Aalto University
School of Engineering

MEC-E1003 Machine Design Project

Sept. 9, 2022

Prof. Sven Bossuyt

Learning goals for the course

Students...

1. Can relate theory and exercises to practice
2. Can iterate a design from the initial concept to a working prototype
3. Can document their contribution within a team-based effort
4. Are familiar with typical issues in project management and teamwork, and ways to address those issues

Access to prototyping facilities is restricted this year, due to ongoing construction, so expectations and assessment criteria for the prototype will be scaled back accordingly.
However, you must still validate your concept and iterate the design with some prototype, and produce design documentation for prototyping and testing

Credits: 5 ECTS

Grading: 1 - 5

Duration: 9.09.2022 - 16.12.2021

Teacher in charge: Sven Bossuyt

Schedule: Overview and milestones

Week	Deadline	Description
Week 35-36	Sept 9	Group selection and pre-questionnaire
Week 37	Sept 16	Design brief for group project
Week 37-38	Sept 23	Stirling engine starter project (individual work)
Week 40	Oct 7	Initial concept for group project
Week 43	Oct 28	Concept pitch + peer review & 1st evaluation questionnaire
Week 46	Nov 18	Status report & 2nd evaluation questionnaire
Week 47		Status report peer review
Week 49	Dec 7	Information poster
Week 49	Dec 9	Gala: Prototype demonstration & gala reflections
Week 50	Dec 16	Final report & final evaluation questionnaire

Stirling engine starter project

9.09.2022 - 23.09.2022, Friday 12.15 - 16.00

Assemble the Stirling engine kit and Test Performance (individual work)

- Students will be provided with disassembled stirling engine kits, a toolbox with the parts in it, and with a set of hand tools and measurement tools.
- Each student, working alone, will check out a kit for 2 days.
- In those 2 days, they follow provided design documentation to check each part against part drawings, to follow assembly instructions to assemble the engine, and to check the assembly against assembly drawings.
- They operate the engine and confirm performance

Group project

Students, working in teams, will complete a specific mechanical design task, representative of mechanisms used in machines. They will develop an initial concept, build a prototype to demonstrate its working, and carry out more detailed designs of critical components.

For the concept, as a team, reflect on everyday- or industry-related activities and solutions you would like to improve, or to simply try and replicate. In other words, start with an existing object, and design it to be in some way better (perhaps better by some metric that was not important for the original design, sustainability for example).

Project-based learning in this course will be supported by the theory and exercises taught in the courses from the common studies, taught concurrently.

In the end of the course, there will be a final gala where you will be required to demonstrate the prototype of your solution.

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Previous years

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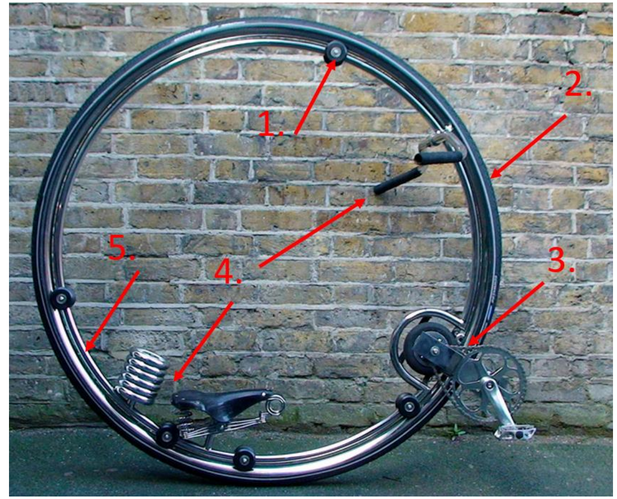

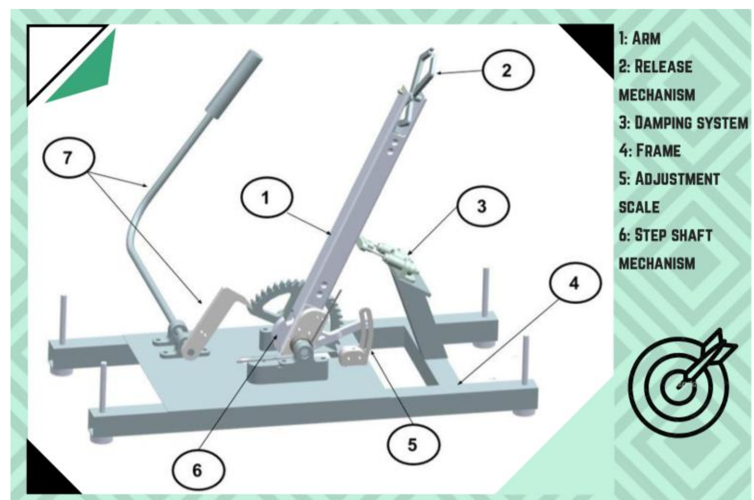

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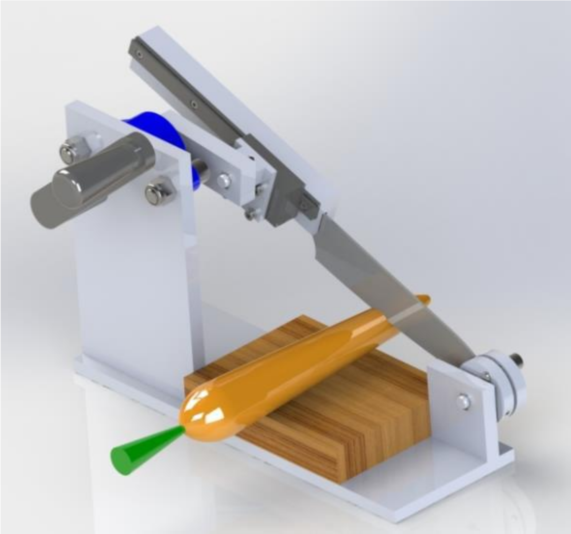

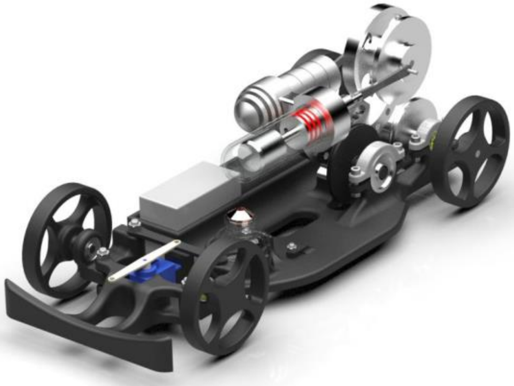

Group project: Changes this year!

- Most of the teamwork will happen in person again
- Iterating from initial concept to working prototype will still be limited, if students cannot access the production facilities of the Aalto Industrial Internet Campus for prototyping.
  - *Multi-body dynamics or finite element modelling can be used to iterate the design*
  - *Some preliminary prototype with cardboard cutouts or a wireframe model is still possible*
- Teams still need to prepare and document a plan for manufacturing and testing a working prototype

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Assessment

Final outcomes and grading

30% Stirling engine starter project

70% Final design project

Prototype demonstration & reporting

Report should include

- Final design documentation,
- Manufacturing and testing reports,
- Conclusions about course and demo, constructive self-evaluation by including scope for improvement

One grade for the whole report and gala presentation

- Individual grades modified according to contribution to team effort

Contribution to team effort

Mutual assessment within each team

- With the help of three evaluation questionnaires
- Includes self-assessment
- May be overruled in teams where it doesn't work well

Multiplicative combination of four factors

- Timeliness
- Participation/effort
- Quality
- Communication

Criteria for assessment of the contribution to the team effort

Criterion	Characteristics lowering the grade	Grade 3 (good)	Characteristics improving the grade
Timeliness	Work is often not ready on time	Work is usually completed on time, according to the common plan agreed	Work is always completed before the agreed deadline
Participation	Avoiding duties	Participation in the group work, attending meetings, contributing to discussions, taking their part of duties	Taking responsibility for their own duties and readily available to help others
Quality	Deliverables and tasks are incomplete, not working, or poorly documented	Deliverables and tasks are completed in a way that meets expectation	Deliverables are working reliably and are well documented
Communication	Not communicating as planned, difficulty in reaching-out via selected channels	Active communication whenever necessary via planned channels	Proactive, taking initiative in team communication

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Questions?

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MEC-E1003

Stirling Engine Starter Project

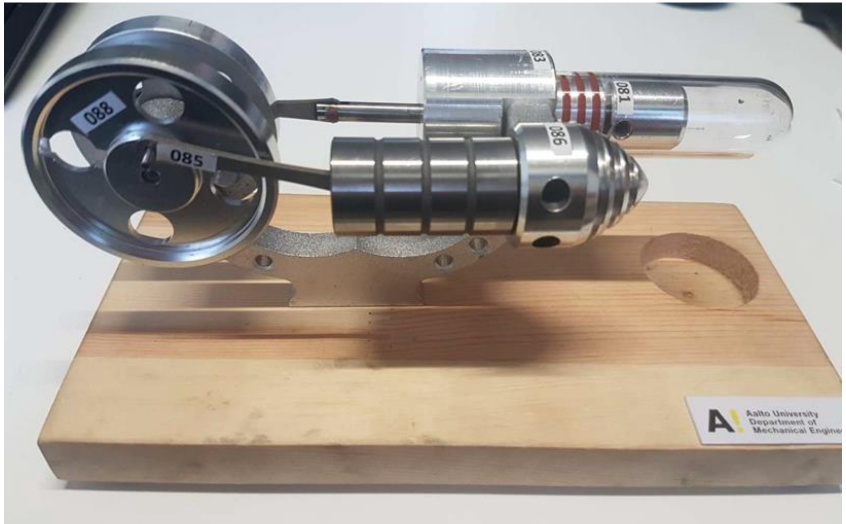
What is this starter project about?

- This project will provide a introduction to mechanical fabrication: specified parts for ***machining***, ***assembly***, ***inspection***, and ***compliance***. *These are all skills you will need to be successful at designing machines*.
- This is a ***hands-on experience*** project. It is purposefully given *now*, before you have learned any theory on cutting, machining, measurement, or fabrication.
- It provides a practical background before you study the theory.

