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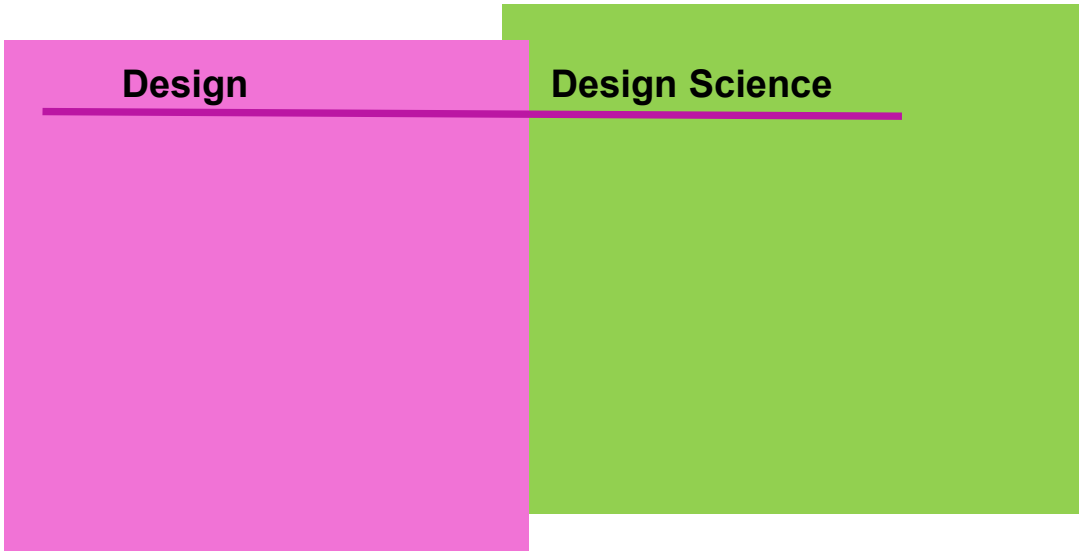
MEC L1001 Design Science

Introduction

What is…



Learning Objectives:

By the end of the course, students will be able to:

- **Develop a general understanding of the field of design science and, associated, design research**
- **Ability to apply advanced design science methods and principles**
- **Ability to formulate design science hypotheses and experimental methods**
- **Ability to abstract design principles from certain fields and apply them to other areas, fields or design problems**

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Schedule and Learning Objectives

		Topic
Wed	06.02.2019	Design Science – discuss papers
Wed	13.02.2019	Needfinding – discuss papers, identify open areas, propose means to test
Wed	20.02.2019	Winter break
Wed	27.02.2019	Creativity – discuss papers, identify open areas, propose means to test
Wed	06.03.2019	Functional thinking – discuss papers, identify open areas, propose means to test
Wed	13.03.2019	System Architecture/Modularity – discuss papers, identify open areas, propose means to test
Wed	20.03.2019	Project check in
Wed	27.03.2019	Prototyping – discuss papers, identify open areas, propose means to test
Wed	03.04.2019	Introduction to paper writing task + discuss finding good and bad papers on Design
Wed	10.04.2019	Discussion on what makes for a good/bad paper and why, initial review of writing task plan
Wed	17.04.2019	Close to easter, no class?
Wed	24.04.2019	Paper writing, editing, etc.
Wed	01.05.2019	Wappu holiday, no class
Wed	08.05.2019	Paper presentation, debate etc. + Projects due

Learning objectives:

- Develop a general understanding of the field of design science and, associated, design research
- Ability to apply advanced design science methods and principles
- Ability to formulate design science hypotheses and experimental methods
- Ability to abstract design principles from certain fields and apply them to other areas, fields or design problems

30.1.2019

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Where?

