2 Research Approach

To interrogate this question we decided to work with others, specifically subject matter experts who were also interested in exploring these kinds of questions. We worked with these subject matter experts by collablratively shaping and supporting an intensive design-make workshop. We brought together:

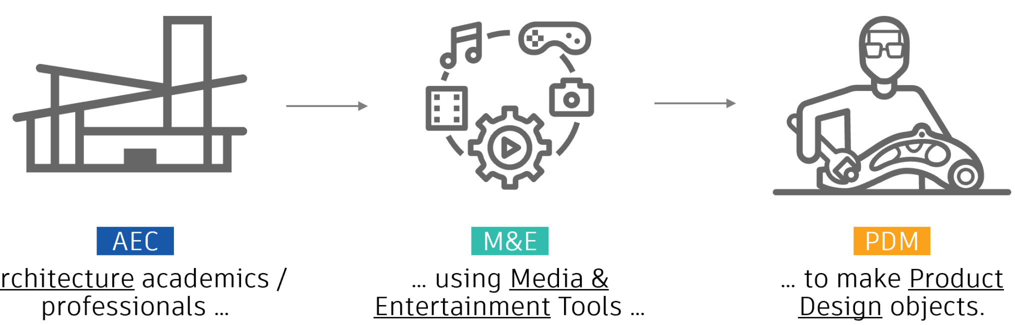


Figure 2 – Procedural Modelling Convergence Case Study

Complementing the design-make workshop (which focused more on technical/hands-on aspects) we added to the hypothesis with a theoretical approach, which included a 3-part process outlined below:

- **Brainstorm** a set of scenarios of how we thought procedural modeling could positively impact industrial design
- **Stress test** these scenarios with our invited external team and other SMEs
- **Cross-reference** everything and aggregate our observations and lessons learned

Our Approach with Our Collaborators

A parallel inquiry

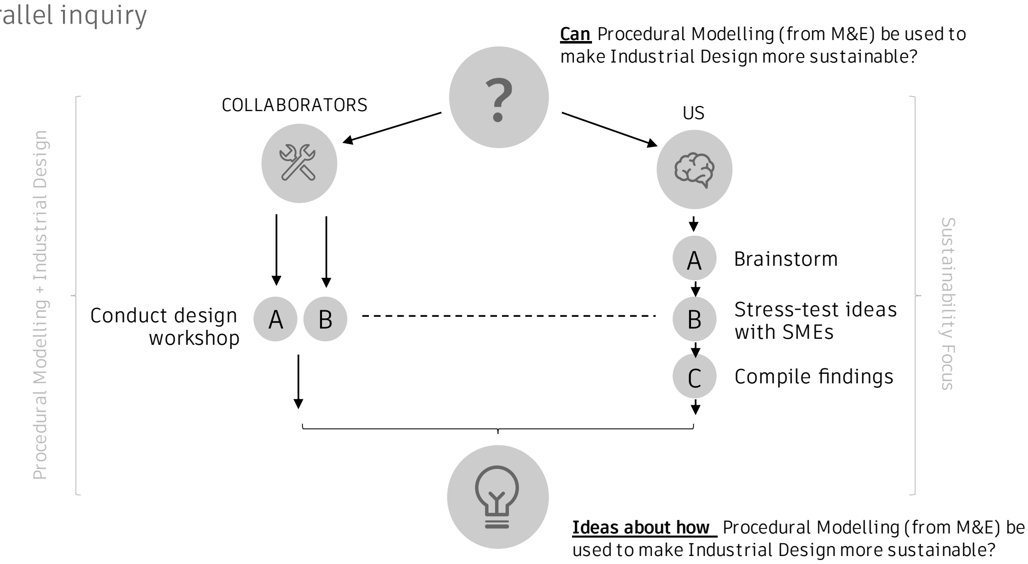


Figure 3

This two-pronged approach is summarized in the above diagram. The ‘left’ and ‘right’ branch each demonstrate the unique path our external collaborators and ourselves took, and how they interconnect.

2.2.1 Our External Collaborator

The Architectural Association (or AA for short) is a world renowned architectural design institution located in London, England. The school is recognized as a leader in topics related to advanced computational design, experimentation, and design-to-make workflows in both topics related to architecture and industrial design. Distinguished alumni from the school include the likes of Frei Otto, Sir Peter Cook, and Zaha Hadid (Figure 4). While the school supports a robust curriculum rooted in experimentation they are also able to explore advanced niche topics which they deliver through their “Visiting School” program. The Visiting School is a series of 2-3 week intensive post-professional workshops developed and delivered by a series of invited specialists (also known as “tutors”) to lead a group of students through a guided workshop.

Our Autodesk Technology Centers team worked with the Visiting School (known as the AAVS for short) program to co-develop a workshop solely focused on the convergence of procedural modelling and industrial design. This workshop was virtually held through the Autodesk Technology Centers Outsight Network during the late Summer of 2021, and was entitled “F2 – Morphological Experiments Between Force and Form”. Two groups of tutors led a cohort of 24 students from 16 different countries to create a range of rapid experiments. One group pursued a fusion of physical-digital explorations using robotic clay printing and simulation, and the other group focused on digital agent-based simulations reacting to forces. Both groups applied their technological focus points on simple industrial design objects: chairs and planters.

