Development of a Virtual Experiment to validate the relationship between Engineering Changes and Learning Curves using design structure matrices

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The Why

"Industry push towards continuously introducing novel and more complex products in manufacturing plants worldwide"

Challenges:

- How to deal with more complex products that needs to be produced faster and faster?
- How to more accurately forecast resource planning after introduction?

Previous work

Master thesis already explored this relationship with a low-tech LEGO experiment (Dooper et al., 2022)

Here participant had to assemble Model A before continuing to Model B. Each model is assembled iteratively for 5 times. The models differ in complexity

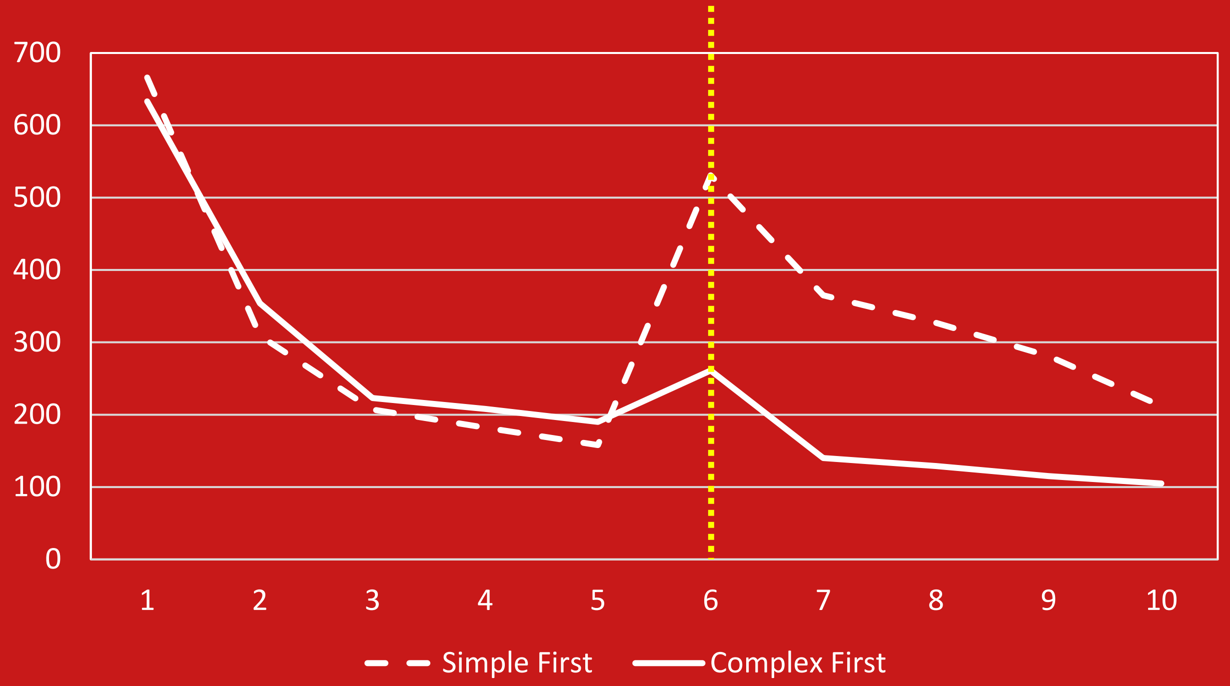
Small sample group (n = 8)

Model A

Model B

Dooper, D., Etman, P.L.F.P., Alblas, A.A., 2022. Quantifying the Impact of Product Changes on Manufacturing Performance, in: DS 121: Proceedings of the 24th International DSM Conference (DSM 2022), Eindhoven, The Netherlands, October, 11 - 13, 2022. The Design Society, pp. 38–47. https://doi.org/10.35199/dsm2022.05

Greater uptick in Cycle Time when engineering change occurs from simple to complex variant.



