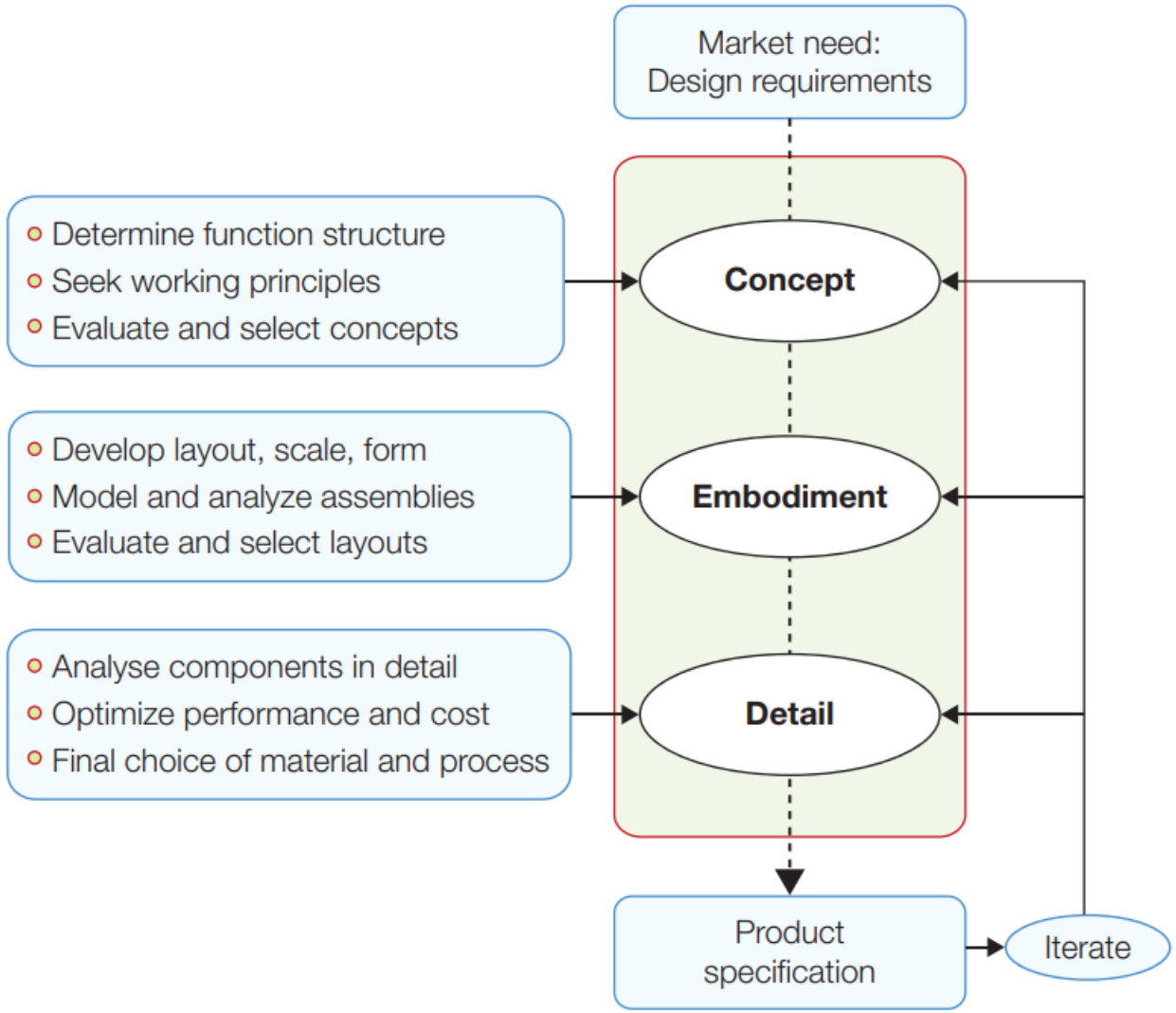
Product development & engineering design

ME-320

PROF. JOSIE HUGHES

Lecture 2: Ideation and Design Selection

Recap: Stages of Design



How do we capture, and how do we formulate a neutral problem statement.