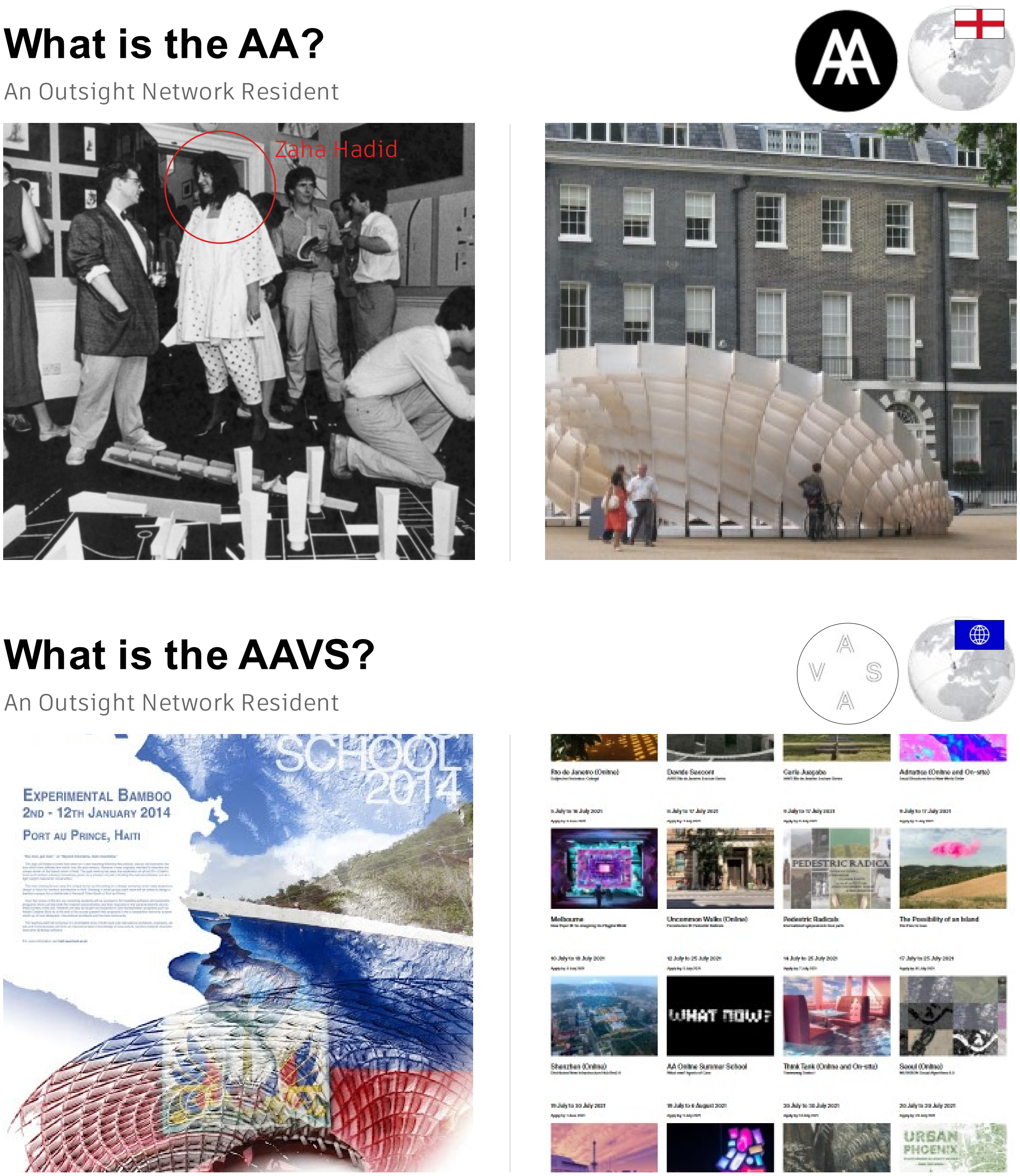


Figure 4 (Highlights of the AA institute and AAVS program)

To learn more about the AAVS program please visit:
https://www.aaschool.ac.uk/academicprogrammes/visitingschool

AAVS - Team

"Collaborative" Researchers

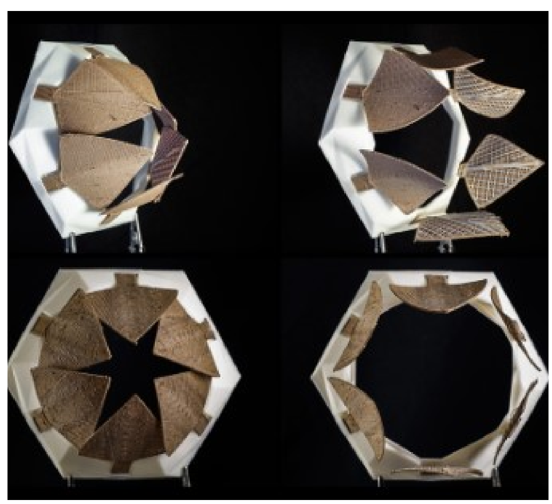
Vahid Eshragi | Ali Farzaneh | James D'Alessandro | David Correa | Isabel Ochoa | James Clark -Hicks | Nic Lee