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What is
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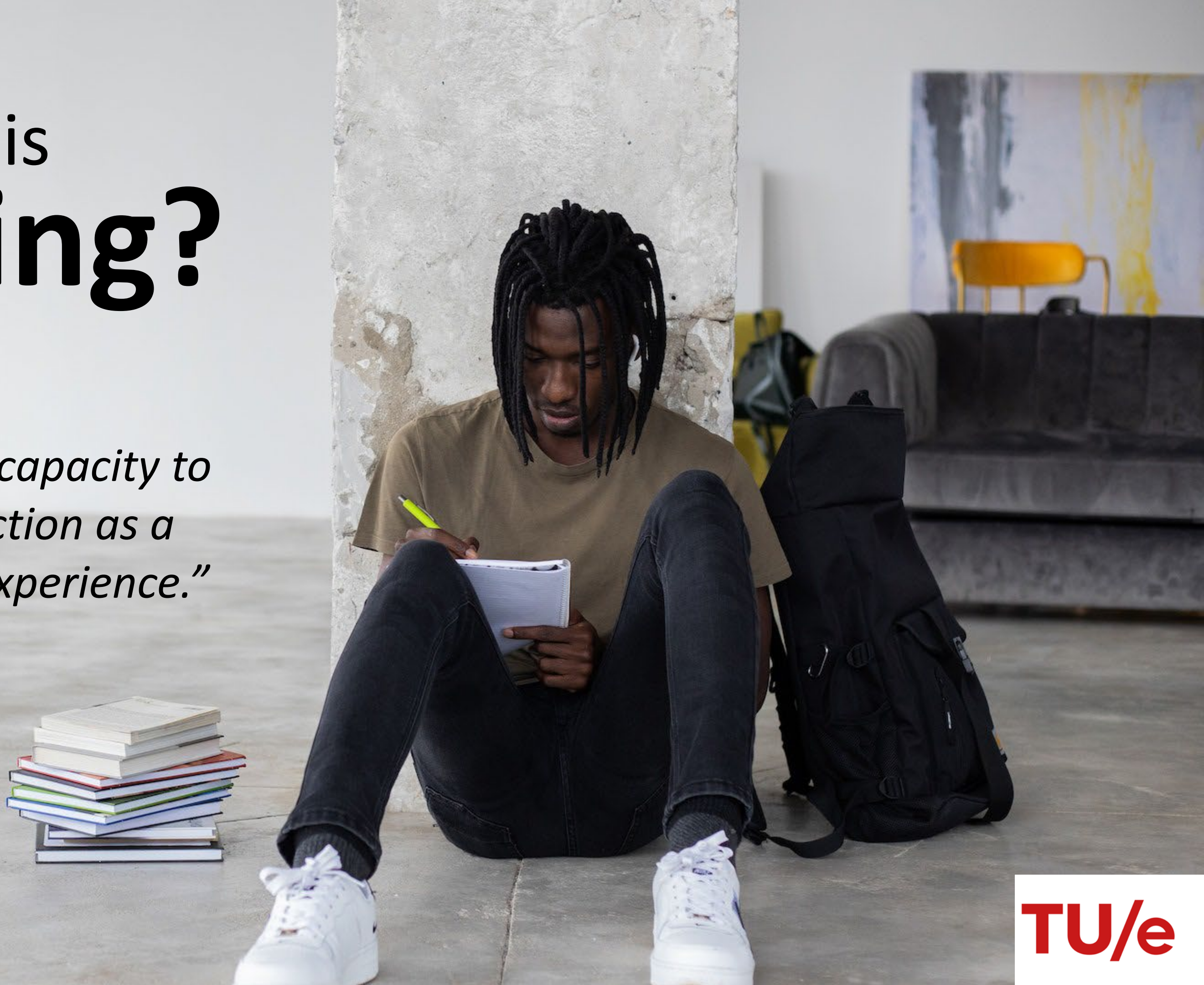
"Increasing one's capacity to take effective action as a result of gained experience."