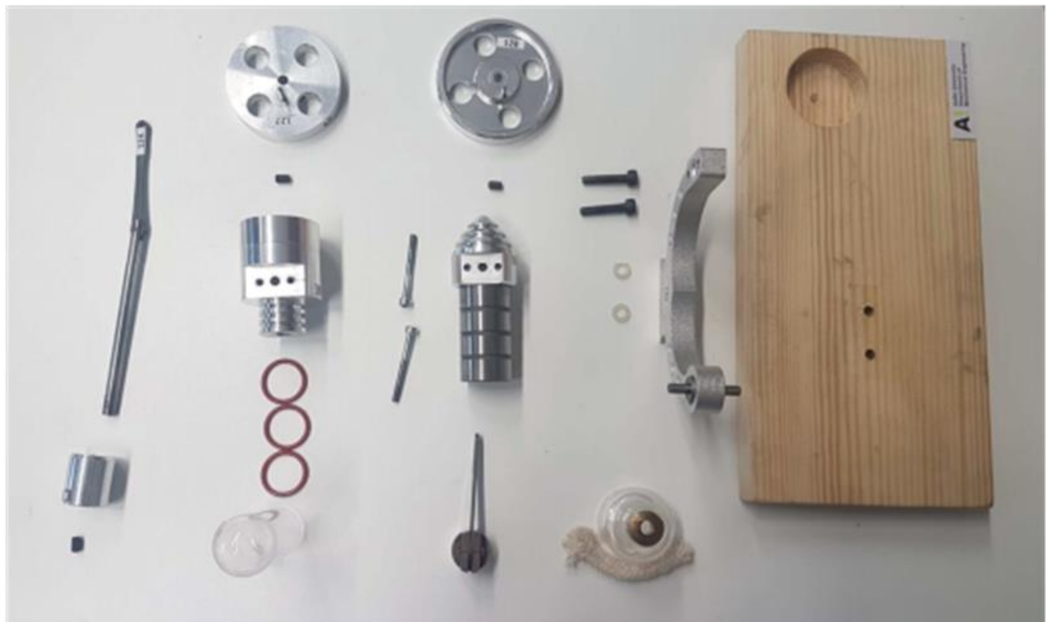
Miniature Stirling Engine

First three weeks

- You will inspect parts, assemble, and test a working miniature Stirling engine built of machined parts.
- The more precisely you fabricate parts and assemble the engine, the faster it will go

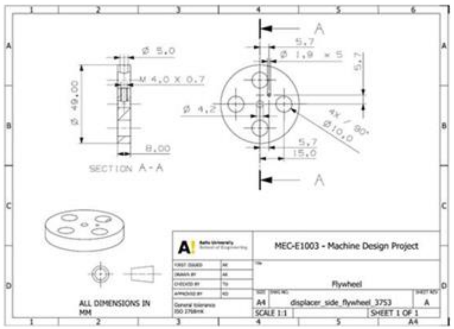


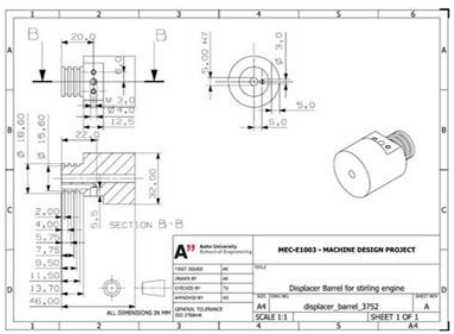
Miniature Stirling Engine
kit of parts



Miniature Stirling Engine

part drawings which were used as a basis for machining the parts





35mm and 50mm aluminum rod stock

Miniature Stirling Engine

individually inspect all of the parts

Miniature Stirling Engine
“customer acceptance” test for acceptable speed performance

Starter project learning outcomes

This starter project is to provide a hands-on experience for the basis of future courses.

After completing the starter-project the successful student will be more comfortable designing machined parts and assemblies

- Understand machine tool capabilities
- Understand dimensions and tolerances and design documentation
- Understand tolerances and measurement inspection
- Understand design verification and validation
- Understand engineering estimation in design

Starter project grading

- **HW 1: Engine project work (75%)**
  - Individual inspection measurement assignment
  - Performance quality: speed of machine result

- **HW 2: Engine Engineering Analysis (25%)**
  - Engine redesign improvement homework assignment
  - In-class activities

Course workload

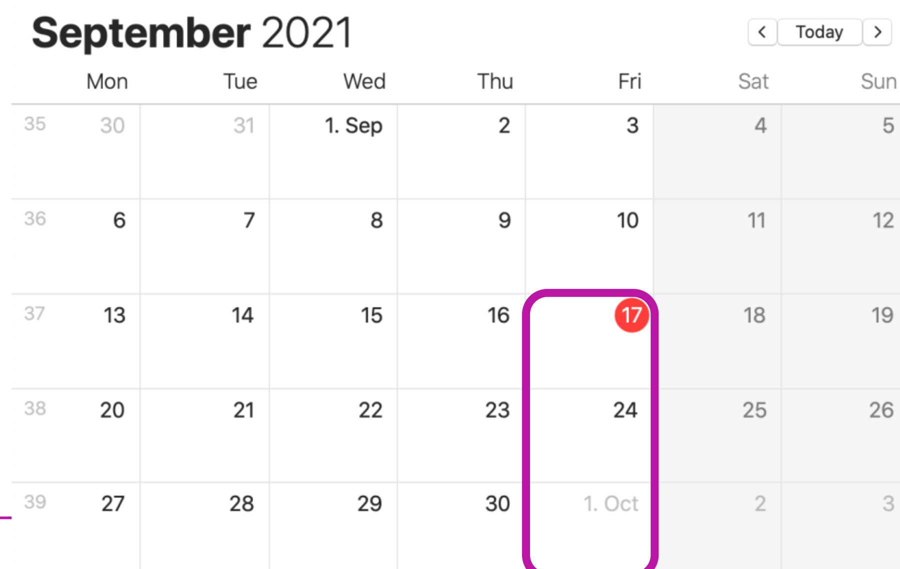
- **5 credit course: 135 hours**

- **This starter project: 5 hours**
  - Measurements: 2 hours
  - Assembly: 1 hour
  - Test and disassembly: 1 hour
  - Homework 2: 1 hour

- **Earning grade 5: you need to do good work, not many hours**

Pedagogy and attendance

- This starter project includes in-class discussions with *hands-on* activities. *Active participation* is essential to your learning and therefore *attendance* is *strongly recommended*.



Why this starter project?

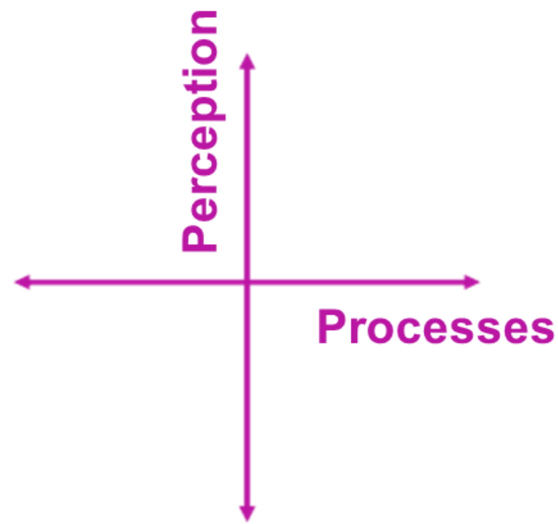
How do you learn?

Learning pedagogy

Learning theory:

the Kolb learning model

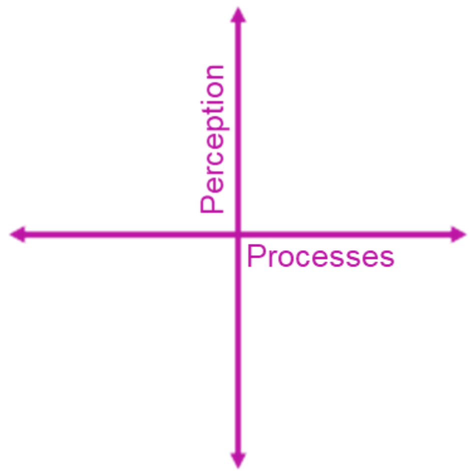
- **Perception**
  - What's going on in your head while learning?
- **Processes**
  - What are you doing while learning?