3 key stages of design & some of the associated design methods and tools

https://ttpoll.eu/p/datadriven

Team Sign Up

Project Groups

Please create projects groups of 5 students and sign up in the sheet below providing a group name and number, names, scipers and emails of everyone is each group. If you would be prefer to be randomly allocated, please add your name, sciper and email to the columns on the right hand side of the sign-up sheet.

Deadline for signing up Tuesday September 10th at mid-day.

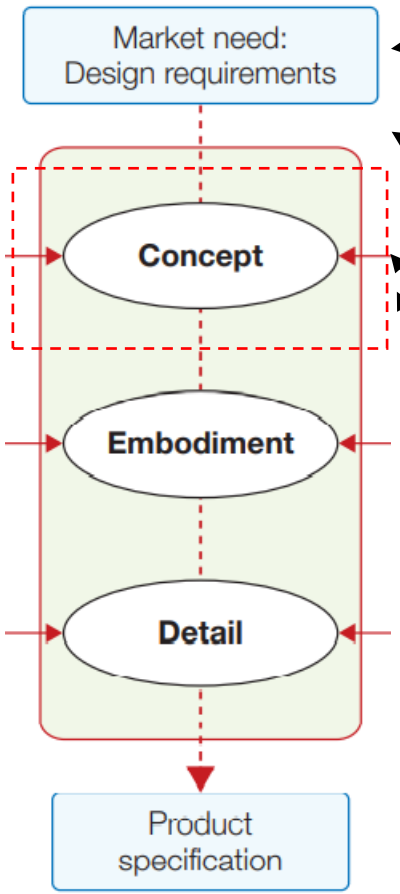
Sign up sheet:

1GiQcrJ2ttffkiwstNVEjvSFxKUSYCRr5Wniq3QOz7_c
https://docs.google.com

Connect to Google Drive to update

- Everyone who signed up has now been assigned to groups of 5
- Please everyone check you have found everyone in your groups
- Any questions/problems come and speak with me

Today's Topics: Stages of Design



What market need translates to a good product?

How do we build a specification from a market need?

How do we come up good concepts?

How do we decide which is the best solution?

This is not just an engineering challenge, but also a challenge in understanding humans, and team work.

Identifying Product Opportunities: The SET Factors

A product opportunity exists when there is a gap between

what is currently on the market…

and the possibility for new or significantly improved products …

that result from emerging trends.

Identifying Product Opportunities: The SET Factors

A product opportunity exists when there is a gap between

what is currently on the market… Current State

and the possibility for new or significantly improved products … Future State

that result from emerging trends. Current Rate of Change

How do we identify or quantify this gap?