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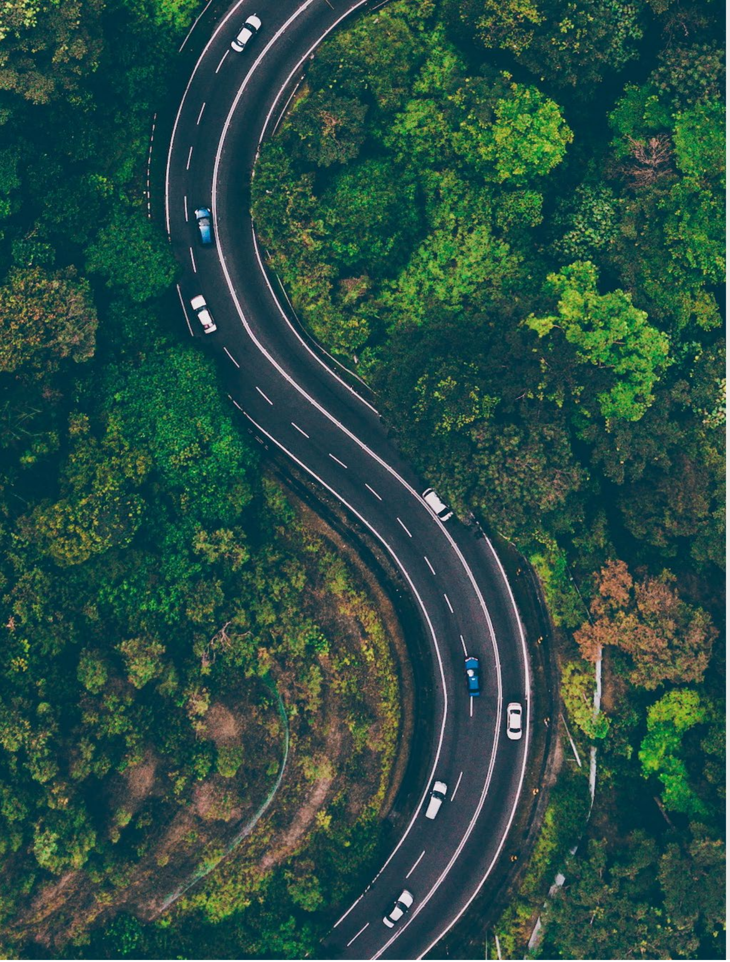
What is **Learning?**

“Increasing one’s capacity to take effective action as a result of gained experience.”