Learning pedagogy

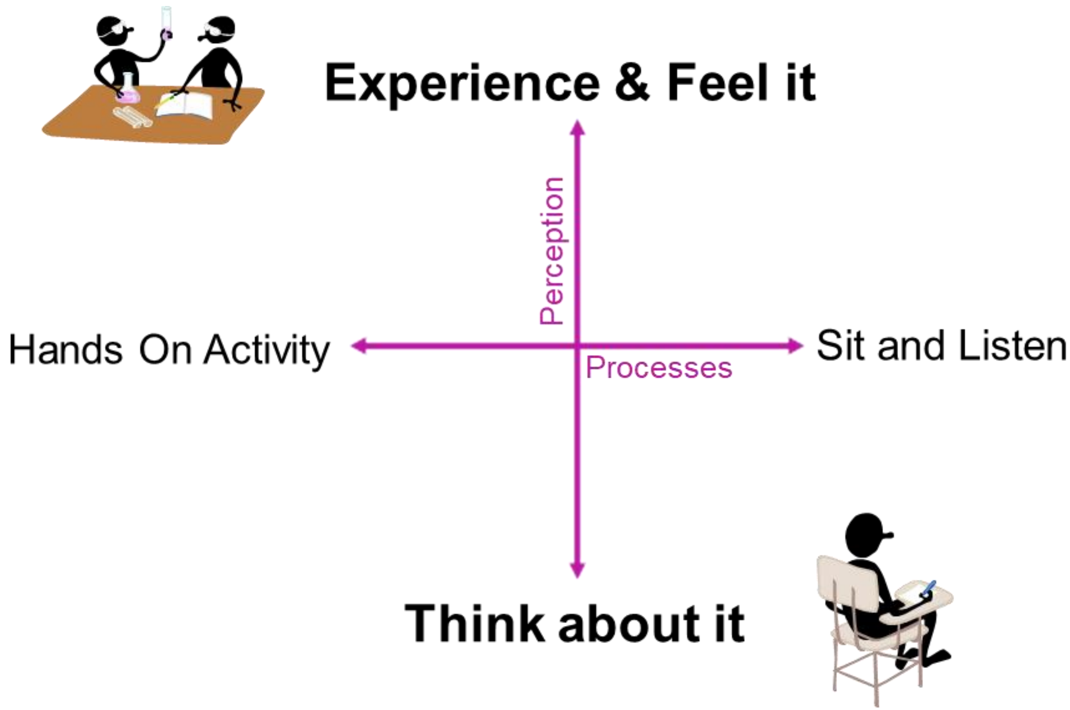
the Kolb learning model

Hands On Activity

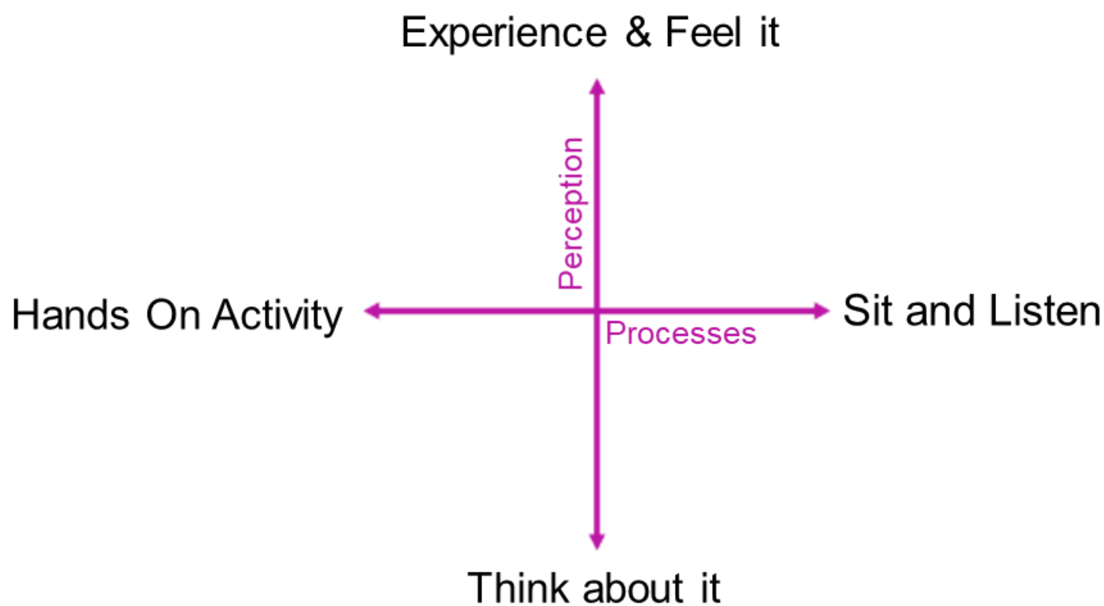


Sit and Listen

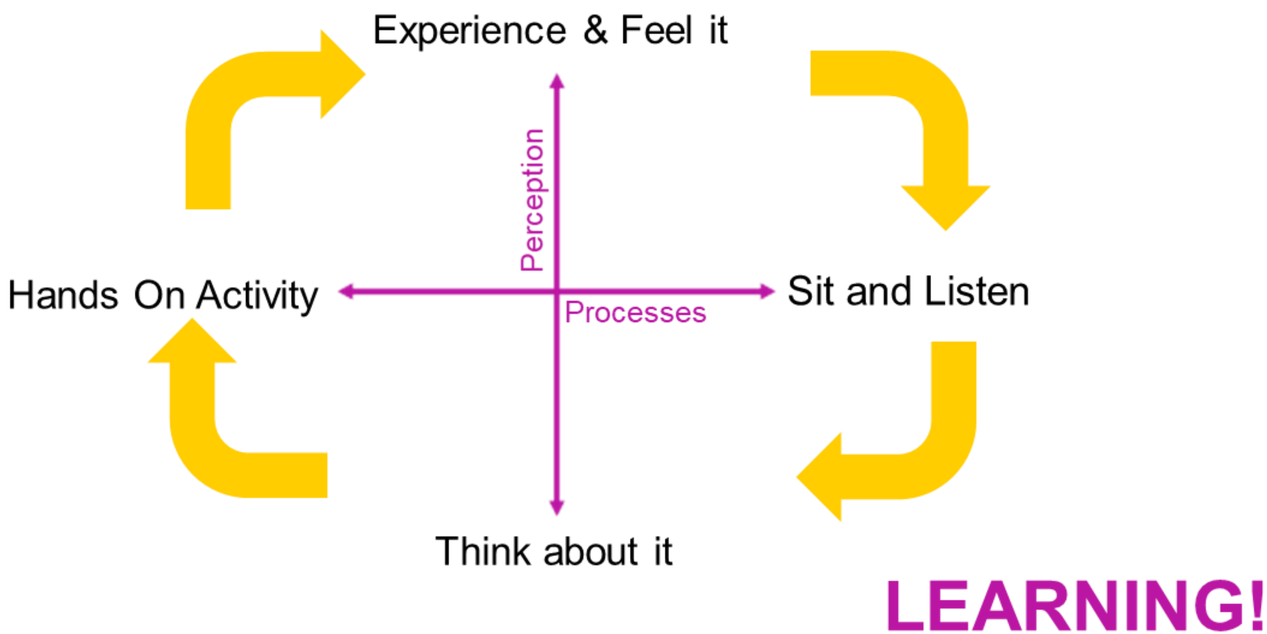
Learning pedagogy
the Kolb learning model



Learning pedagogy
the Kolb learning model

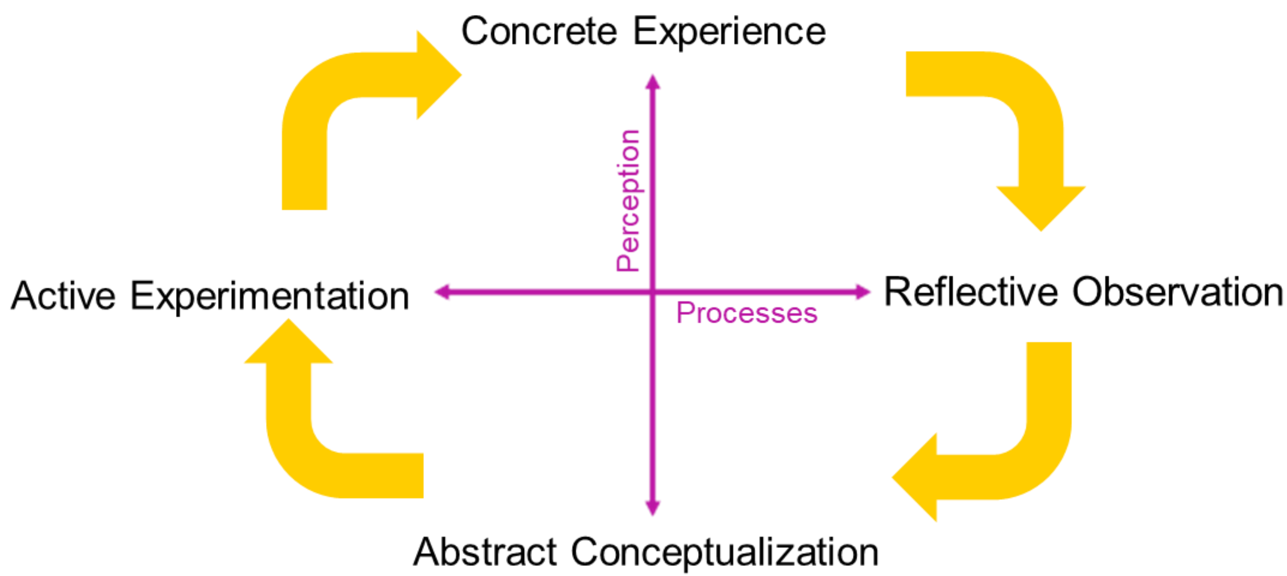


Learning pedagogy
the Kolb learning model



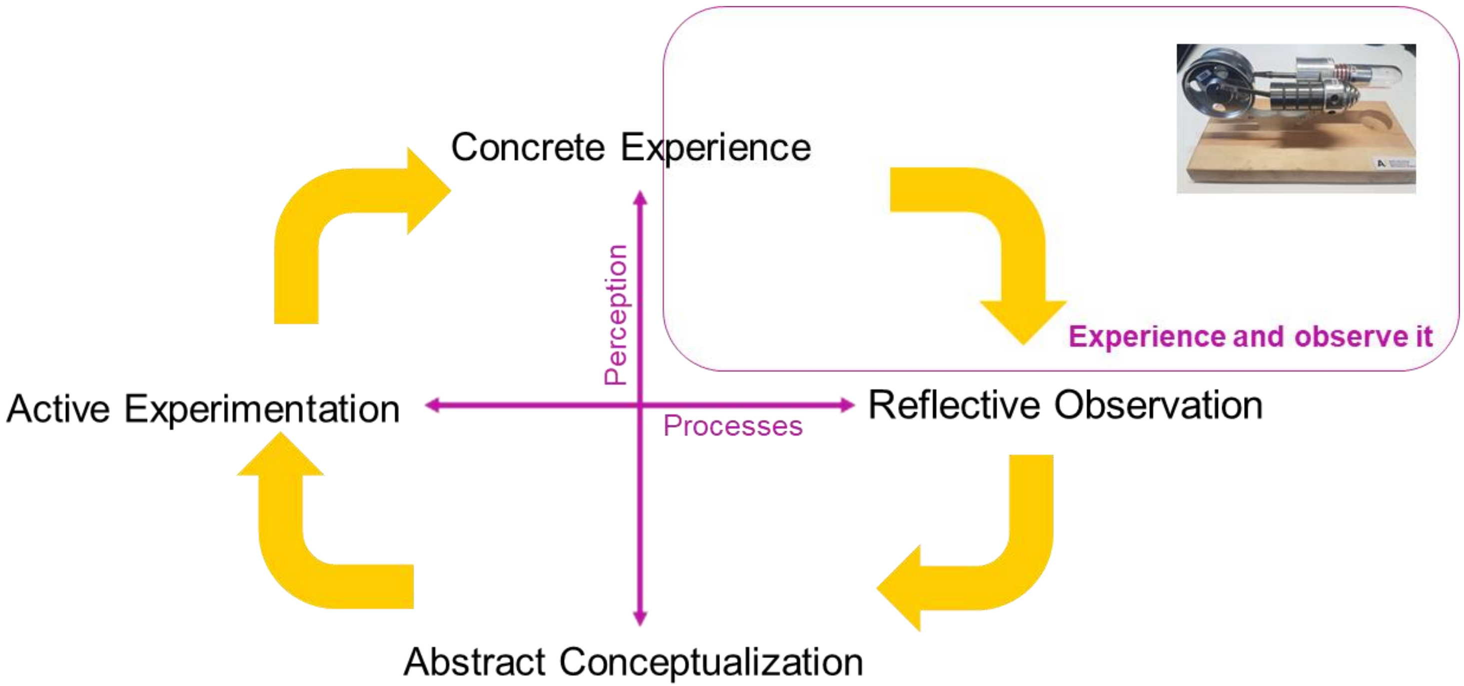
Learning pedagogy
the Kolb learning model

The ***entire curriculum*** closes this loop.