24 students (16 different countries)

Figure 5 (LEFT – AAVS Directors / RIGHT – AAVS Tutors)

University of Waterloo – School of Architecture

4D Printing and Clay Printing

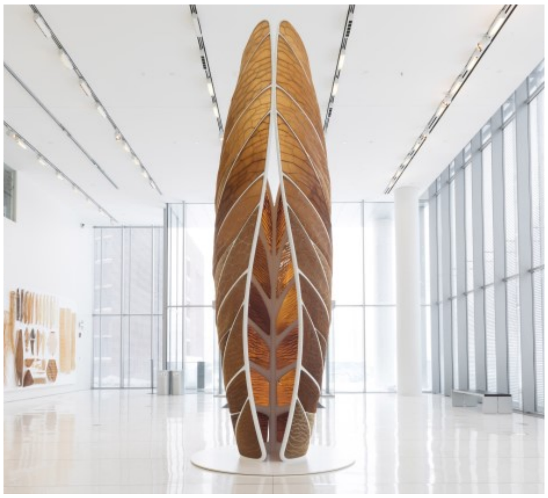


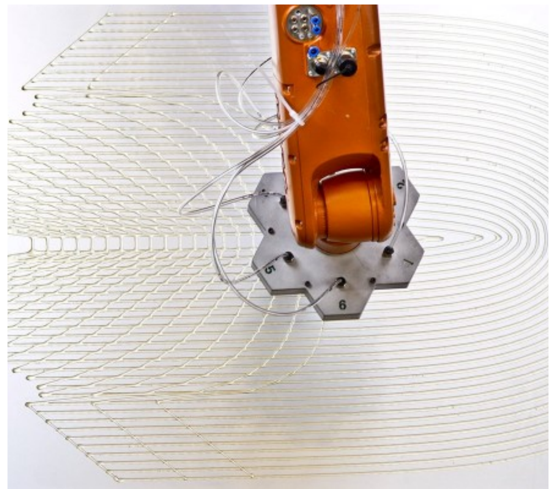
Courtesy: David Correa

Figure 6 - The first tutor team comes from a research background exploring 4D printing, reactive materials, and clay materials

MIT – Mediated Matter Lab

Anisotropic Bio-Printing





Courtesy: Nic Lee

Figure 7 - The second tutor team comes from a research background exploring bio-materials, 4D printing, and customized g-code for printing applications

3.0 Exploring Convergence through a Complimentary Approach

As previously mentioned, our complementary approach to the work of the resident teams consisted of three phases: Brainstorming, Stress Testing, and Aggregating. Below we describe each phase in detail.

3.1 Brainstorm – Sustainable Design Strategies

Both groups (our external collaborators and ourselves) chose to explore a simple industrial design object *(Figure 8)* as our focus. Specifically, the design and materiality of a chair was elected to ground our ideas. How the chair was designed and made became the launching-point of our brainstorming sessions, which were honed down into 5 distinct “sustainable design strategies” that could leverage procedural modelling technology.

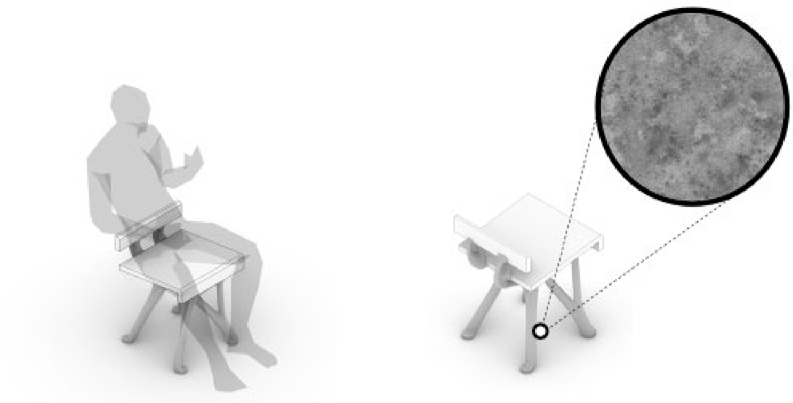


Figure 8 – Depiction of a chair, the focal point of our sustainable design strategies that use procedural modelling

3.1.1 Sustainable Design Strategies Using Procedural Modelling

We arrived at 5 ambitious design strategies, where we imagined procedural modelling could play a role in unlocking sustainable design. These strategies are further outlined in *Section 3.1.3 – 3.1.7*) and capture varying degrees of interplay between these two concepts throughout a design-to-make workflow. These design strategies are: Biomimicry, Design for "Afterlife", Design for "Repair", Manufacturing Modifications, Design for "Awareness"

3.1.2 Impact on Materials and Product Development

To better envision where the value of using procedural modelling (as it pertains to sustainability) manifests, *Figure 9* illustrates the two parallel cycles that are occur to bring an idea to reality. These being the 'Development' and 'Material Lifecycle'. The cycles complement each other other and are intrinsically connected through 'Manufacturing'.

- Development Cycle (Process) – The sandbox in which all makers and designers find themselves in. This cycle outlines the steps needed to bring a product from concept through to the consumer market.
- Material (Product) Lifecycle – The phases in which material (and eventually products) go through. Each stage is characterized by inputs and outputs, as well as material value loss (or in some cases, gains). A 'closed' material lifecycle would be representative of a circular economy.