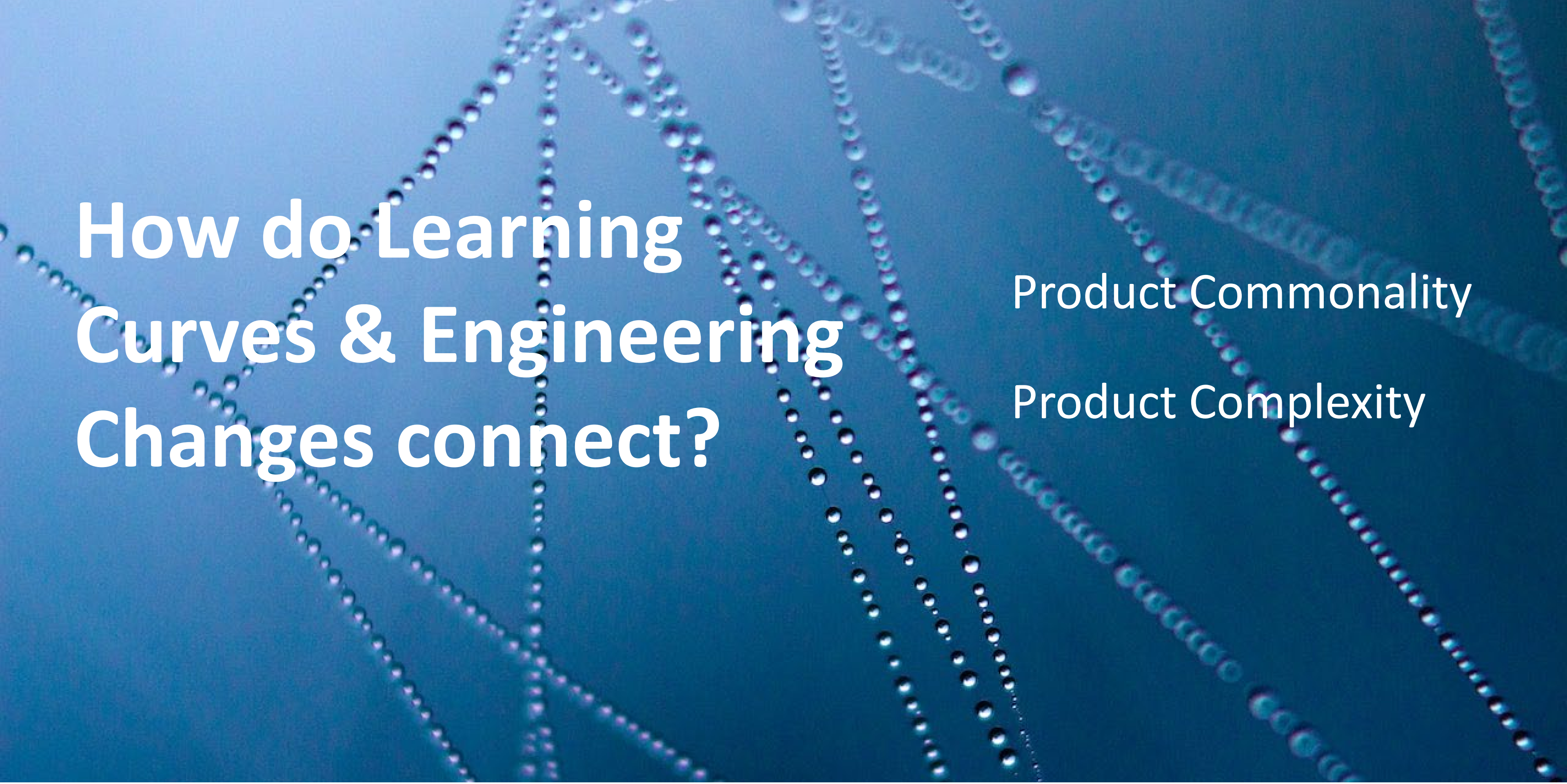


Learning Curves

Learning Curves are a mathematical representation of a worker's performance on repetitive tasks.

It quantifies the relationship between performance & gained experience (learning).

Proven to be an effective tool to monitor individual workers' performance when performing repetitive tasks, leading to a reduced process loss due to a lack of experience during the first production cycle after engineering changes



How do Learning Curves & Engineering Changes connect?

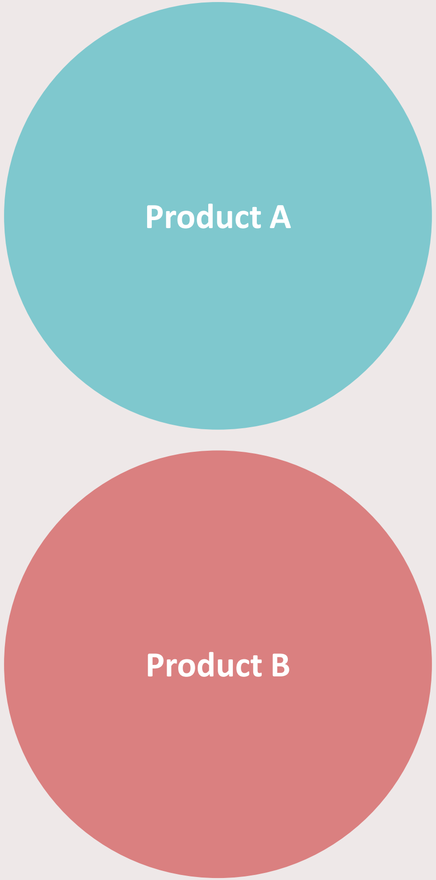
Product Commonality

Product Complexity

Product Commonality

Engineering changes are often incremental and new improved products often share a large set of components with their predecessor.

This overlap of components can be called product commonality.