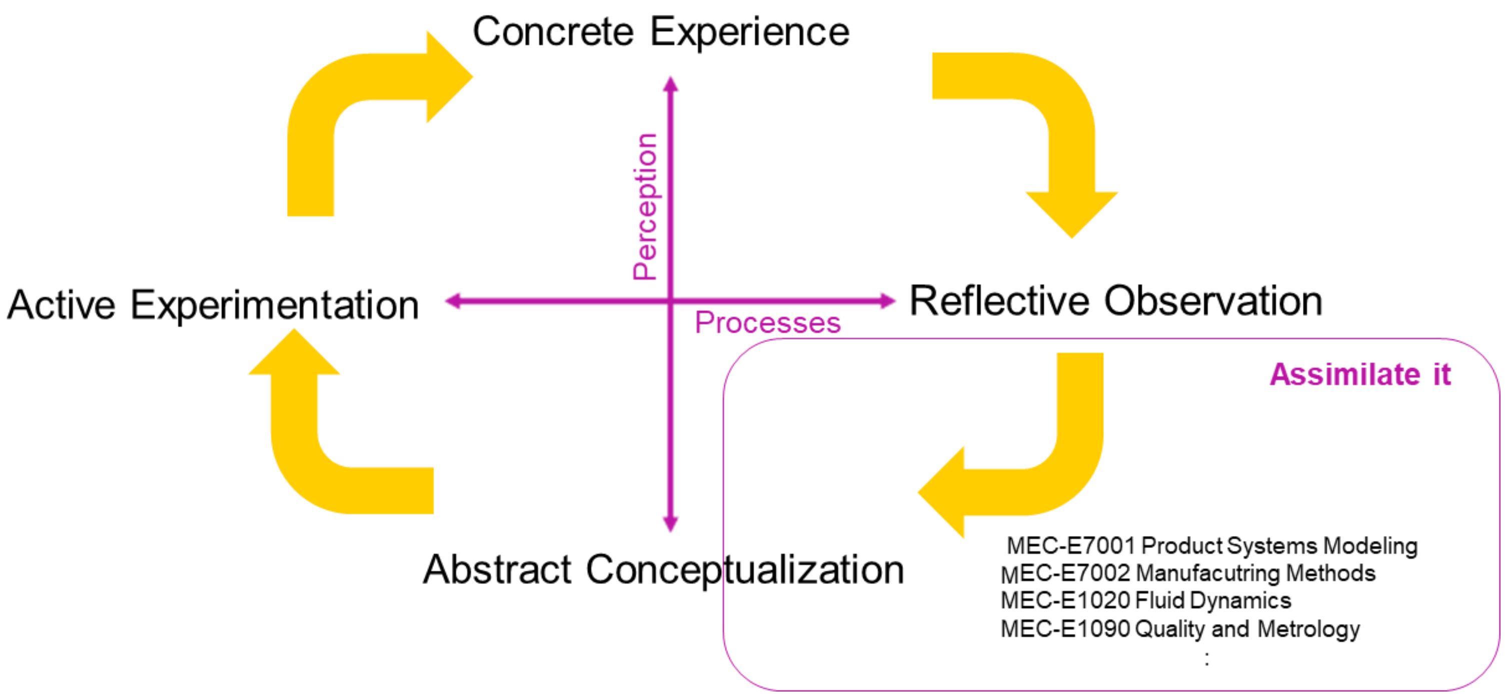


Learning pedagogy

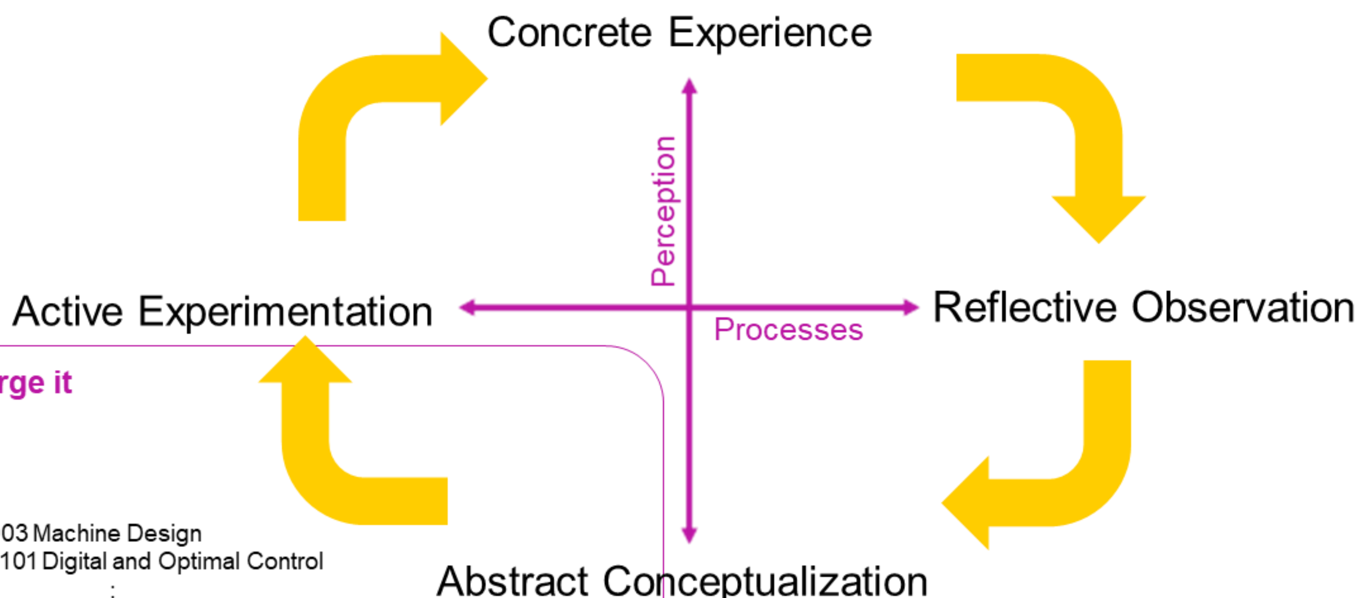
the Kolb learning model



Learning pedagogy
the Kolb learning model



Learning pedagogy
the Kolb learning model

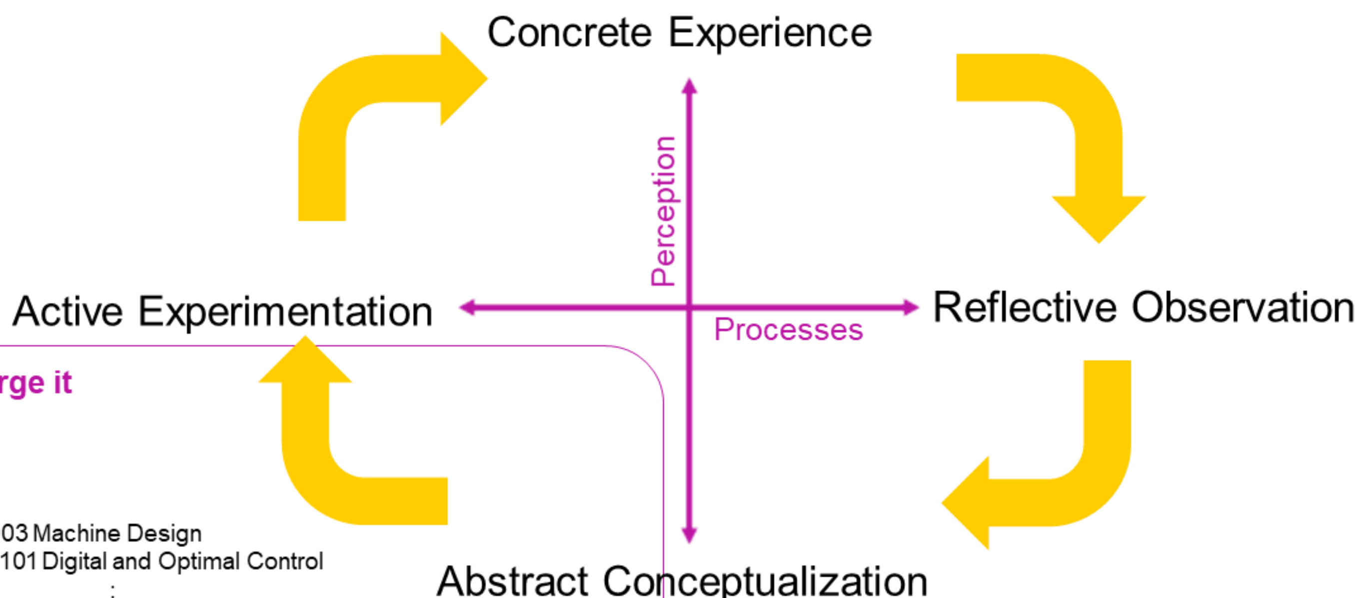


Converge it

MEC-E1003 Machine Design
ELEC-E8101 Digital and Optimal Control
:

Learning pedagogy

the Kolb learning model



Converge it

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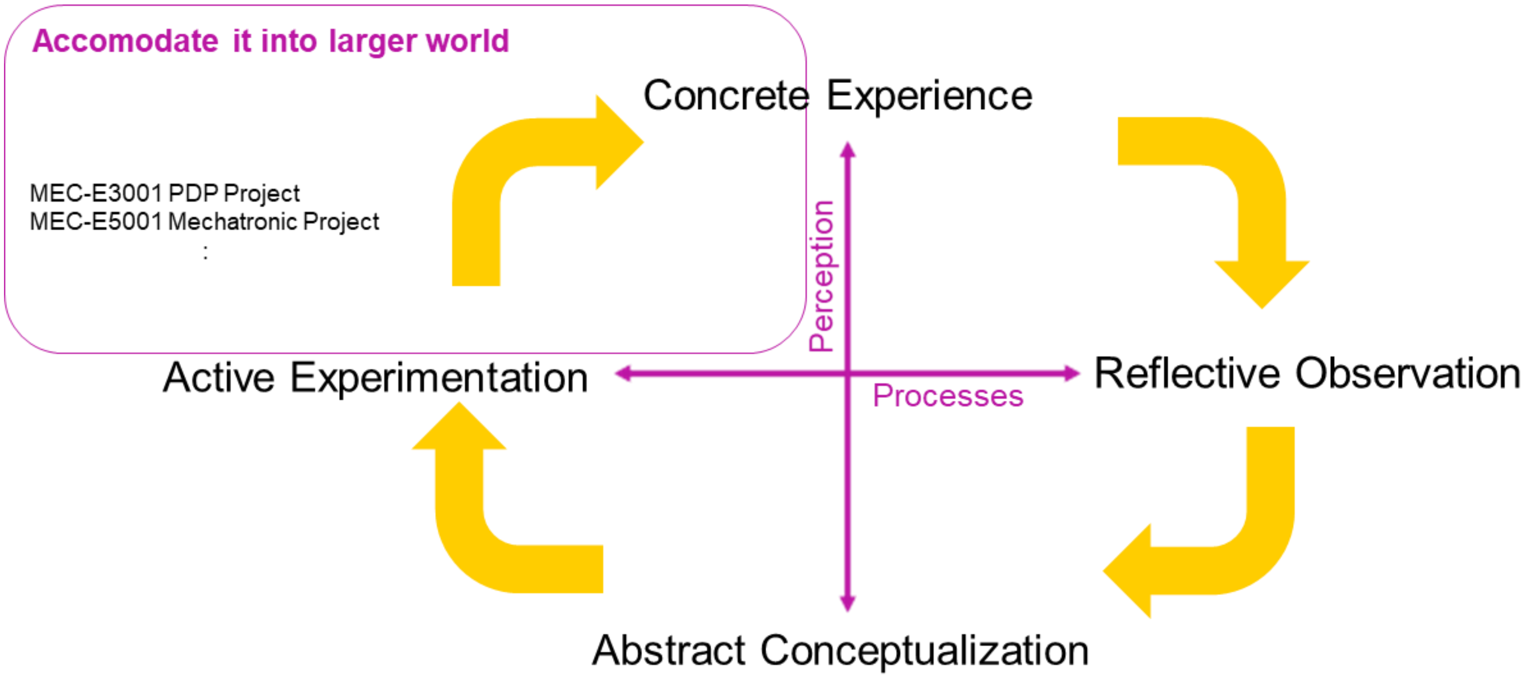
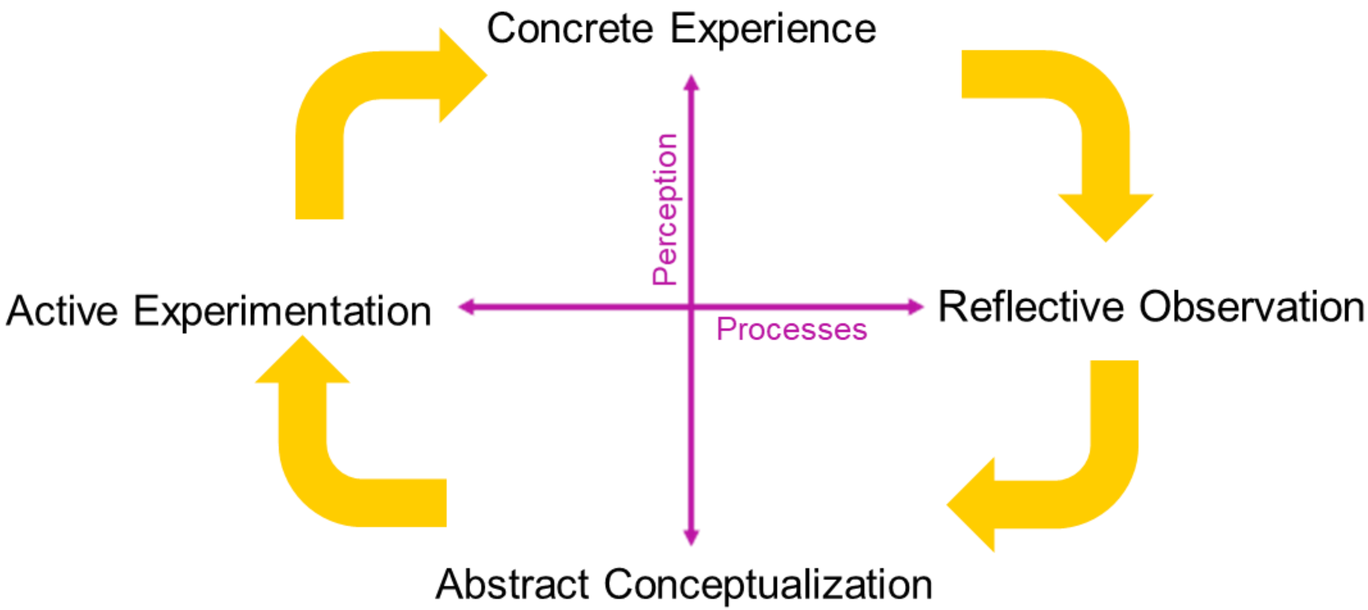
Learning pedagogy
the Kolb learning model