Ke 30.1, Puuhamaa, 14-17
Ke 6.2, EngineRoom, 14-17
Ke 13.2, EngineRoom, 14-17
Ke 27.2 EngineRoom, 15-18
Ke 6.3, EngineRoom, 14-17
Ke 13.3, Puuhamaa, 14-17
Ke 20.3, EngineRoom, 14-17
Ke 27.3, EngineRoom, 14-17
Ke 3.4, EngineRoom, 14-17
Ke 10.4, EngineRoom, 14-17
Ke 17.4, EngineRoom, 14-17
Ke 24.2, EngineRoom, 14-17
Ke 1.5, EngineRoom, 14-17
Ke 8.5, EngineRoom, 14-17

Grading

Quizzes	**20%**	- Check basic understanding of class pre-reading
Project	**30%**	- Individual project
Paper	**30%**	- Team paper writing task
Class Participation	**10%**	- your participation is class discussion and other activities
Time keeping journal	**10%**	- next slide

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Workload estimation

Weeks	12			
lectures	3	36		
Homework/readings	2	24		
project	40	40		
paper	40	40		
		140		
No hw 1st week, so				138
and no lectures last week (count toward paper)				**135**

Time keeping journal 10% - keep a simple journal to estimate your time usage every week. Use it to plan your own work and help me plan the course better for next time. Graded pass/fail.

What is…

Science

- Research is the process of finding something out that we don't already know
- Scientific research builds on the existing knowledge base and is repeatably verifiable

Design Science

- Design research is the process of finding something out about design that we don't already know
- Design Science builds on the existing knowledge base about design and is repeatably verifiable

Some definitions

Engineering design research is the instrument of exploration, description, arrangement, rationalization, and utilization of design knowledge (Pugh 1990)

Design research aims at increasing our understanding of the phenomena of design in all its complexity and at the development and validation of knowledge, methods, and tools to improve the current situation in design (Blessing 2002)

Pugh, S. (1990) Engineering Design – unscrambling the research issues. Research in Engineering Design 1(1):65-72

Blessing L. (2002) What is this thing called design research? In: Proceedings of the 2002 international CIRP design seminar, Hong Kong, 16-18 May 2002, pp. 1-6.

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What is a Design Process?

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Name Design Methods

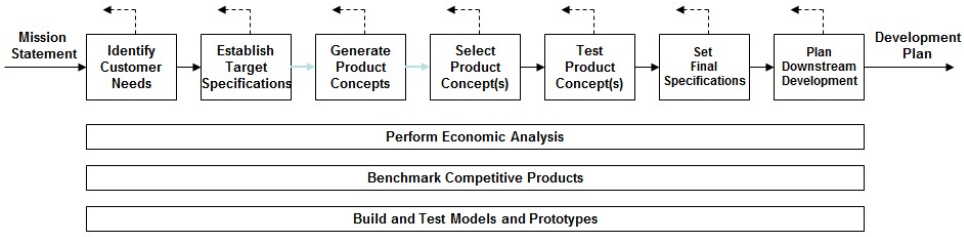
Understanding **Development** **Realization**

C **Conceive:** the first phase where new ideas develop and overall perspectives and problems are identified.

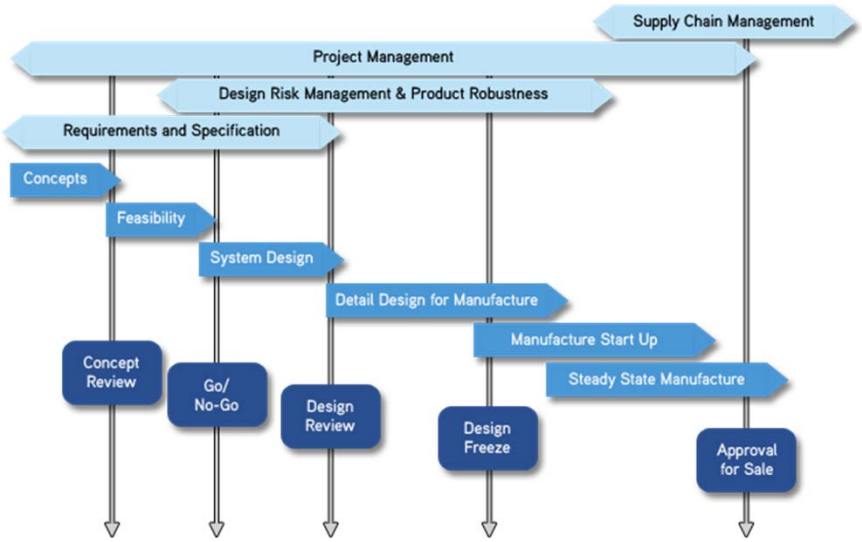
D **Design:** the design phase where you produce a solution to the problem.