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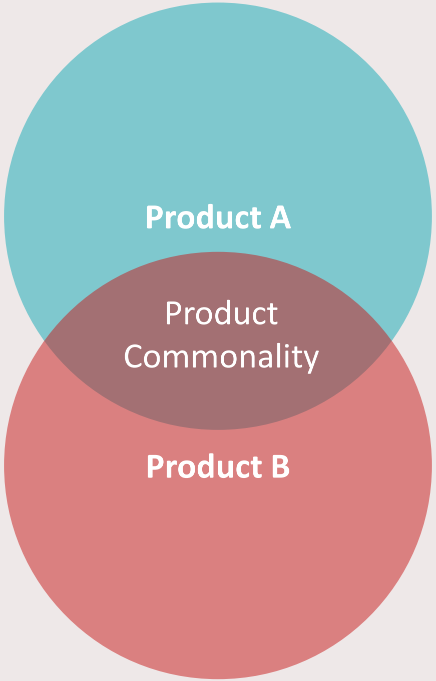

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Product Complexity

A product's Structural Complexity C can be quantified using 3 properties of the system (Sinha et al., 2014) :

1. Individual Component Complexity α_i
2. Interface Complexity $\beta_{i,j,k}$
3. Topological Complexity A

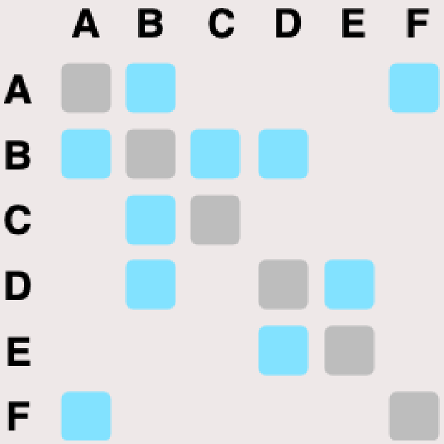
$$C = \sum_{i=1}^{n} \alpha_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{m} \beta_{i,j,k} \cdot \frac{E(A)}{n}$$

Sinha, K., 2014. Structural complexity and its implications for design of cyber-physical systems. Massachusetts Institute of Technology. PhD Thesis.