Learning pedagogy

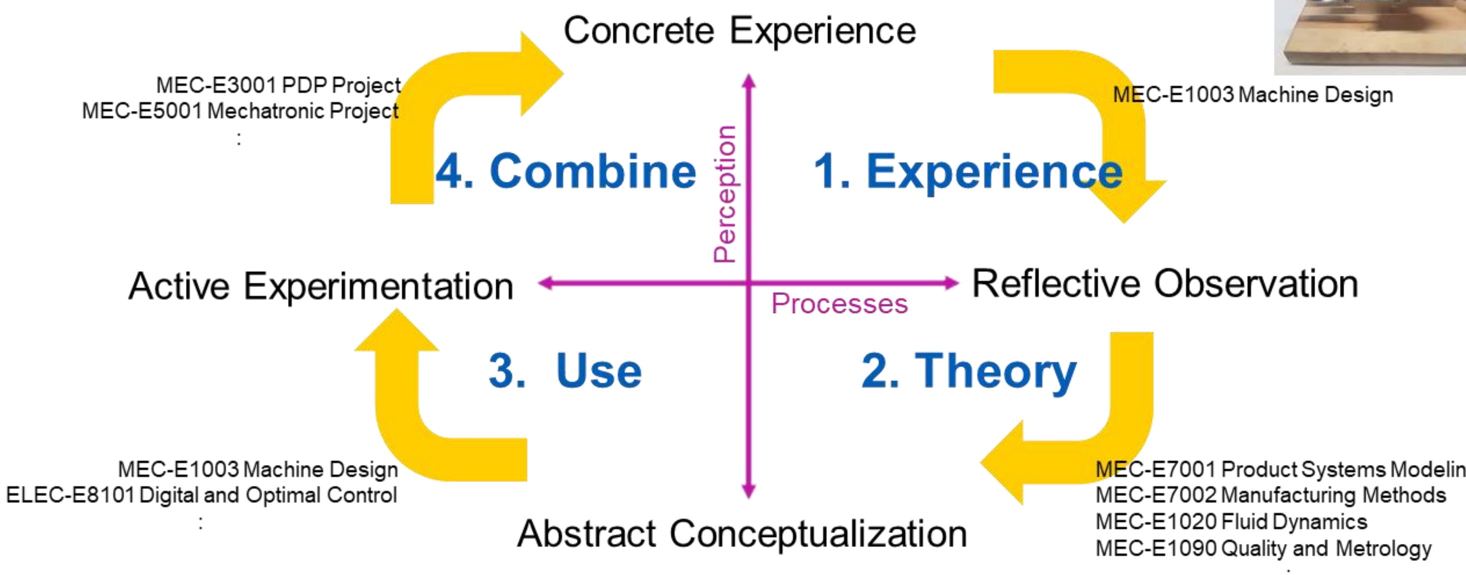
the Kolb learning model

Which do you do first?

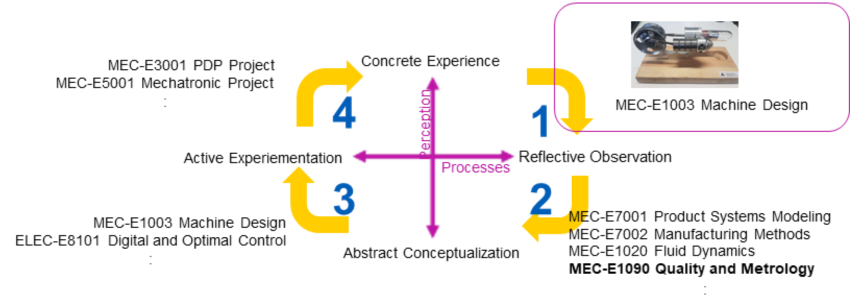


Learning pedagogy
the Kolb learning model

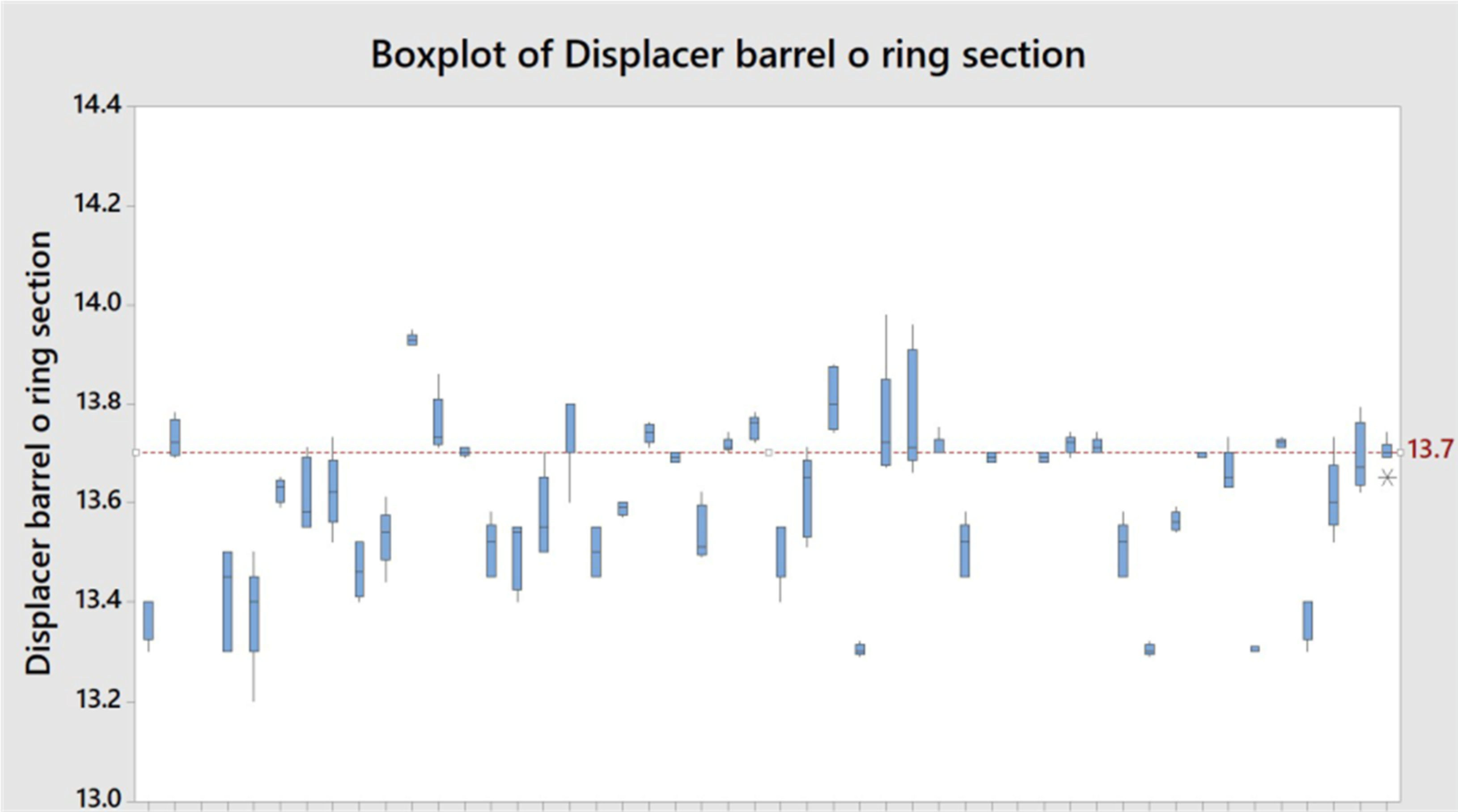
Learning is best when first *experienced*.



There is always a first time for everything

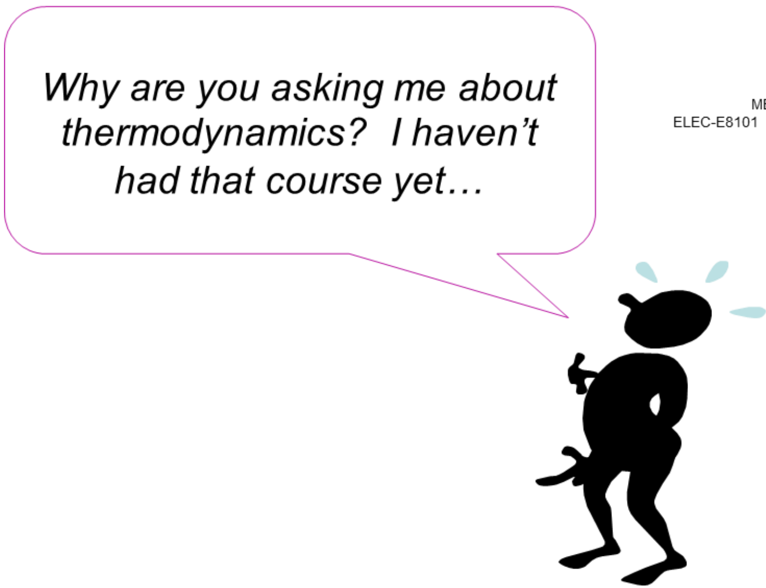


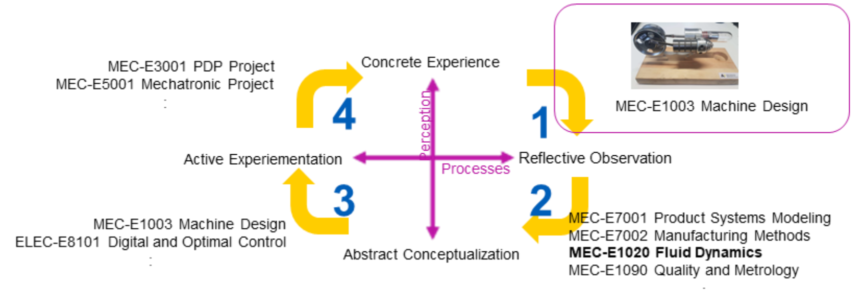
Why are you making us take all of these measurements?



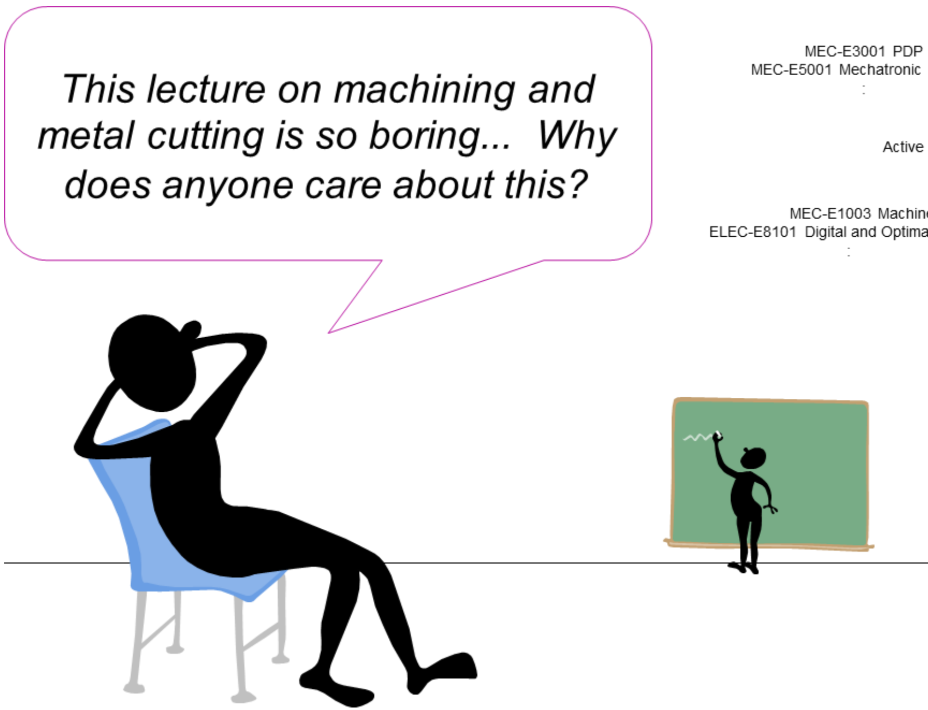
Boxplot of Displacer barrel o ring section
Displacer barrel o ring section
14.4
14.2
14.0
13.8
13.6
13.4
13.2
13.0
13.7