Identifying Product Opportunities: The SET Factors

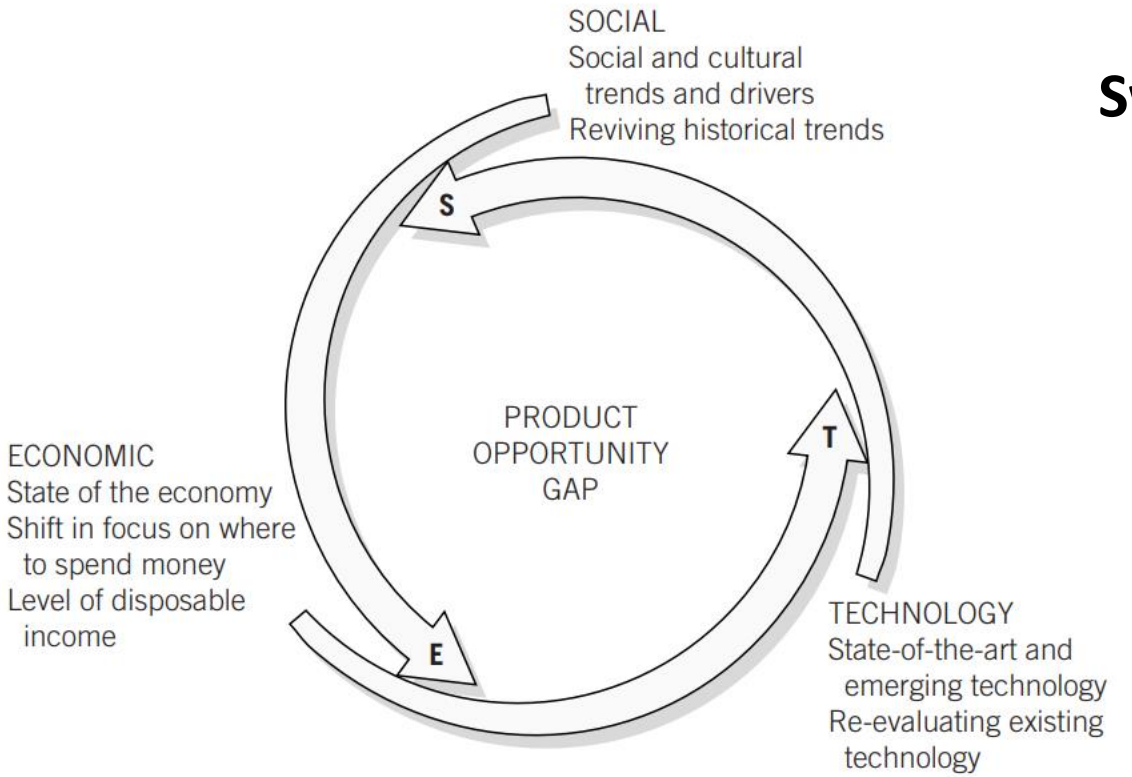


Figure 1.2 Scanning SET Factors leads to POGs.

How do we identify or quantify this gap?

Sweep a number of factors in three major areas.