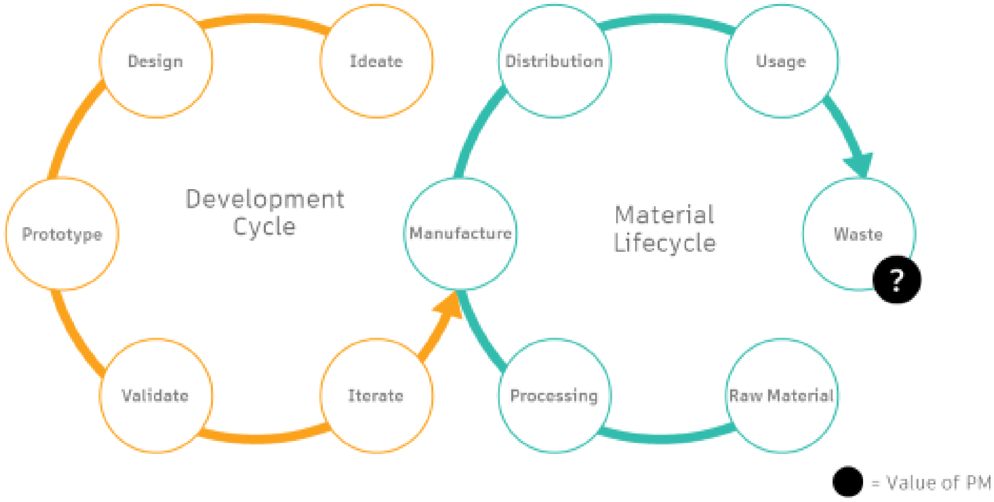


Figure 9 – Overlap between between a traditional development process and a material lifecycle.

This relationship is important to note, as a sustainable outcome through the use of procedural modelling can create additional connective tissue between these two distinct cycles. The following sustainable design strategies are mapped on Figure 15.

3.1.3 Biomimicry

The use of procedural modelling to emulate a form or process observed in 'nature'. Biomimicry relates to sustainable design as our largest circular system (Earth) has proven the value of self-sufficiency over thousands of years.

Chair example – Using a material to mimic a creature's skin to increase overall durability of the object.

Figure 10 - Biomimicry

3.1.4 Design for "Afterlife"

The use procedural modelling to enhance or simulate functions like material biodegradability, recyclability, decomposition, etc. Effectively, designing for an afterlife ensures the future transformation of a product provides nutrients to the environment in which it is disposed in.

Chair example - Producing and simulating the growth of a bio-materials (e.g. coral) and when properly discarded in its natural environment (water), this object encourages the additional growth of an existing ecosystem.

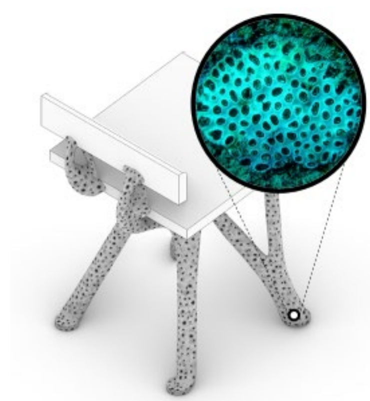


Figure 11 - Afterlife

3.1.5 Design for "Repair"

The use of procedural modelling to indicate wear/tear, usage patterns and ergonomics. Keeping a product in usage for as long as possible can prolong its negative environmental impact. This could be further enhanced by allowing for repairability, recyclability, modularity, or disassembly. Part of the challenge here is knowing when or how to replace certain components.

Chair example – Create a rippling surface finish to indicate wear. As the chair deteriorates, new colours reveal themselves creating a visual aid and indication for replacement.

Figure 12 - Repair

3.1.6 Manufacturing Modifications

The use procedural modelling to intentionally reduce energy or material in manufacturing processes by limiting a high intensity factor (i.e. energy, time, or material). 'Desiging out waste' or optimizing a manufacturing process means we can limit the amount of phases where waste is generated.

Chair example – The development of complex lattice and infill structures to provide efficiency (or material optimization) without sacrificing part integrity.

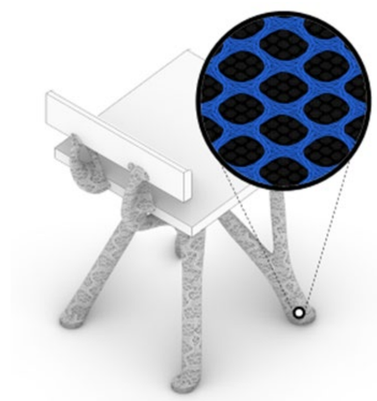


Figure 13 – Manufacturing Modifications

3.1.7 Design for "Awareness"

The use procedural modelling to communicate the creation/use of an object in order to alter consumer perception and consumption awareness. Consumers are oftentimes disconnected from the amount of effort and resources it took for a product to reach its final (usable) form. This sustainable design strategy tries to remove this disconnection and provide continuous awareness by encoding certain data into a design using procedural modelling.

Chair Example – Communicating energy consumption and usage through a texture or articulated surface on the chair. Users will feel a deeper connection to the history and effort required to make the product.