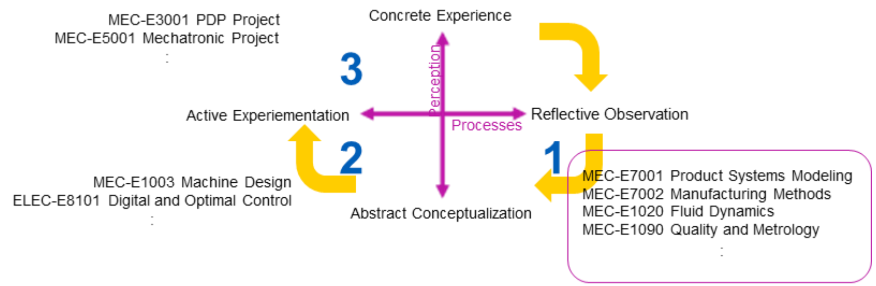
There is always a first time for everything



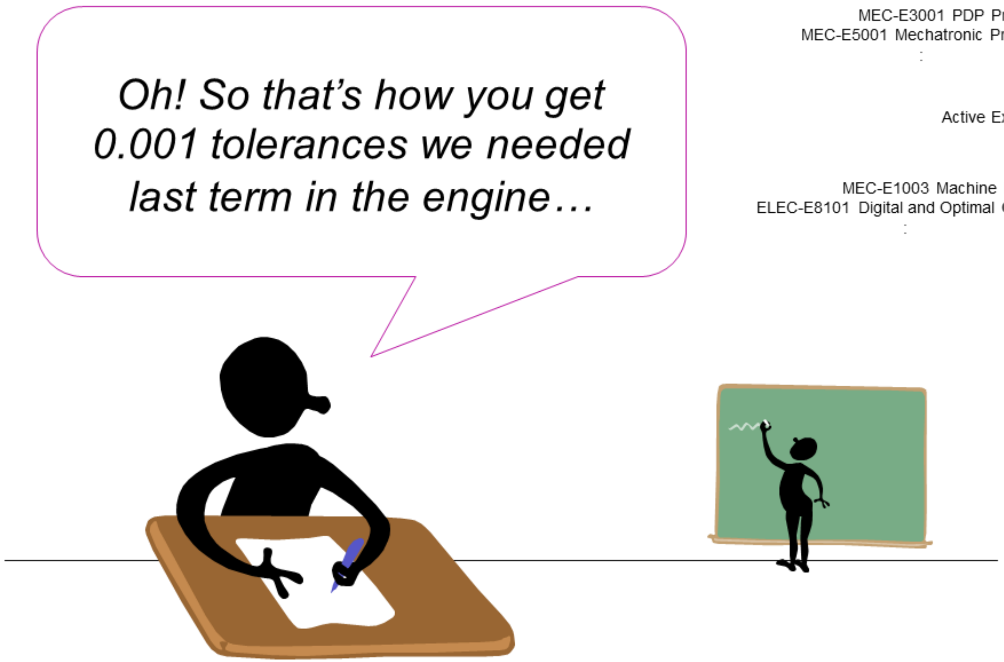


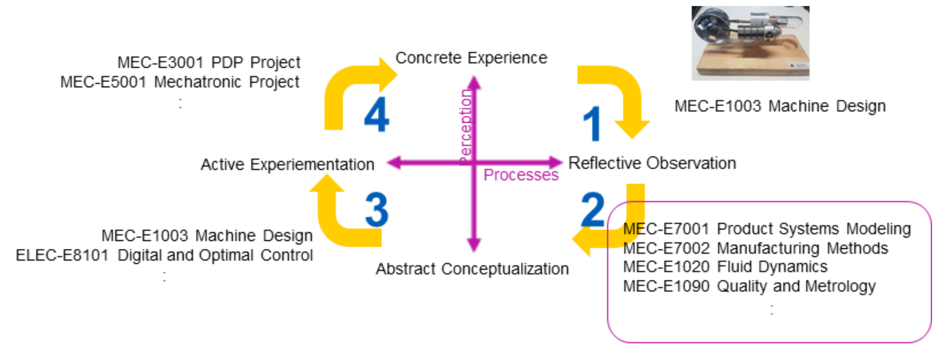
Suppose you get theory first



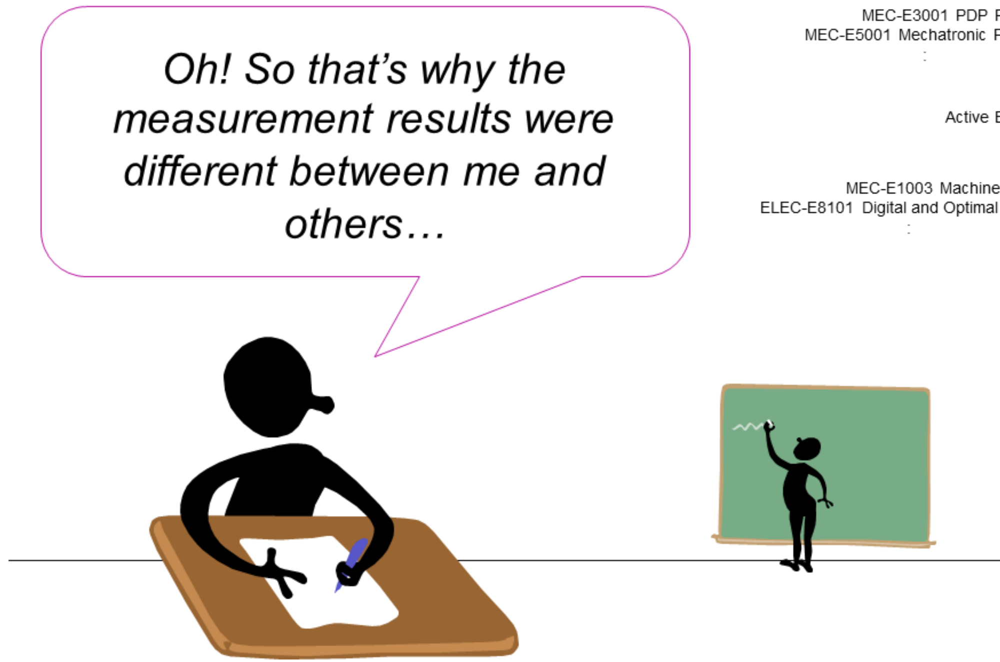


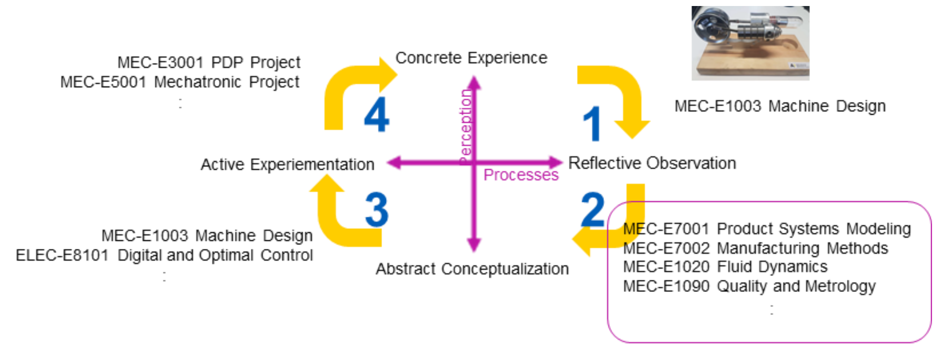
Hands-on experience





Hands-on experience

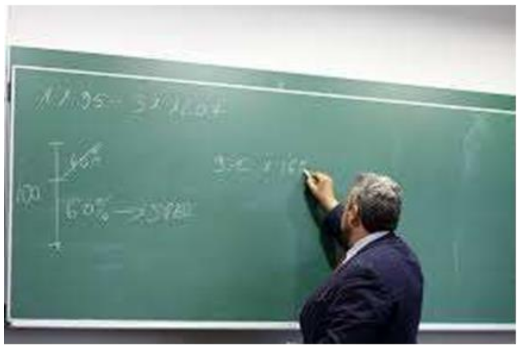




Why this starter project?

This starter project is to provide a *hands-on experience* for the basis of future courses.

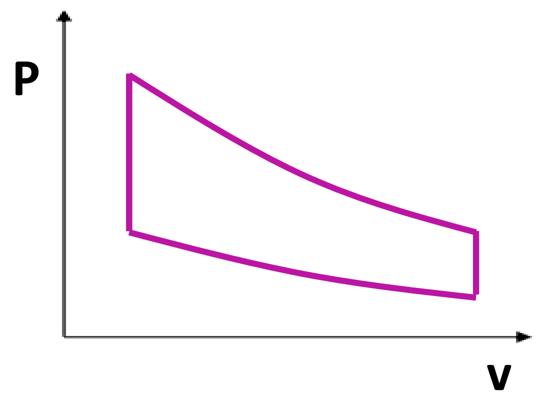
After completing the starter-project the successful student will be more comfortable designing ***machined parts and assemblies***



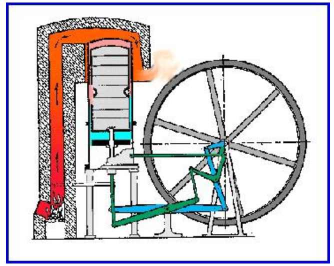
Stirling engines

A Stirling engine operates not through internal combustion, but rather from simple heat transfer.

It can approach Carnot thermodynamic efficiency.