I **Implement:** the phase where you structure the project or create the process so that the solution can be realized.

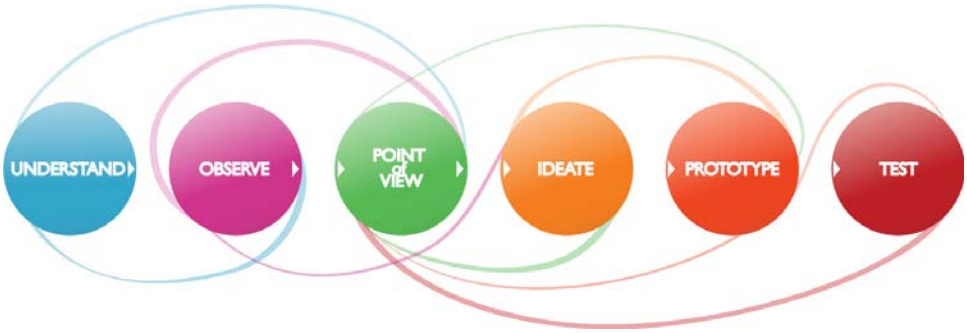
O **Operate:** the final phase where you apply the solution to the problem in practice.



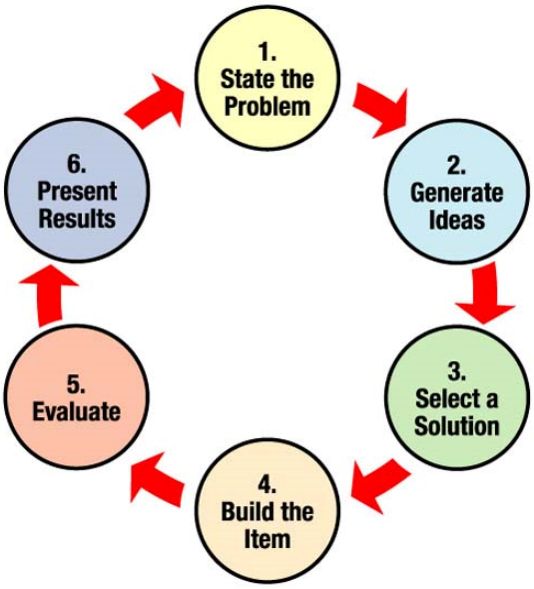
Ulrich & Eppinger: Product Design and Development