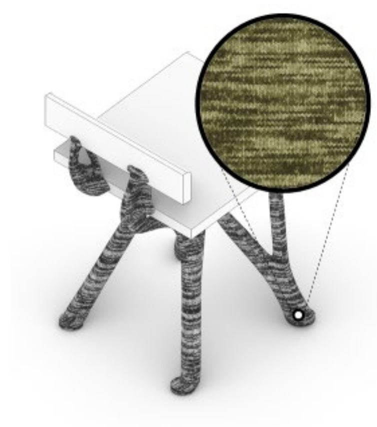


Figure 14 - Awareness

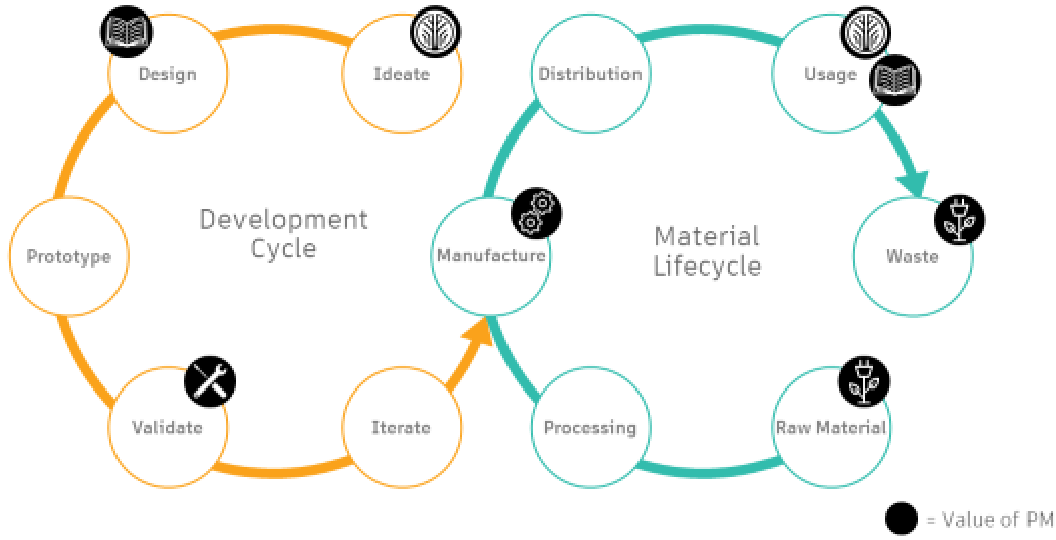


Figure 15 – Mapping the sustainable design strategies on the development and material lifecycle to better understand where the value of procedural modelling is being realized.

3.2 Stress Test – Feedback on Sustainable Design Strategies

To validate/stress test our 'Sustainable Design Strategies' we sought feedback from our resident team members, and collected their expert opinions through two mechanisms: a survey and a follow-up interview.

3.2.1 Surveys

The surveys were comprised of a series of questions organized into 5 distinct categories (which we called "question clusters"). The question clusters, are listed below to provide an overview of what was asked.

QUESTION CLUSTER_01: "Why Procedural Modelling?"

- *How have you been leveraging "procedural modelling" technologies – such as Autodesk Maya/Bifrost, Houdini, or specific Grasshopper plug-ins in your work?*
- *Why have you been leveraging such technology?*
  - *What advantages does such technology give you over other means?*
  - *What are you able to do with such technology that you cannot get from other tools?*
- *What applications have you been steering your experiments towards?*
  - *Scale, function, medium/material?*
- *When do you feel introducing such tools/technologies are appropriate?*
  - *Do you start a design with such tools?*
  - *Do you embellish/finish a design with such tools?*

QUESTION CLUSTER_02: "Procedural Modelling VS Other Comp. Design Tools?"

- *How do you position tools like procedural modelling versus other design technologies?*
  - *Do you prioritize procedural modelling over other tools in your work?*

    - *If so, why?*
- *How would you describe the different advantages of procedural modelling over other tools such as Generative Design?*
    - *NOTE: in this question Generative Design can refer to both:*
        - *Topology Level-Set Optimization (such as in Fusion360)*
        - *Genetic Algorithms / Evolutionary Design (such as Refinery)*
- *How would you imagine such technologies (procedural graphics and Generative Design) working together?*

QUESTION CLUSTER_03: "Procedural Modelling for Functional Design?" (1)

- *How do you imagine procedural modelling being used to enhance the function of a design?*
    - *NOTE: in this question 'function' is a deliberately broad term, please feel free to interpret this as it is relevant to your work (e.g. aesthetics, performance, sustainability, circularity, etc.)*
- *What role can procedural modelling play in enhancing aspects of sustainability and/or circularity in a design?*
    - *NOTE: this question builds upon the previous question – but, focuses specifically on aspects of sustainability/circularity*

QUESTION CLUSTER_04: "Procedural Modelling for Functional Design?" (2)