- Social
- Technology
- Economic

Identifying Product Opportunities: The SET Factors

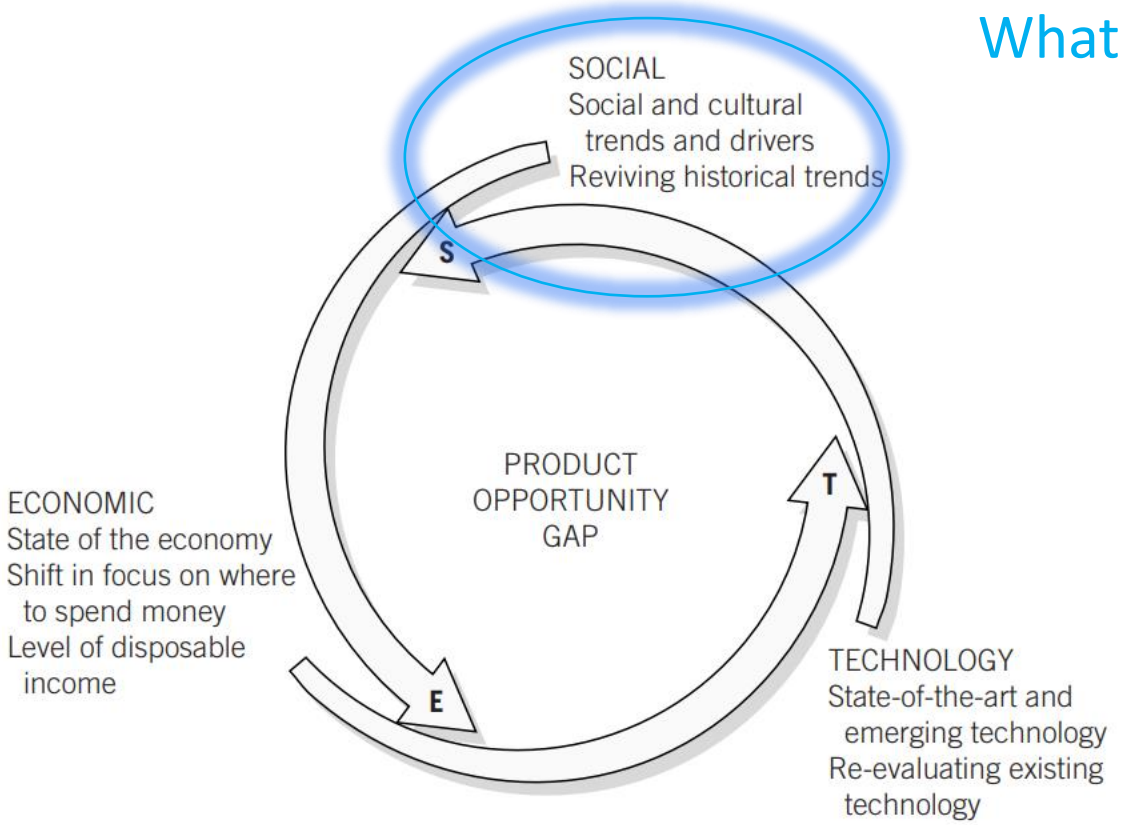


Figure 1.2 Scanning SET Factors leads to POGs.

What **Social** factors could affect product opportunity?

Identifying Product Opportunities: The SET Factors

Requires a constant sweep of a number of factors in three major areas.