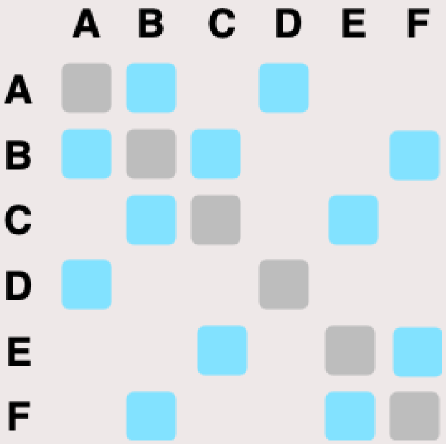
Quantification of parameters with DSM

Product Commonality

Product Complexity



Product A

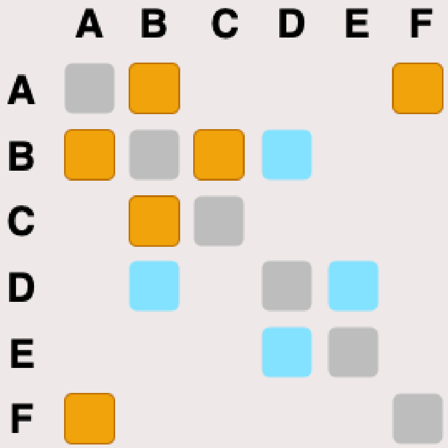


Product B

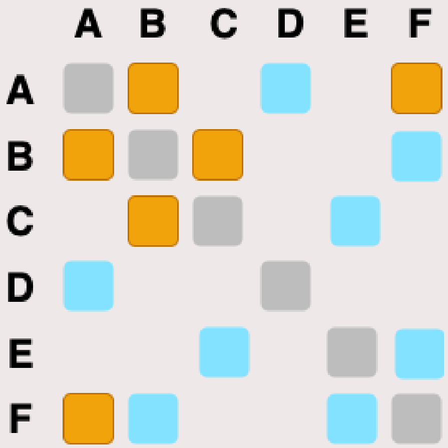
Quantification of parameters with DSM

Product Commonality

Product Complexity



Product A



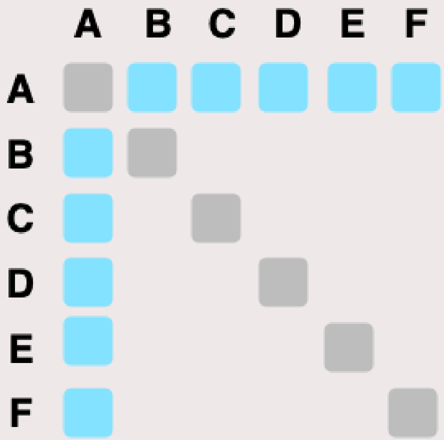
Product B

Quantification of parameters with DSM

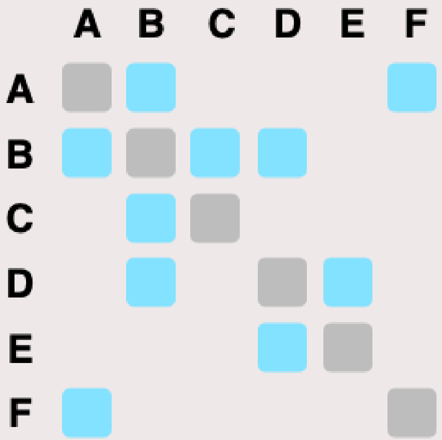
Product Commonality

Product Complexity

Topological Complexity is quantified using DSMs, individual component & interface complexity through expert elicitation.



System A with E(A) = 4.47



System B with E(A) = 6.90

Design Requirements new experiment

DR1 Scalability
DR2 True experimental design
DR3 Differentiate in both product complexity (isolated) & commonality
DR4 Direct feedback for errors
DR5 Mitigating effects of psychomotor learning
DR6 Exact assembly behavior logged
DR7 Assembly time logged
DR8 Gamification Elements to mitigate dropout & distraction

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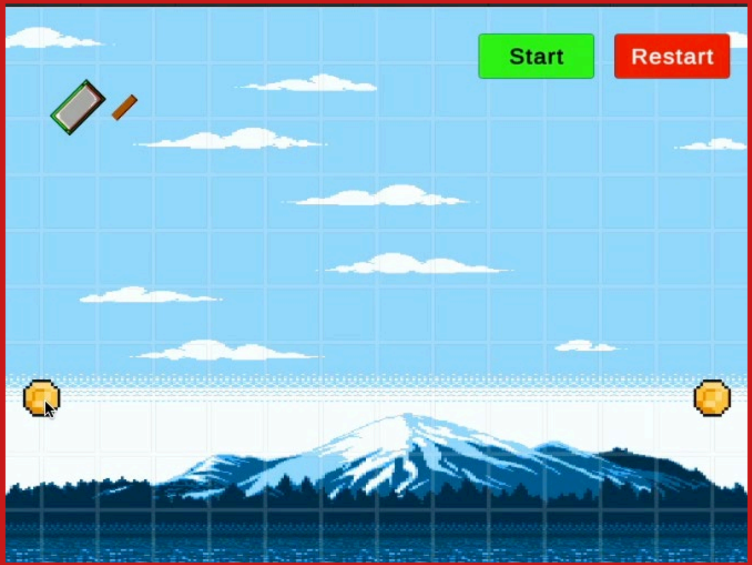
Build a Bridge Experiment

For this experiment participants need to build a bridge model between two points for 5 iterations before moving to another bridge model. Models vary in complexity & commonality.