- *We have drafted 5 scenarios for using procedural modelling to enhance the function of a design as an extension of the previous questions to continue discussion:*
    - *1) Biomimicry (thinking about 'nature' at the BEGINNING of your design)*
        - *Using procedural modelling to emulate a function observed in 'nature'*
        - *This could be to optimize/enhance performance, material usage, energy, etc.*
    - *2) Afterlife (thinking about 'nature' at the END of your design)*
        - *Using procedural modelling to enhance functions like biodegradability, recyclability, decomposition, transformation, etc.*
    - *3) Design for Repair (extending the life of your design)*
        - *How can procedural modelling help to prepare a model for repair*
        - *NOTE: Technically there are 6 R's are: reduce, reuse, recycle, repair, rethink, refuse*
        - *NOTE: see video introducing this HERE*
    - *4) Manufacturing Modifications*
        - *How procedural modelling could be intentionally used to reduce energy or material in manufacturing processes*
    - *5) Cultural Awareness / Storytelling*
        - *Using procedural modelling intentionally to communicate the creation/use of an object to encourage cultural change around consumption*
            - *This could mean encoding a story about 'how much material or energy' was used in the making of the object*
- *How do you feel about each of these drafted scenarios?*
    - *Do you agree with them? If so, please elaborate on how you would imagine this working in your work/research/practice?*

- *Do you disagree? Or do you have alternative ideas or scenarios? Please elaborate.*

QUESTION CLUSTER_05: "Where could Procedural Modelling Go Next?"

- *<u>Where</u> do you see the future of procedural modelling being useful for the design disciplines (such as architecture or industrial design)?*
    - *NOTE: this can be based on your own experiments (or perhaps the experiments of others)*
    - *NOTE: you can be deliberately broad / future-thinking in this response*
- *<u>What</u> role can 'data' play in the use of procedural modelling?*
    - *NOTE: data in this question can refer to sources such as:*
        - *Material lifecycle*
        - *Manufacturing processes – collected machine data*
        - *Object usage over time (such as wear-n-tear, lifespan, etc.)*
        - *Environmental pressures (such as air, light, moisture, etc.)*
        - *Performance analysis / simulations*

3.2.2 Interviews

Surveys (see above) were completed by filling out text-based answers. These answers were then used as the basis to conduct follow-up interviews with each of the participants. The purpose of the interviews was to clarify answers and get more detail and nuance on how the participants were intending to use procedural modelling for their practice (including in-depth discussions on how they say sustainability fitting into the process).

3.3 Aggregation – Sustainable Design Strategies

The final phase of our approach required further analysis of the work completed to date. This stage took place through a series of debirefings to compile and summarize answers from the surveys and interviews. These debriefings allowed us to more effectively dissect individual answers and to aggregate cross-cutting themes - Section *4.0 Observations*, captures and distills these concepts.

4.0 Observations

4.1 Nomenclature & Syntax were Challenging

Interviewees all defined "Procedural Modelling" very differently, oftentimes confusing it with other terms (e.g. "Computational Design", "Visual Programming"). We noted that this could create a barrier-to-entry for others in Product/Industrial Design to adopt procedural modelling due to a lack of understanding around it's definition and possible applications.

In addition, many interviewees highlighted that the UI/UX for procedural modeling felt "cumbersome" and this contributed to a challenge in collaborating with others using procedural modelling tools.

Ultimately, adoption of these tools does not guarantee success and these challenges have likely affected the rate of adoption within industry. If capturing a ‘design intent’ in these tools were made easier, many interviewees suspected industry adoption would rise.

4.2 Behaviour & 4th Dimensional Control

However, despite the shortcomings of user experience and adoption (noted above), there was clearly still a strong allure for design professionals (in Architecture and Product/Industrial Design) to leverage this type of technology. Interviewees stated the specific advantage of procedural modelling tools is to collate multiple sources of data/information and to manipulate models with advanced forms of control and complexity. Specifically, they noted 4 sub-topics that were considered invaluable features in procedural modeling that could not be found in other technologies (such as solid-modelling tools):

- **Behaviour** (E.g. Rigid Body Dynamics, Particle Collisions, Agent-Based Motion)
- **Material Properties** (E.g. Creating a new material or the ability to ‘manipulate’ anisotropic materials)
- **Time** (E.g. seeing *Behaviors* and *Material Properties* modify or change within a process/system over time)
- **Scale** (E.g. factors on a micro or macro level – both require working with extensive data points/polygons)

4.3 Investment in Procedural Modelling

The ability to leverage procedural modelling for the advantages (noted above) comes at a cost, with many interviewees noting that the learning curve to properly framing design challenges and intent as being “very steep”.

Interviewees described embarking on multi-year investments of time, energy, and personal funding to learn the technology/tools enough to employ them creatively with the degree of control they expect. However, many interviewees did not understate the importance of procedural modelling in maximizing their ability to control a system and in shaping their creative practice or identity.

4.4 Benefits & Strengths to Procedural Modelling

From the observations noted above, we have summarized that procedural modelling applications in Product/Industrial Design granted users with the following abilities:

- To “extend beyond perceived design limitations”
- To design, simulate or animate something that is impossible to conceive
- To embed a sense of wonder and curiousity into a design
- To ‘hack a material’
    - Adding mechanical strength (e.g. manipulating the layout of an anisotropic material)

- Adding surface articulation for the purpose of elevating another material attribute
- Exploring advanced simulation to see how a material will react under certain environmental conditions.