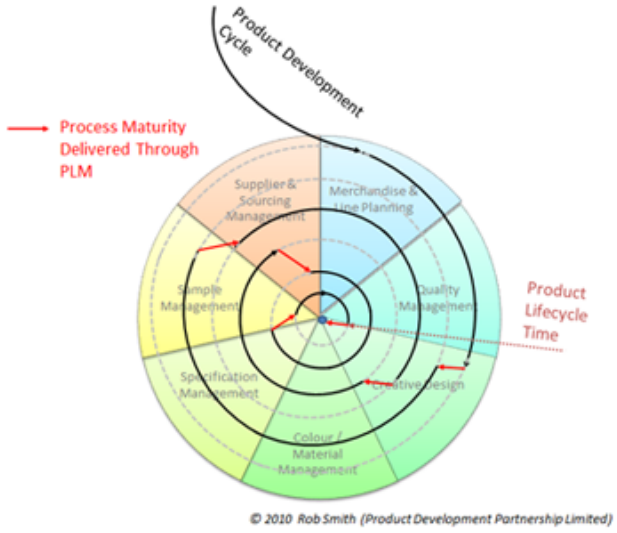
http://www.wide-blue.com/resources.php

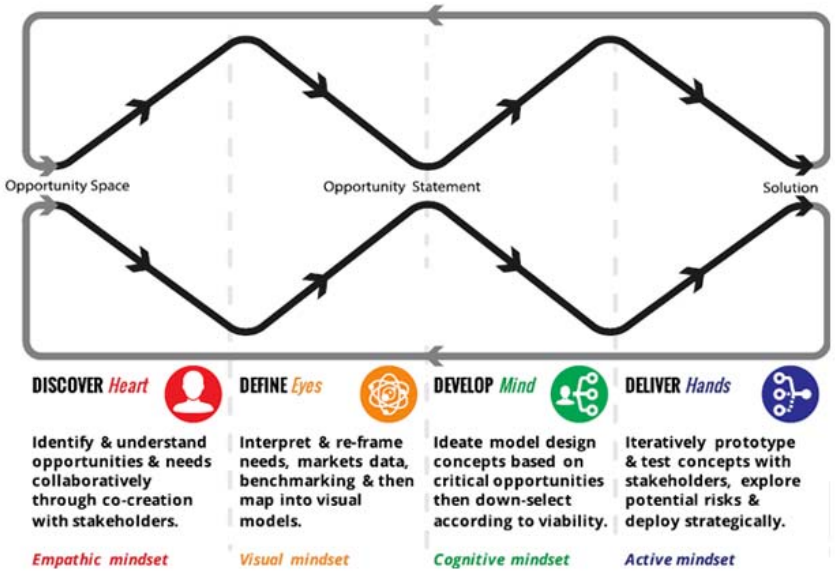


https://dschool.stanford.edu/groups/k12/wiki/17cff/



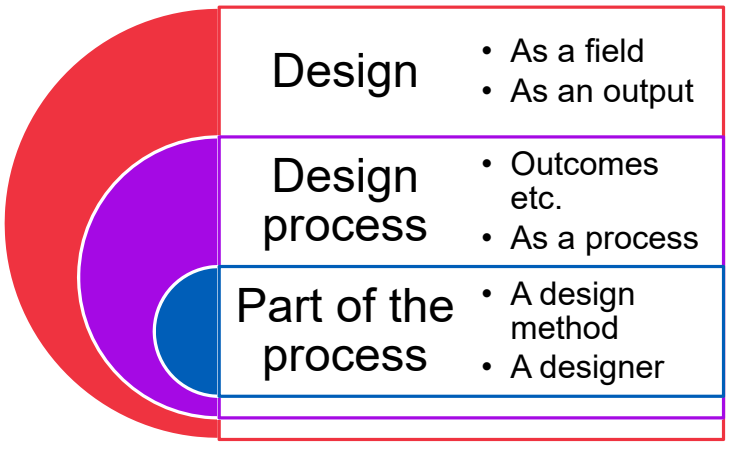
http://www.nasa.gov/audience/foreducators/plantgrowth/reference/Eng_Design_K4.html





www.sutd.edu.sg

Scales of Investigating Design



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Design Methods as part of Design process

- Understanding
  - Observations
  - Customer interviews
  - Etc.
- Development
  - Functional thinking
  - Idea generation
  - Product architecture development
  - DFX
  - Etc.
- Realization
  - Initial low-fidelity models
  - Prototypes
  - Etc.

Science, Mathematics, and Engineering Design

Methods of Science and Mathematics Compared to Engineering		
Design **Scientific Process**	**Design Process**	**Mathematics Process**
Identify a testable question clarify question research state of knowledge **Generate an hypothesis** **Develop operational definitions** **Design a method to test the question** **Collect materials** **Carry out the test** **Evaluate results** **Conclude** answer the testable question **Add to knowledge base**	**Identify the problem** clarify task assess customer needs research state-of-the-art **Develop specifications** identify functional requirements identify constraints **Conceptualize** analyze and develop sub-systems evaluate ideas against specifications make preliminary sketches evaluate and refine select best idea **Plan and select materials** **Produce** **Evaluate and test feasibility** **Modify** **Reflect** **Add to state-of-the art**	**Identify the problem** what is the "issue"? how can mathematics be applied to help solve the problem? **Clearly identify the given data, known information, and unknowns** **Determine the mathematics of the situation** what concepts are in the problem? develop alternative strategies and approaches for formulating as a mathematical problem **Organize the information into a mathematical problem(s).** **Solve the problem. Check result.** **Evaluate results** how does your solution address the issue? does it make sense? **Add to knowledge base**

Homework

Readings – Find the following 3 papers, read them and be ready to discuss (Quiz!)