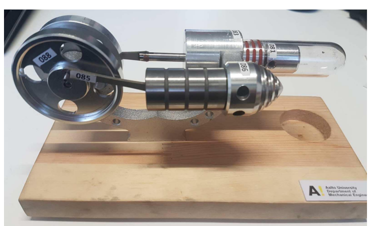


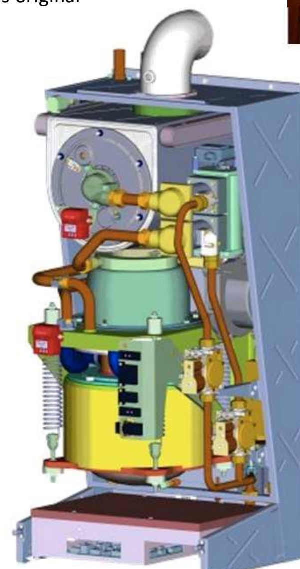
Alternative Stirling engines



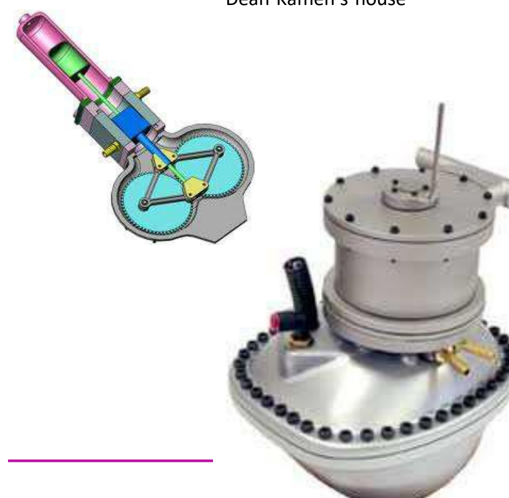
Robert Stirling's original

Dean Kamen's house



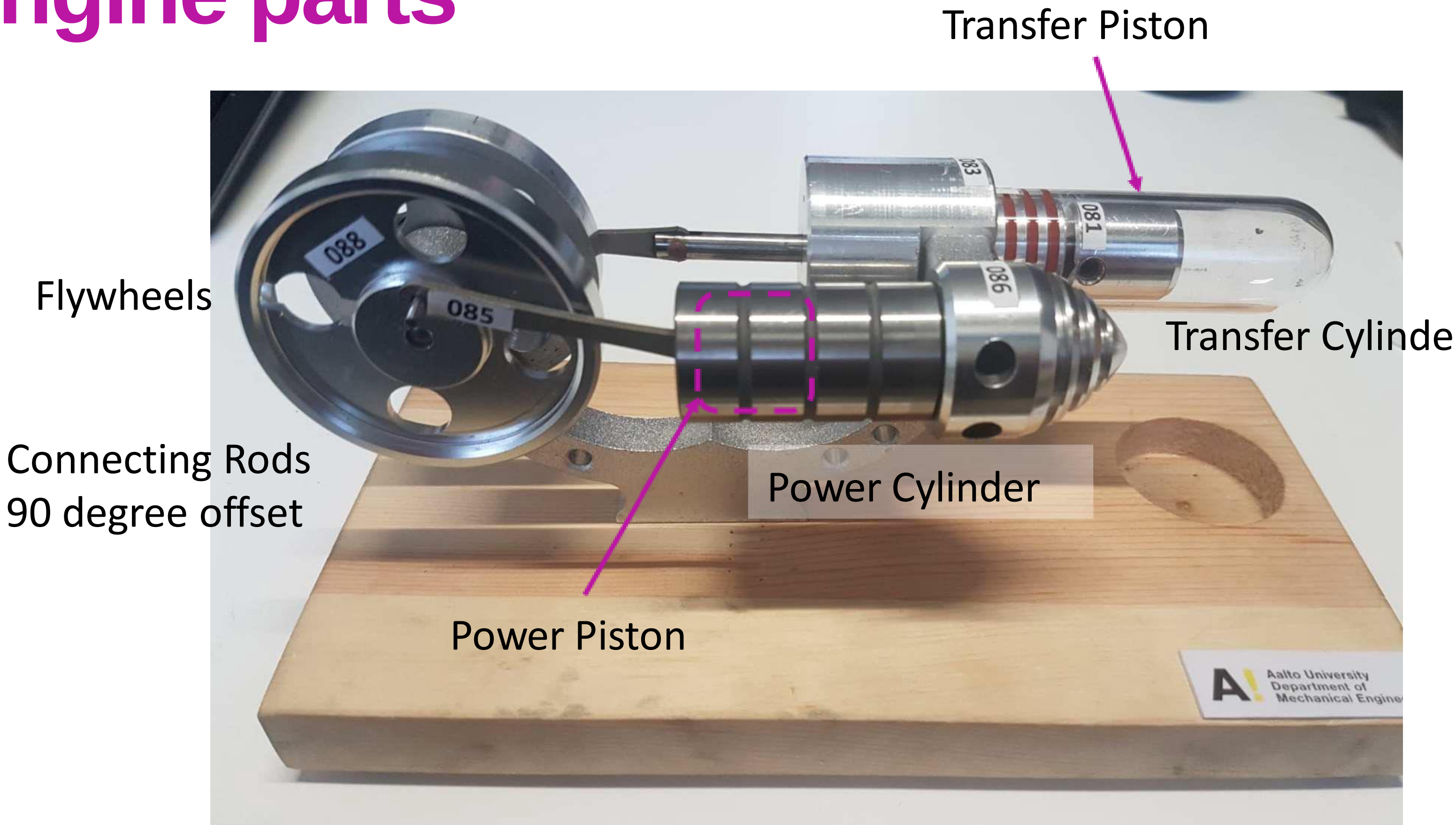


Siemens CHP design



NASA designs for space

Engine parts

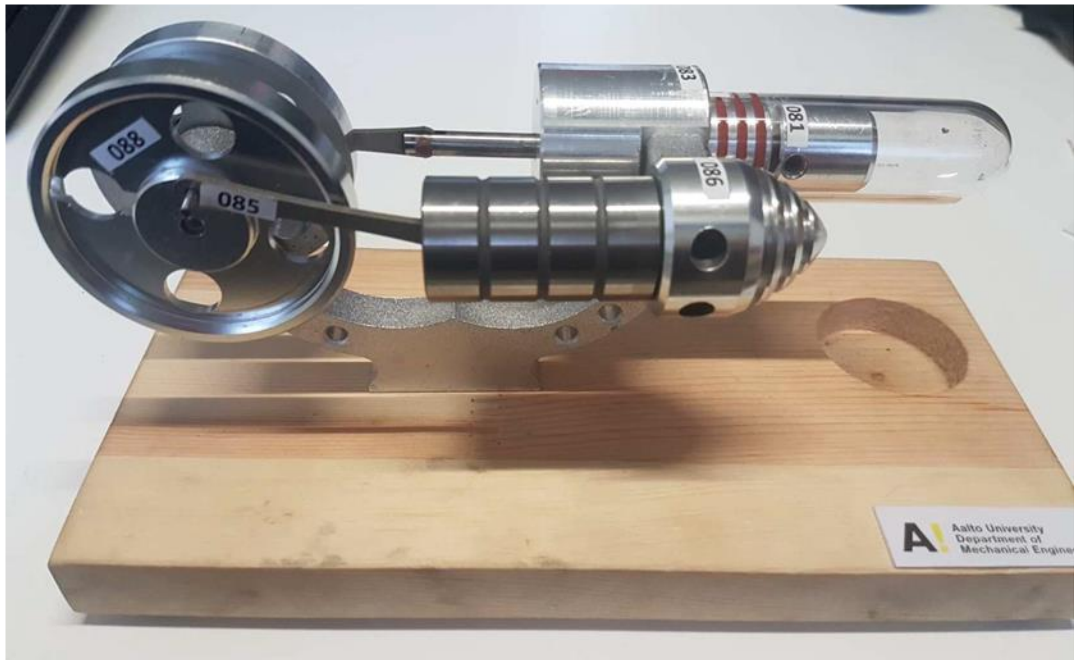


Safe operation

- **Follow the operating instructions**
- **Only operate with a fire safety certified staff member present**
- **Fill burner NO MORE THAN HALF FULL**
  - The fuel expands with temperature. Filling it full can cause it to pour out all over while burning.
  - Once spread, you cannot blow it out. Use a fire blanket or let it safely burn off.
- **Ensure the wick fits snugly**
  - A loose wick draws excess fuel and spills all over.

Engine operation

Watch it spin. What makes it go?



Miniature Stirling engine

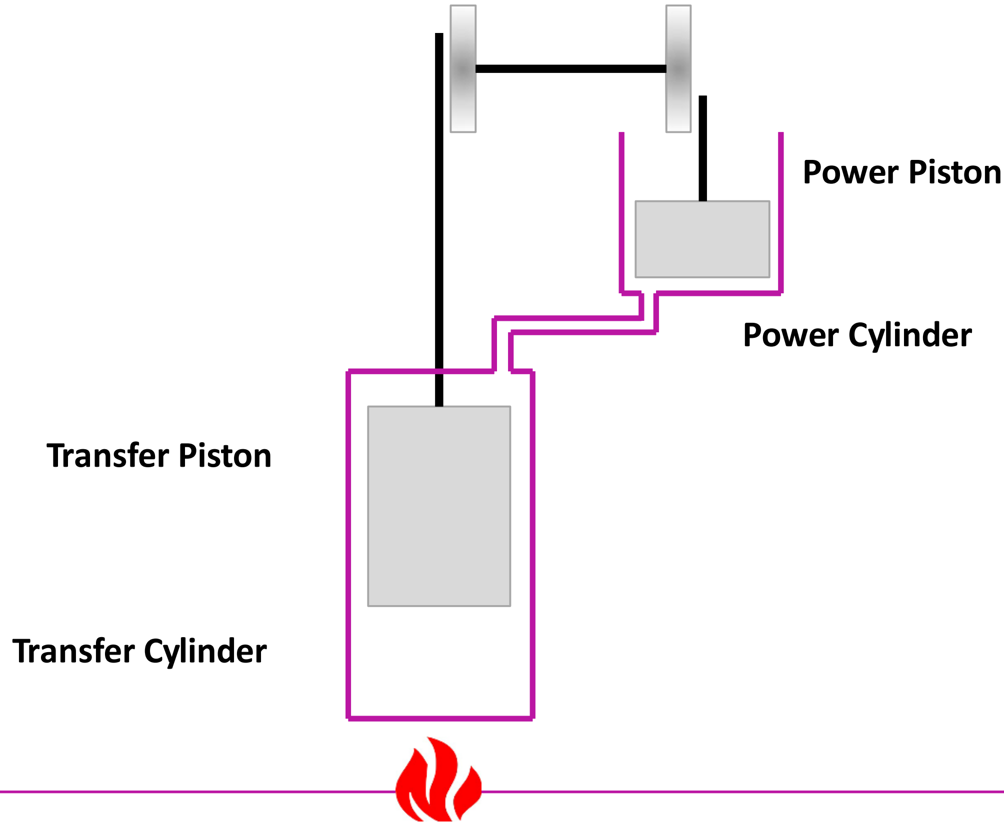
Observe it operating

Observe it operating:

- How big is it?
- What distance does each piston move?
- How large is the displacer piston?
- How large is the displacer cylinder?
- How fast is it spinning?
- How loud is it?
- How hot is the hot side?
- How cold is the cold side?

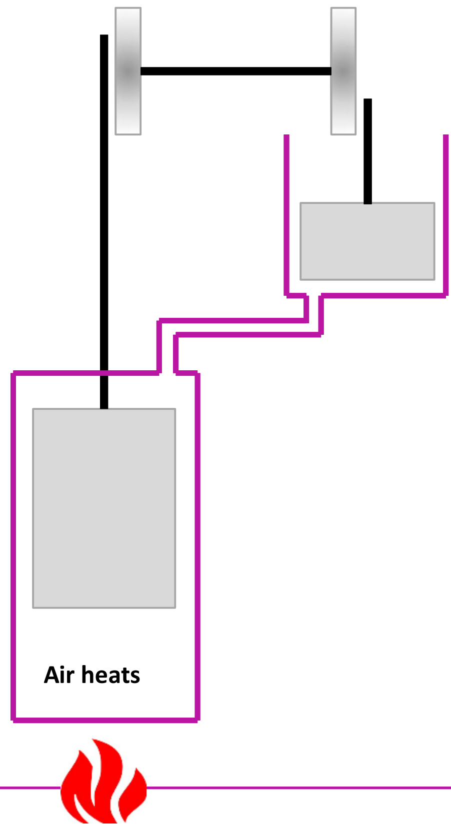
Stirling engines: How does it work?

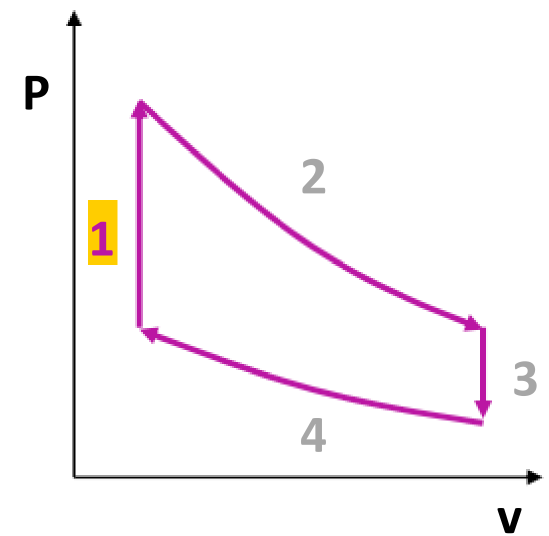
What makes it turn?