4.5 Biggest Design Strategy Takeaways – Sustainability and Functionality

Based on the feedback received from our resident team, we wanted to see the impact this would have on our proposed '5 Sustainable Design Strategies', below are some findings.

4.5.1 Impact vs. Difficulty

Figure 15 (below) illustrates where the interviewees (resident team) imagined the correlation between perceived Impact vs Difficulty when thinking about the '5 Sustainable Design Scenarios'. Note that Design for Afterlife and Design for Awareness were both considered to have a 'high' impact with light-to-moderate difficulty. This was a surprise for our Autodesk Technology Centers team, because we had originally assumed that Design for Repair and Biomimicry would have ranked higher on the impact score.

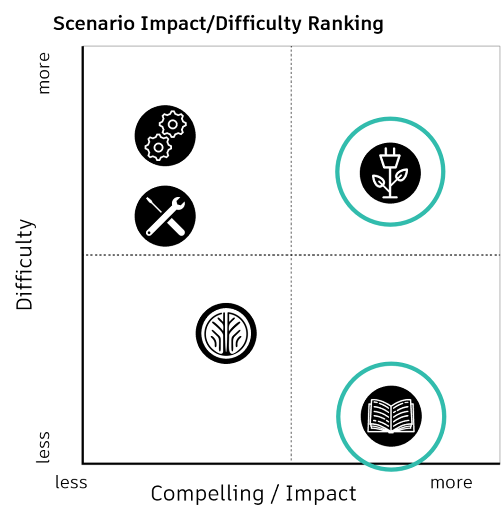


Figure 15 – Impact vs. Difficulty Matrix

4.5.2 Major Themes in Design Strategies

Beyond the findings revealed through the Impact vs Difficulty matrix, we also wanted to receive feedback on each of the '5 Sustainable Design Scenarios' themselves. Below are a series of observations based on feedback the interviewees provided on each of the scearious:

- **3.1.3 Biomimicry involves more than mimicking form**. To better produce a sustainable outcome, designers would need to copy the processes and functions of a nature system. Whether this will require procedural modelling remains application specific and driven by function that is being copied on both a micro or macro level

- **3.1.4 Design for "Afterlife" has the most potential.** Although some were resistant to this idea in the beginning, all interviewees acknowledged a deep interest and the potential for leveraging this type of design strategy. Many stated that design for afterlife was the most provocative and could be paramount to true circular design.

- **3.1.5 Design for "Repair" has its limitations.** Although agreeable, interviewees acknowledged that this type of design strategy would need to be at the forefront of the design goals. As well, this type of design strategy does not generate the same level of impact and potential as its counterparts.

- **3.1.6 Manufacturing Modifications has multiple interpretations.** Interviews had many different visions of what procedural modelling could do in the context of manufacturing, especially when paired with sustainable design. While some understood this design strategy to be specific to limiting a energy or consumption intensive factor (e.g. material, electricity), others believed procedural modelling is better suited to simulate very bespoke or emerging methods of fabrication (e.g. clay slumping simulation) or environmental factors (energy consumption in a building). One interviewee even went as far as positioning this design strategy as a way of procedurally manufacturing a component, by leveraging AI, historical data and machine constraints to produce the functional geometry.

- **3.1.7 Design for "Awareness" is a must and has the potential to change consumer perception.** Despite being labelled as 'novel' and 'provocative', educating society through design was viewed as starting point and major tool that could be used to alter consumer mindsets.

4.5.3 Procedural Modelling & Other Computation Design Tools

A final observation based we wanted to highlight was how the residents imagined Procedural Modelling tools interfacing with the growing use of other advanced computational tools in Product/Industrial Design – namely Generative Design. Figure 16 (below) illustrates that generally all interviewees imagined that Generative Design could be leveraged "first" in a design approach; where higher performing candidates relative to performance requirements could be whittled down to a handful of exceptional iterations. Then Procedural Modelling could be used as a means of enhancing those iterations to add: complexity, surface articulation, lattice structures, etc. Upon talking with the interviewees further we realized that they could currently only imagine a 1-way flow of using these two technologies together – that of Generative Design-to-Procedural Modelling. Going in the reverse direction was considered an "interesting" thought experiment that interviewees would have to reflect upon further in their own creative practice.

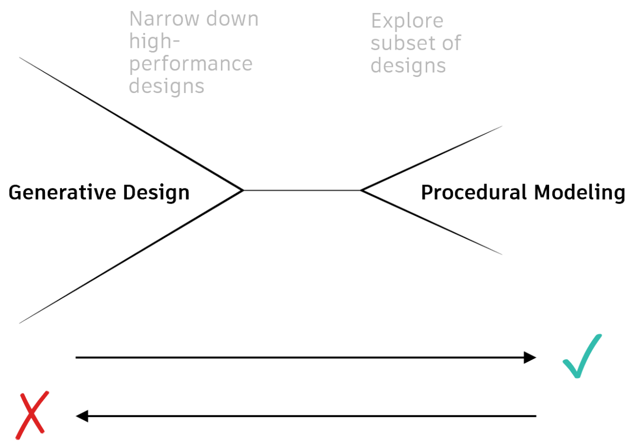


Figure 16 – Generative Design to Procedural Modelling Workflow

5.0 Engage with us!

Throughout the course of this talk and handout we have continually referred to the Autodesk Technology Centers, the Outsight Network, and residents. The Autodesk Technology Centers are a division within Autodesk Research – which as an organization conducts research by working with external organizations from a variety of sectors (academia, industry, and start-up/entrepreneurs). The Technology Centers provide support to these external teams (called residents) within an open-innovation model that fosters collaboration and idea-exchanges in what we call an Outsight Network. This community of residents together explore the future-of-making across a range of industries. In exchange for observing these teams' research *as case-studies) the Technology Centers provide a series of resources at no cost.