Horvath, I. (2004). A treatise on order in engineering design research. *Research in Engineering Design*, *15*(3), 155-181.

Hevner, A. R. (2004). DESIGN SCIENCE IN INFORMATION SYSTEMS RESEARCH. *MIS Quarterly*, *28*(1), 75-105.

Chakrabarti, A., & Blessing, L. (2016). A review of theories and models of design. *Journal of the Indian Institute of Science*, *95*(4), 325-340.

But before we go…

Introduction to Project

Alone … ~40 hours of work … 2 options:

Design Project - preferred

- Select one in depth method (to be) covered in class
- Apply it to a real industry or technology development project
- Report (follow scientific report writing, e.g. IMRAD-structure)

Reverse Engineering Project

- Apply all methods as a thought process to a single device (e.g. toaster)
- Report (follow scientific report writing, e.g. IMRAD-structure)

Design Project

- **Select one in depth method covered in class**
  - Follow the method exactly as described, reproduce research
- **Apply it to a real industry or technology development project**
  1. You may apply it in your company OR
  2. Katja has identified a few Aalto tech development projects you can work with OR
  3. You can also source your own projects
  - Have Katja approve project before proceeding to ensure it is a proper fit for the course
  - Results need to be sharable at least in this class
- **Report (follow scientific report writing, e.g. IMRAD-structure)**

Reverse Engineering Project

- **What is reverse engineering**

  Definition: Reverse engineering initiates the redesign process, wherein a device is predicted, observed, disassembled, analysed, tested, 'experienced,' and documented in terms of its functionality, form physical principles, manufacturability and assemblability (Otto & Wood 1996, ASME DTM)

  Definition: Reverse engineering is "the in-depth study and analysis of an existing product to recreate the design decisions and information developed by the original design team." (Gabriele, G. A. RPI, New York)
- **Apply all methods (mostly) as a thought process to a single device (e.g. toaster)**
  - Obtain a simple electro-mechanical device, where it is easy to see what the product does and how and one that has screws on it so that you can open it up to see what is inside. Do NOT plan on using the device after tearing it down.
- **Report (follow scientific report writing, e.g. IMRAD-structure)**

Project areas

Marine Tech
Medical Device Design (ELEC)
Mechatronics
(Your own)

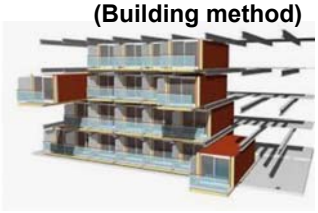
Each area has potential for more than one project as long as they are different from one another.

Ultra-lightweight design of living quarters of experience-liners

Design approaches, criteria and tools (technical, economical, esthetic)

From traveling to cruising to experiencing

Industrial Implementation (Building method)



Creativity and Paradigm Shift (Lightest possible structure)

Technology Barriers (Learning from failures)

Prosthetic wrist

Figure 1 – LEFT: testing of the two DoF controller in the virtual reality through a set of multi-DoF tasks. RIGHT: testing of the system with the patient using a prototype wrist system, which seems to be too bulky for a prolonged use.

We have designed, implemented and preliminarily tested a simultaneous and proportional controller for two degrees of freedom (DoF) articulation of a prosthetic wrist (patent pending). This controller extracts information from the reminiscent muscle activity (electromyography – EMG) of the stump and translates it into estimated wrist joint angles. We have so far mapped these estimates into virtual reality environments and robotic arms, but no commercially available system is able to deliver the functionality needed to support this type of control. We are looking after designing a multi-DoF, lightweight, compact actuated robotic wrist that will maximize user experience by making the most out of the unique controller that we have

To do so we will need to:

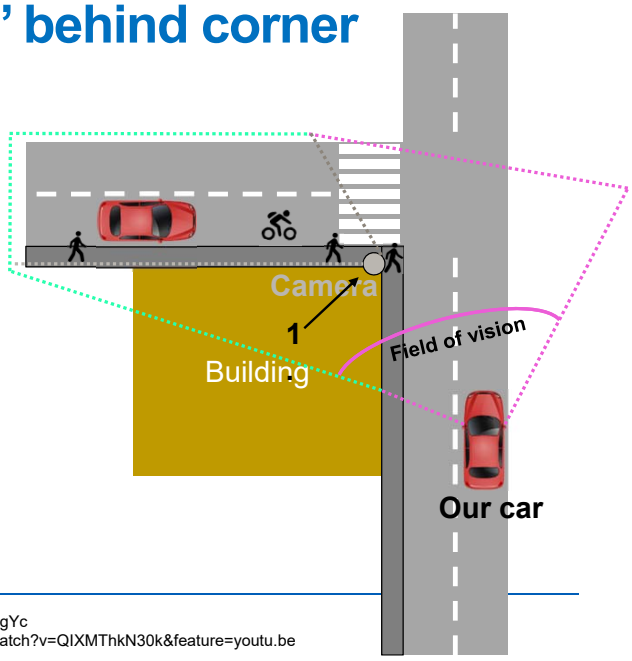
- Understand the user priorities and needs
- Come up with compact and lightweight design with sufficient functionality
- Devise the best simulation (VR) and lab-based validation scenarios
- Understand the competition and the target compatible systems

Figure 2 - The latest prototype of the two DoF (flexion/extension and rotation) wrist unit. The system turned out to be light though too long and consequently fragile.

Our initial work has been motivated directly by users who were personally complaining to us about the shortcoming of their devices. Most of the devices are either not featuring any wrist unit or if there is one it is either passive or requiring an elaborate activation scheme. Once we have solved the controller side, we have realized that the existing wrist units feature only a single DoF or are too bulky limiting the user pool that can benefit from having it. We have done some preliminary designs, however traditional approaches seem to result in either fragile or less than compact structures.

‘X-ray vision’ to ‘see’ behind corner

- Machine Vision (MV) camera (1) is installed in the infrastructure
- Traffic user recognition (cars, cyclists, pedestrians)
- The location of the users can be calculated with MV algorithm
- The users are shown to the driver of “our car” on a screen, creating a sort X-ray vision through the building



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X-ray vision: https://www.youtube.com/watch?v=P13Jz691gYc
EV rally Helsinki-Monte Carlo: https://www.youtube.com/watch?v=QIXMThkN30k&feature=youtu.be

Questions – X-ray vision

How to convey info to car driver?
How to convey into to other road users?
What type of user interfaces are good?

More general questions (and possibly other project)
State-of-the-art user interfaces in passenger cars?
And how the should look like?

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Vehicle Interfaces

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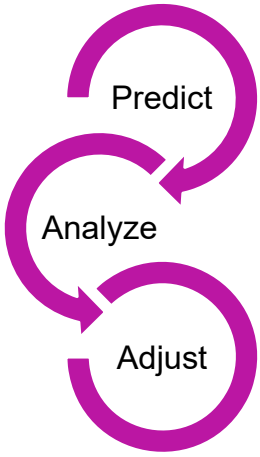
Reverse Engineering steps



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Reverse Engineering - Predict

Identify the main function of the product – what does it do? Why does it exist?

Use/Experience the product

Predict the customer needs, what customer needs is the design addressing? Other requirement is the product meeting? How is it different from competition?

How does the product work? What are its main functions, supporting functions etc?

What assembly and manufacturing decisions were made during the design?

Is this a standalone product or part of a product family? Could you imagine evolving this into a next generation version, what would that be?

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Reverse Engineering - Analyze

Identify the main function of the product – what does it do? Why does it exist?

Use/Experience the product

Do product teardown

Apply the design methods discussed in class to the product, discuss how you think the designer made choices regarding that issue

- The methods can be applied as a thought process (i.e. no need to go to users), but you will need to do e.g. a proper functional model for your product**.**

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Reverse Engineering - Adjust

Go back and look at your original predictions and describe what was confirmed and more importantly what you added or corrected after having applied the design methods to your product.

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Reverse Engineering Project

- Apply all methods as a thought process to a single device (e.g. toaster)
- Report (follow scientific report writing, e.g. IMRAD-structure)

Plan to select your topic in 2 weeks, then budget your time for the rest.

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