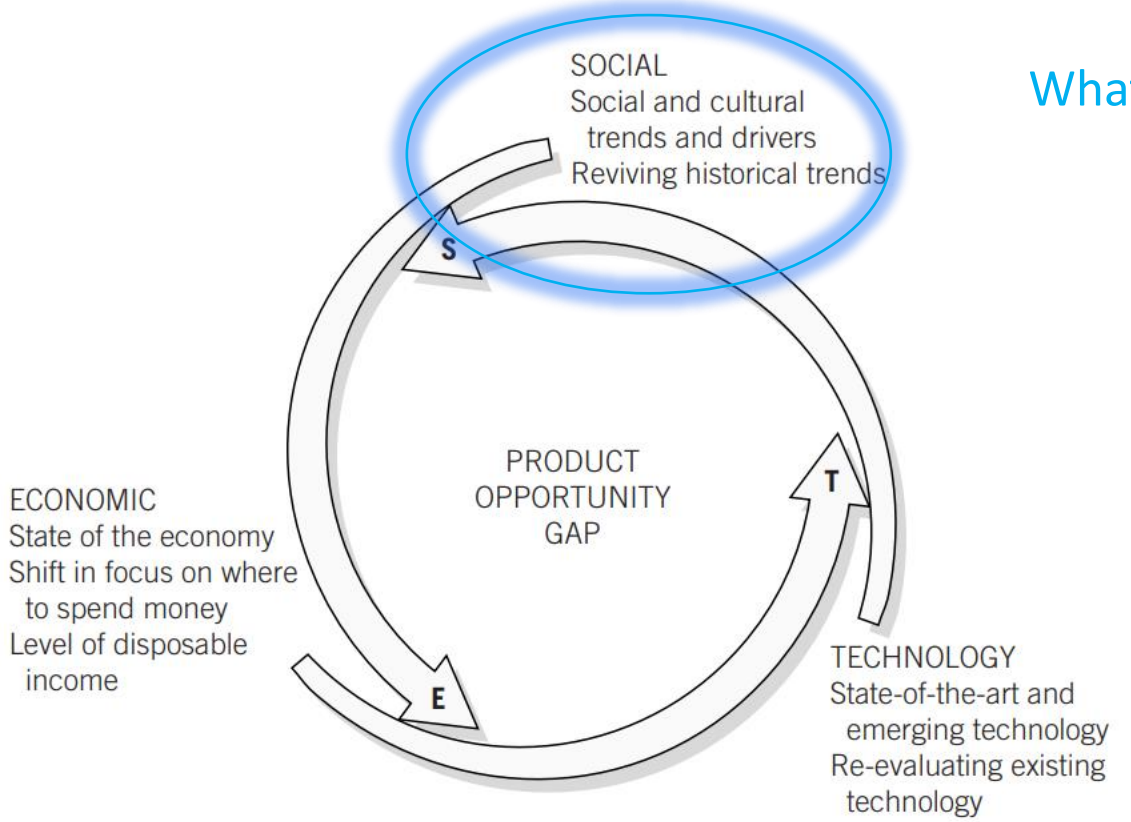


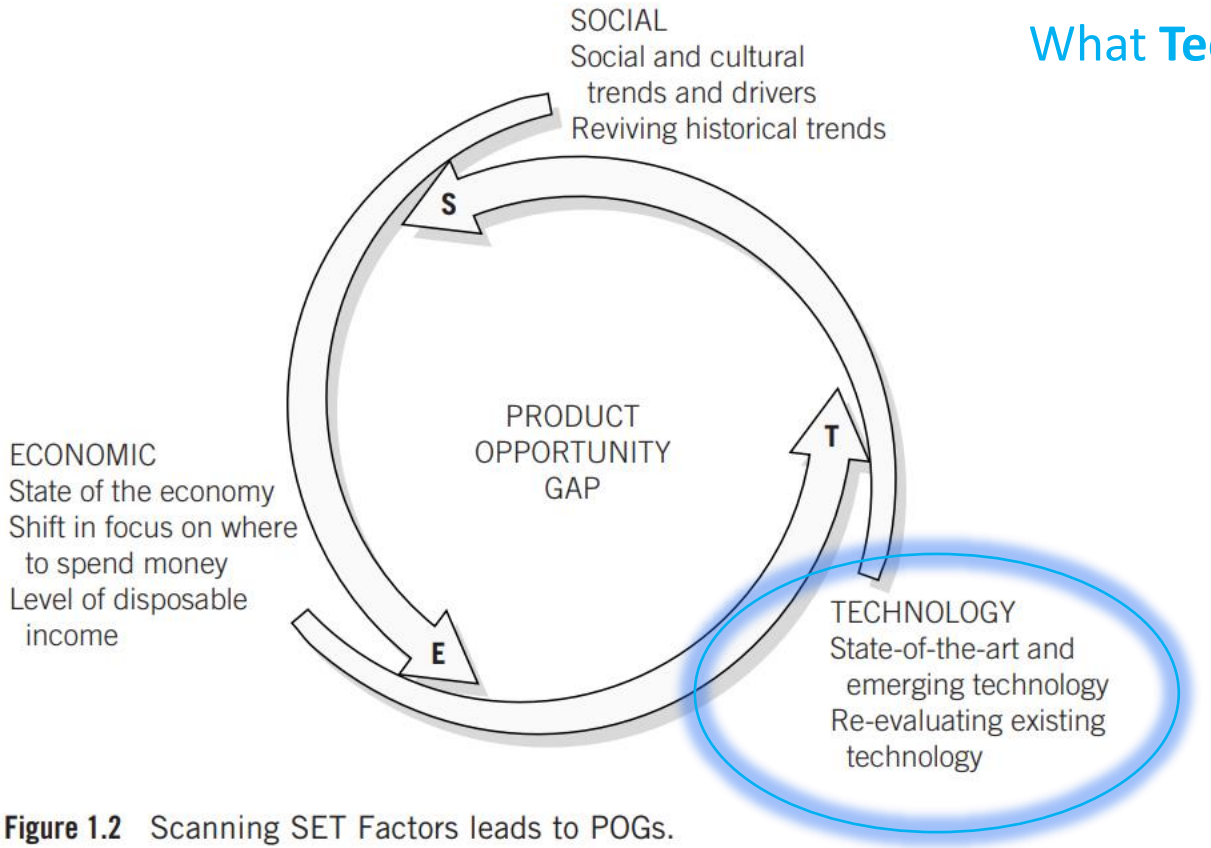
Figure 1.2 Scanning SET Factors leads to POGs.

What **Social** factors could affect product opportunity?

- Family and work patterns (work from home)
- Health issues (e.g. people living for longer)
- Use of technology
- Political environment
- Successful products in other fields,
- Sports and recreation
- Sporting events (e.g., the emergence of new, retro state-of the-art facilities)
- The entertainment industries
- Books (e.g., the Oprah Book Club)

Identifying Product Opportunities: The SET Factors

Requires a constant sweep of a number of factors in three major areas.



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What **Technology** factors could affect product opportunity?

Identifying Product Opportunities: The SET Factors

Requires a constant sweep of a number of factors in three major areas.