The Technology Centers relish supporting teams that embark on innovative and projects that push boundaries. If you would like to explore topics like the one discussed in this talk (or others) please feel free to reach out and discuss your ideas!

6.0 Resources + Definitions

Throughout the course of this talk and handout we have referred to a number of terms that may not be immediately familiar to those coming from a Product Design/Industrial Design background. We have provided definitions to these terms below with links on where to find more information.

6.1 Definitions

Procedural Modelling

- Procedural modelling is considered an "umbrella term" for several techniques in computer graphics to create: 3D models, textures, effects (such as particles or explosions), graphics, and animations. All of these types of output are based on sets of rules, or as the name implies 'procedures'. The sets of rules can be embedded into an algorithm or made configurable by exposed parameters (through the means of sliders/pop-up-panels as part of the UI/UX).

- Although all modelling techniques on a computer require algorithms to manage and store data at some point, procedural modelling focuses on creating a model from a rule set, rather than editing the model via user input. Procedural modeling is often applied when it would be too cumbersome to create a 3D model using generic 3D modellers, or when more specialized tools are required.
- An advantage of using procedural modelling is to assist in creating complex scenes through relatively small scripts – which in turn, makes the designer feel more like an art-director: tweaking and refining the ingredients/scripts to get different outputs.
- Procedural modelling has been developed mainly within and for the Media and Entertainment industries for the purposes of assisting in creating complex scene assets for movies or video games.
- To learn more about the origin of procedural modelling within Media and Entertainment / Computer Graphics industry we encourage readers to explore the following e-book: https://www.csee.umbc.edu/~ebert/book/book.html

Convergence

- When we refer to 'convergence' in this talk/handout we are referring to the term that Autodesk has defined – as it relates to technology and industry.
- For the sake of simplicity we specifically refer to convergence as the process of blending together tools, technology, personas, and industry for the purpose of leveraging strengths in other disciplines when applied to specific challenges. In short, convergence can be thought of as "transdisciplinary" activites.
- To learn more about Autodesk's perspective on convergence we encourage readers to visit: https://www.autodesk.com/industry/convergence

Computational Design

- When we refer to 'compuational design' in this talk/handout we are borrowing the term as it applies to the architectural design community (as a direct influence of our resident team)
- "Computational design" is an umbrella term that refers to the use of computer processing abilities to co-create design assets. This can allude to the use of scripts, generative algorithms, procedural modelling, and many more examples. Note, that this is distinctinctively different from "computerization", which is the use of computers to assist in the digital recording of design decisions.
- One can think of "computerization" as the use of tools like Autodesk's AutoCAD, where the designer manually inputs lines and associations. And similarly one can think of "computational design" as the use of tools like Autodesk's Fusion 360 Generative Design tools, where the designer provides high-level goals and lets iterations be automatically created and curated.
- To learn more about the difference between "computation" versus "computerization" we encourage readers to visit the following paper: https://www.degruyter.com/document/doi/10.1515/9783035620405-006/pdf

Generative Design

- When we refer to ‘Generative Design’ we are generally speaking about the use of genetic algorithms to aid in the automatic creation and curation of design iterations relative to a specific performance metric (or goals).
- Autodesk has two distintctive flavours of Generative Design within our products/services:
- Autodesk Generative Design for Manufacturing - through tools like Autodesk Fusion 360
- Autodesk Generative Design for AEC – through tools like Autodesk Revit/Dynamo
- Readers can learn more about both through the following link HERE

6.2 Additional Resources

In addition to the recorded talk and handout there are a series of shareout-reports from one of the resident tutor-led teams from the AAVS program. There were 4 reports that we felt helped illustrate the concepts of merging procedural modelling with ‘grounded’ examples. We wanted to acknowledge the hard work of these students and their tutor who led them through an extensive program yielding amazing results in a short time.

Finally, we wanted to provide a list of learning resources that were leveraged by the AAVS resident team to explore procedural modelling within Autodesk’s tools. As a reference the resident team experimented with Autodesk’s Bifrost for Maya tool (a visual programming language – that manages complex procedural modelling operations).

To learn more about Autodesk’s Bifrost for Maya readers are encouraged to explore the following links:

- Bifrost Homepage: https://makeanything.autodesk.com/bifrost
- Bifrost Forum: https://forums.autodesk.com/t5/bifrost-forum/bd-p/6060
- Bifrost Bootcamp: https://makeanything.autodesk.com/bifrost/bifrost-bootcamp-214J2-16402K.html
- Rendering Bifrost results with Arnold: https://docs.arnoldrenderer.com/display/A5AFMUG/Arnold+for+Maya+User+Guide