- Virtual experiment allows for easy distribution
- Experiment isolates complexity metric to only structural complexity
- Gamification elements present to mitigate dropout & distraction
- Different assembly sequences show learning

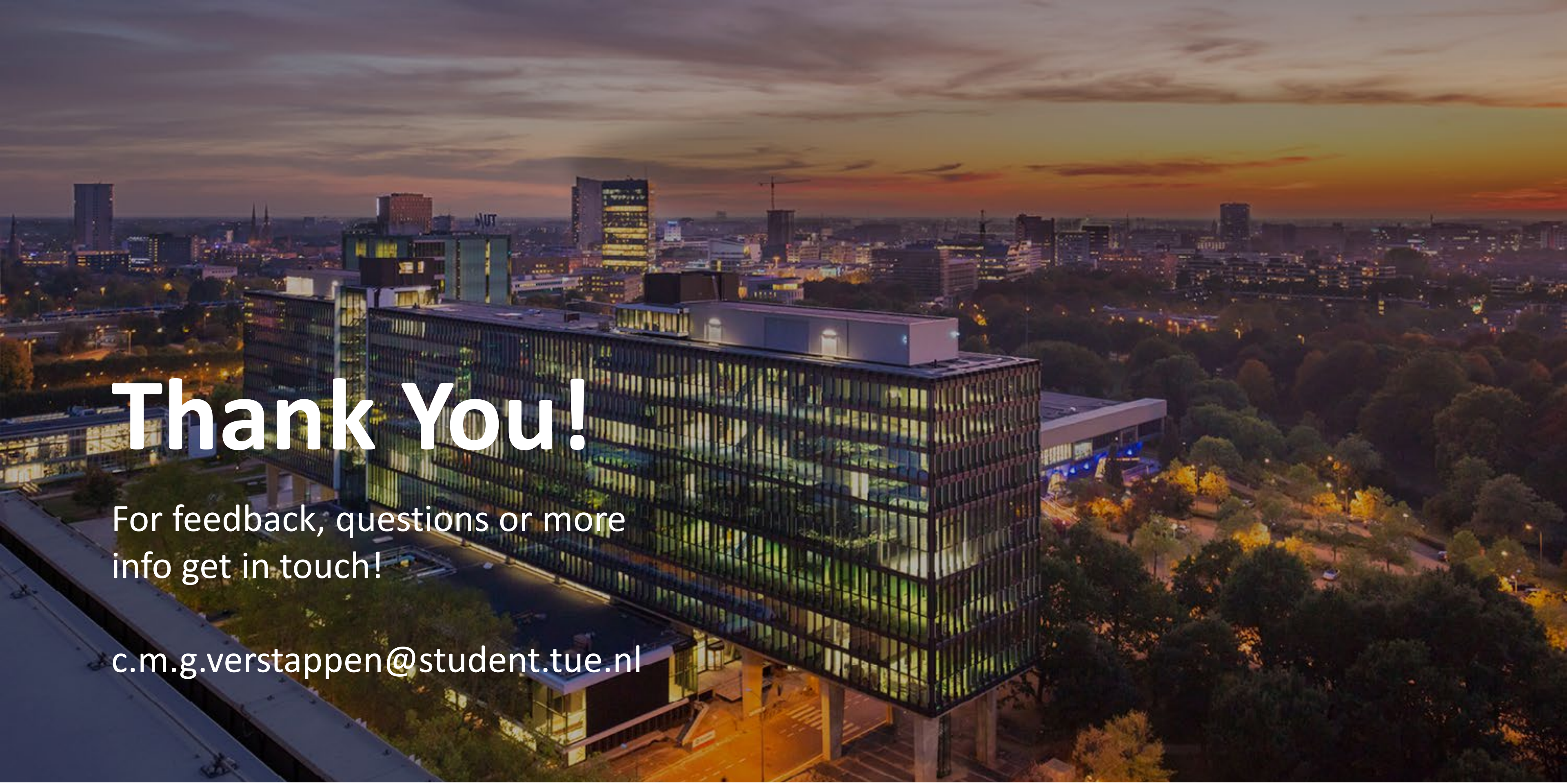


Next Steps

September – October 2023
Build a robust virtual experiment development suitable to roll out to a large sample group.

November 2023
Experiment will be distributed to approx. 120 students with diverse engineering backgrounds.

January - February 2024
Finalization Master’s Thesis about the relationship between learning curves and engineering changes



Thank You!

For feedback, questions or more info get in touch!

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Changing strategy improves assembly times

Iteration 1
24.08 sec

Iteration 2
21.94 sec

Iteration 3
20.05 sec