Stirling engines: How does it work?

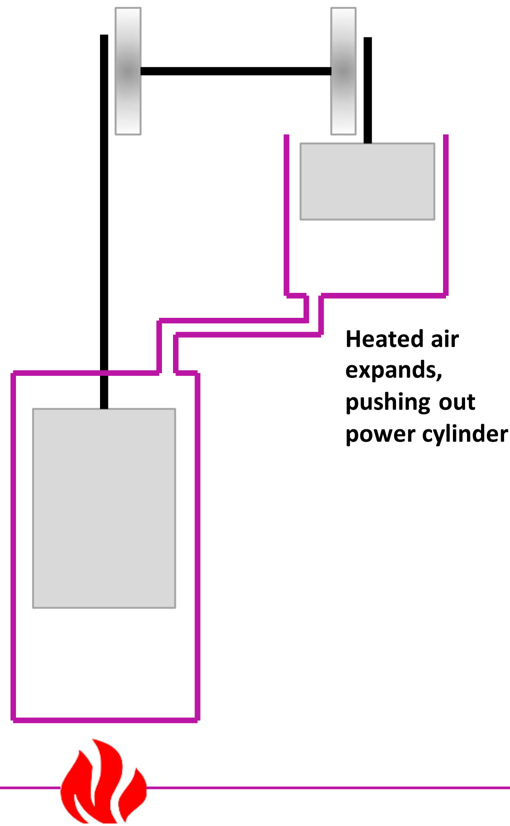
Phase 1: Heating

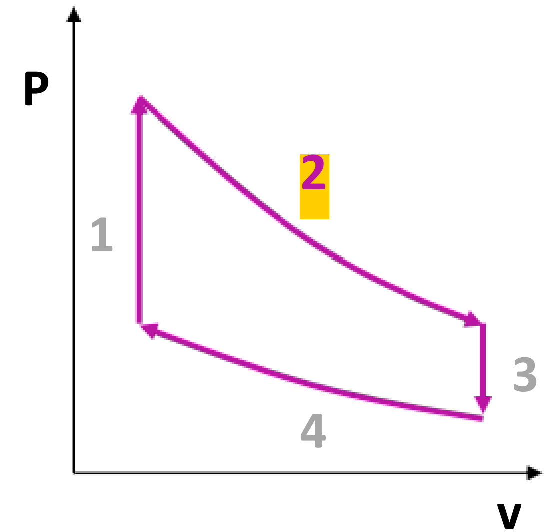




Stirling engines: How does it work?

Phase 2: Expansion

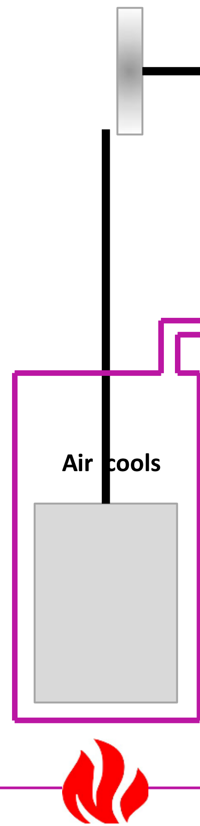


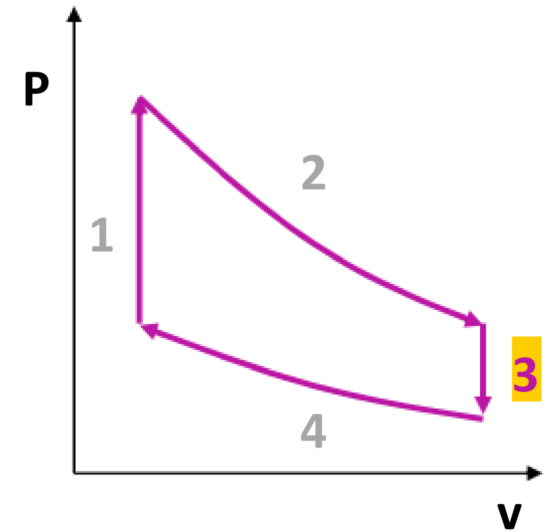


Stirling engines: How does it work?

Phase 3: Cooling

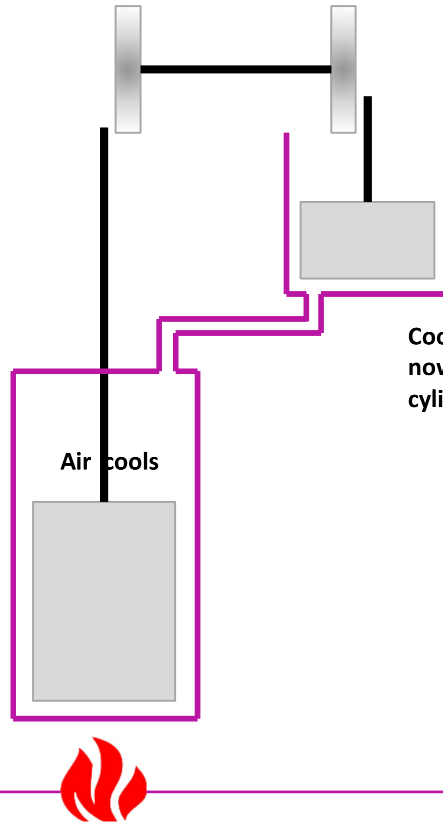
Power cylinder movement also moves transfer cylinder. Now air cools.



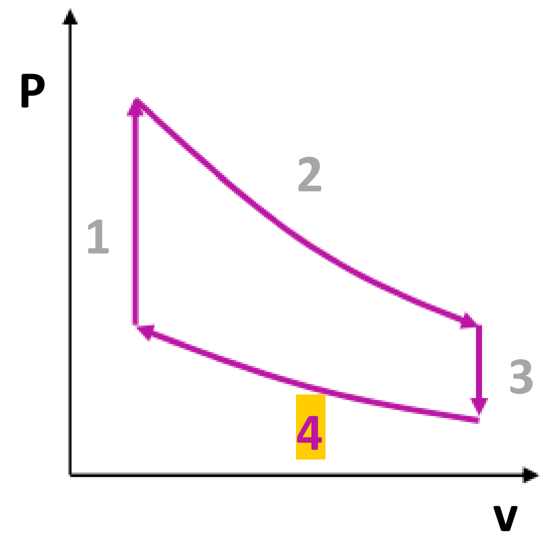


Stirling engines: How does it work?

Phase 4: Contraction



Cool air contraction now pulls power cylinder back.



Stirling engines: How does it work?

The result is motion from heat!

Engineering design

This is a machine design project course

- As a ***mechanical engineering designer***, what is your job?

- What do you do?

- What are your deliverables?

Engineering design

This is a machine design project course

- As a ***mechanical engineering designer***, what is your job?
- What do you do?
- What are your deliverables?
- ***Machines!***

Engineering design

This is a machine design project course

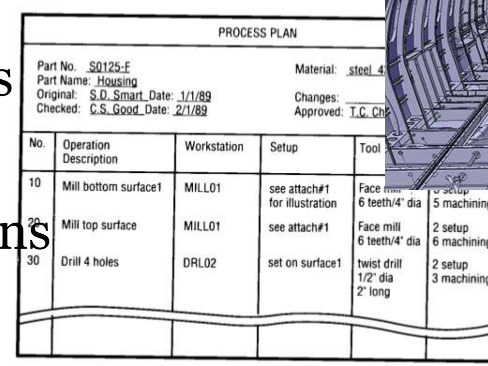
- As a ***mechanical engineering designer***, what is your job?
- What do you do?
- What are your deliverables?
- ~~***Machines!***~~

Engineering design

This is a machine design project course

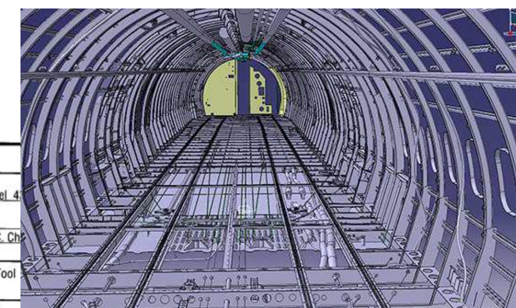
- As a ***mechanical engineering designer***, what is your job?

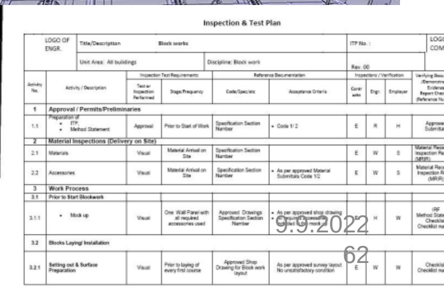
- **Your deliverables are the *design documentation* for machines**
  - Bill of Materials
  - CAD models
  - Supplier specifications
  - Assembly process specifications
  - Inspection specifications
  - System compliance specifications


PROCESS PLAN

Part No. S0125-F
Part Name: Housing
Original: S.D. Smart Date: 1/1/89
Checked: C.S. Good Date: 2/1/89
Material: steel 4
Changes:
Approved: T.C. Ch

No.	Operation Description	Workstation	Setup	Tool	
10	Mill bottom surface1	MILL01	see attach#1 for illustration	Face mill 6 teeth/4" dia	5 machining
20	Mill top surface	MILL01	see attach#1	Face mill 6 teeth/4" dia	2 setup 6 machining
30	Drill 4 holes	DRL02	set on surface1	twist drill 1/2" dia 2" long	2 setup 3 machining





Aalto University
School of Engineering

Design documentation

In this project course, you will be required to deliver design documentation for your main course project

In this Stirling engine starter project, *you will not*.

You will be *given* the design documentation.

Here, you are *not* the designer.

Here you are the supplier.

Here you are the manufacturer.

Here you are the quality control engineer.

Design documentation

In this project course, you will be required to deliver design documentation for your main course project

You will be provided an example of good design documentation.

- Bill of Materials
- CAD models
- Supplier specifications
- Assembly process specifications
- Inspection specifications
- System compliance specifications


MECE-E1003
MACHINE DESIGN PROJECT

Stirling Engine Starter Project

Laboratory Guide

Aalto University
School of Engineering
Department of Mechanical Engineering

Part inspection

As part of this course starter project, you will practice measurement inspection:

Prove a part is as it should be

Part inspection

As part of this course starter project, you will practice measurement inspection.

How accurate is a digital caliper?

Its resolution is to 0.01mm

Part inspection

As part of this course starter project, you will practice measurement inspection.

How accurate is a digital caliper?

Is it calibrated exactly, or does it indicate slightly smaller or larger than actual?

Part inspection

As part of this course starter project, you will practice measurement inspection.

How accurate is a digital caliper?

Will it read the same tomorrow as today?

Will it read the same if you measure or I measure?

Part inspection

As part of this course starter project, you will practice measurement inspection.

How accurate is a digital caliper?

Measurement *repeatability* is the variation you get when you measure the same part dimension by the same person with the same measuring device and setup

Part inspection

As part of this course starter project, you will practice measurement inspection.

How accurate is a digital caliper?

Measurement *reproducibility* is the variations you get set up the device, take a measurement, then turn off the device and another person takes a subsequent measurement

Summary

This course is about machine design.

This starter project demonstrates good design

- Observe machine design principles
- Observe mechanical design documentation

This starter project prepares you to do good design

- Quality inspection experience
- Mechanical assembly experience

With this background, you will begin to understand the skills needed for good machine design.