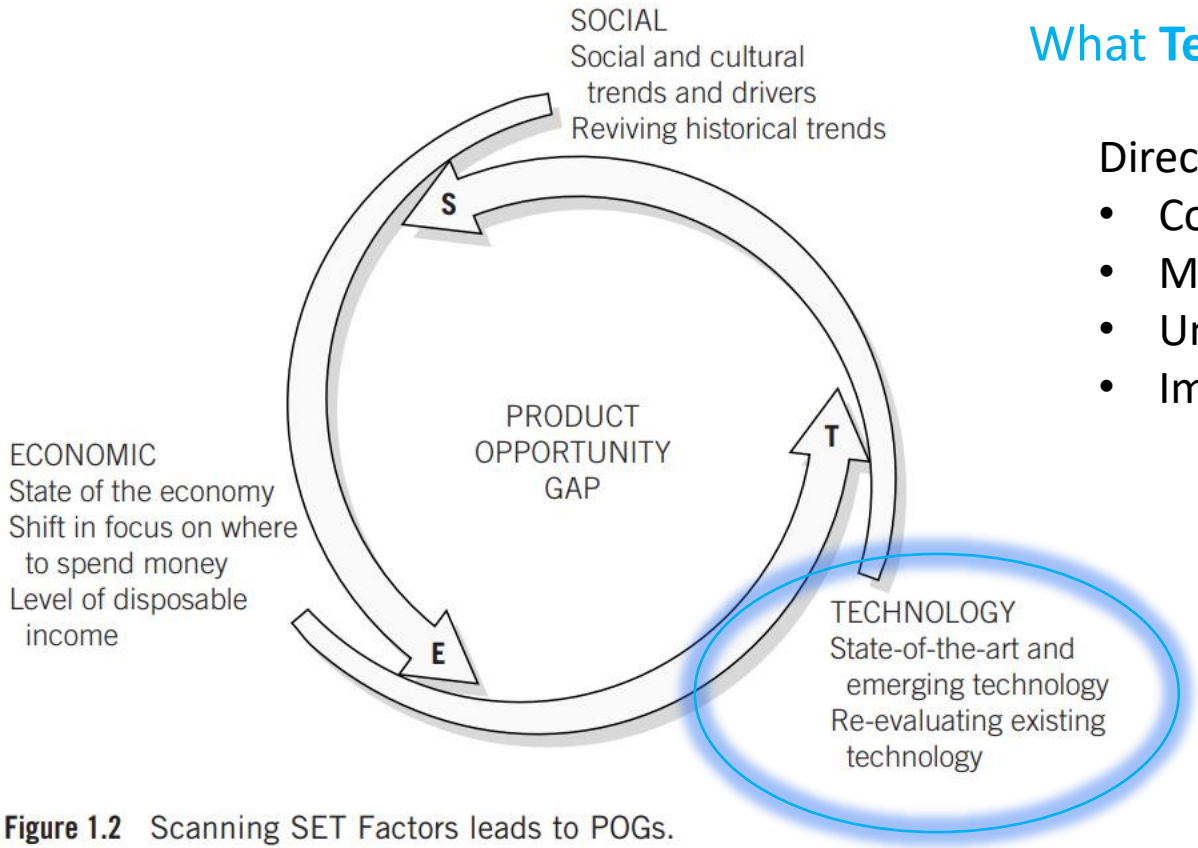


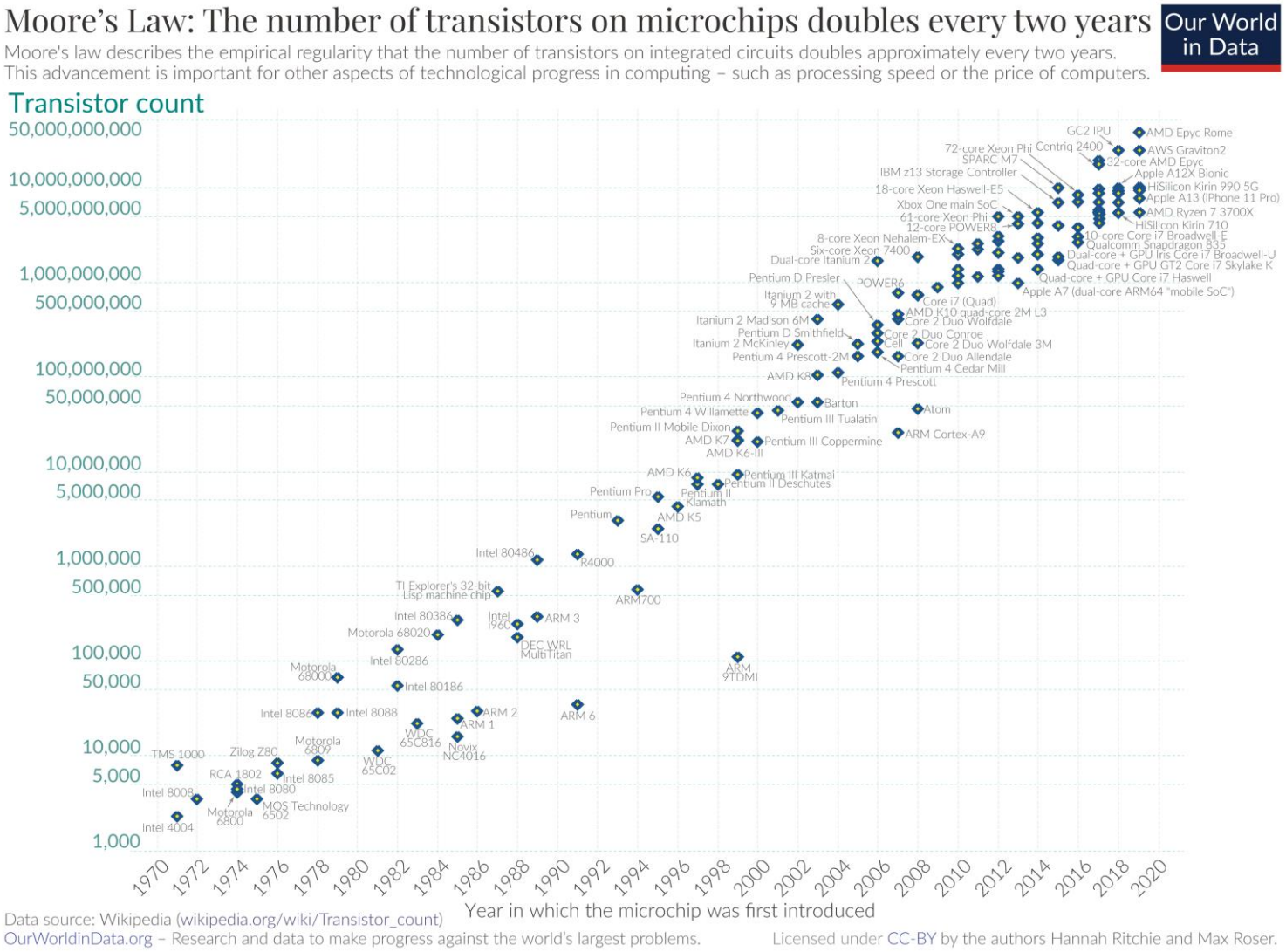
Figure 1.2 Scanning SET Factors leads to POGs.

What **Technology** factors could affect product opportunity?

Direct or predicted results from science that may come from:

- Corporate R&D
- Military research
- University research
- Implied capabilities from research

Identifying Product Opportunities: The SET Factors



For example, Moore's Law (Intel cofounder Gordon Moore's prediction in 1965 that the number of transistors per square inch on integrated circuits would double every year)

→ *Both current and future technology capabilities*

Results from University Science can translate to a product opportunity

EPFL Startups

Search

Company	Year	Status	Sector
Corintis	2022	Private	Electronics
Orbis Medecines	2022	Private	Biotech
EMETS	2022	Private	Cleantech
Oniri	2022	Private	ICT
Resilio	2022	Private	Cleantech
Rea Diagnostics	2022	Private	Medtech
Voltiris	2022	Private	Cleantech
Omnigrasp	2022	Private	Engineering
Virtuosis Artificial Intelligence	2022	Private	ICT
EVOLY	2021	Private	CleanTech
Tune Insight	2021	Private	ICT
Crypties	2021	Private	Fintech
Green Future	2021	Private	Cleantech
Algaltek	2021	Private	Engineering
Fusion Lab Technologies	2021	Private	Medtech
School Rebound	2021	Private	Edtech
Space4impact	2021	Private	Cleantech
Autonomyo	2021	Private	Medtech

Identifying Product Opportunities: The SET Factors

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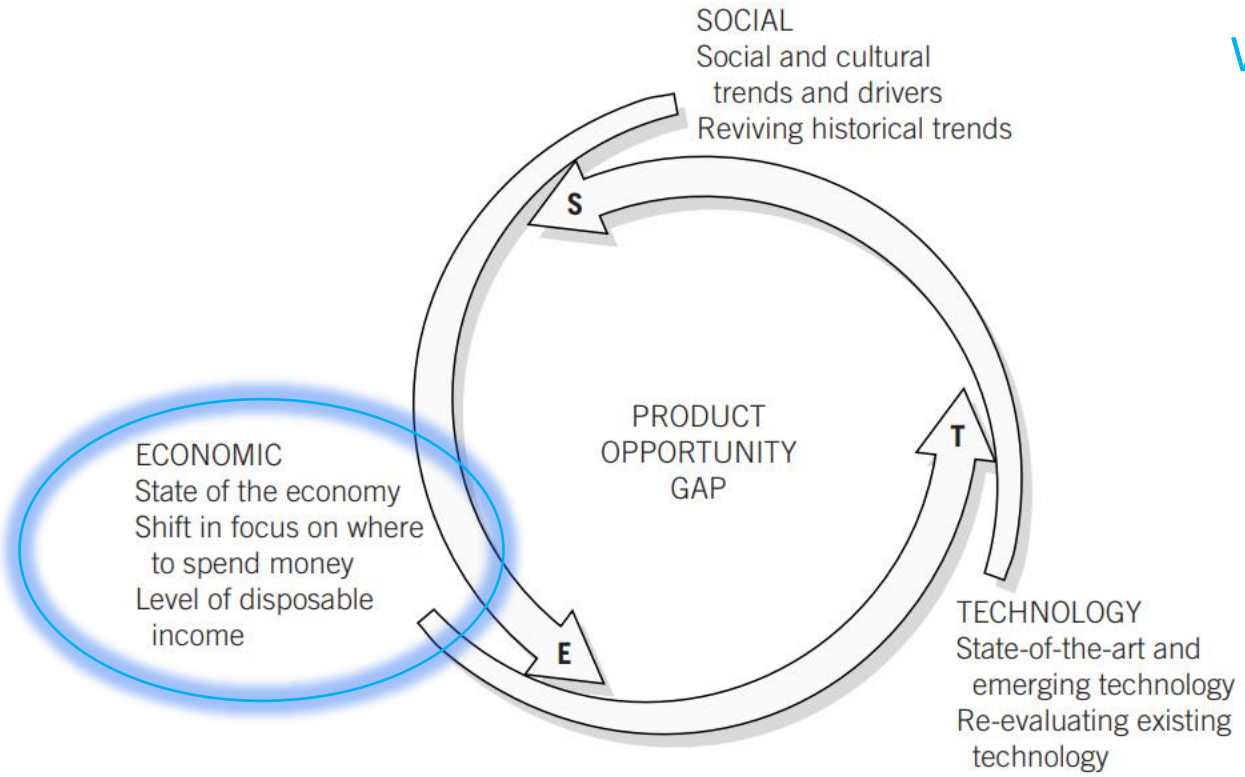


Figure 1.2 Scanning SET Factors leads to POGs.

What **Economic** factors could affect product opportunity?

- Excess income that people perceive they have, or that they expect to have, to give them purchasing power
- who has the income, who is doing the purchasing, and for whom the purchasers are buying
- Cost of salaries

All affected by *stock market, fuel prices, interest rates,*

Identifying Product Opportunities: The SET Factors

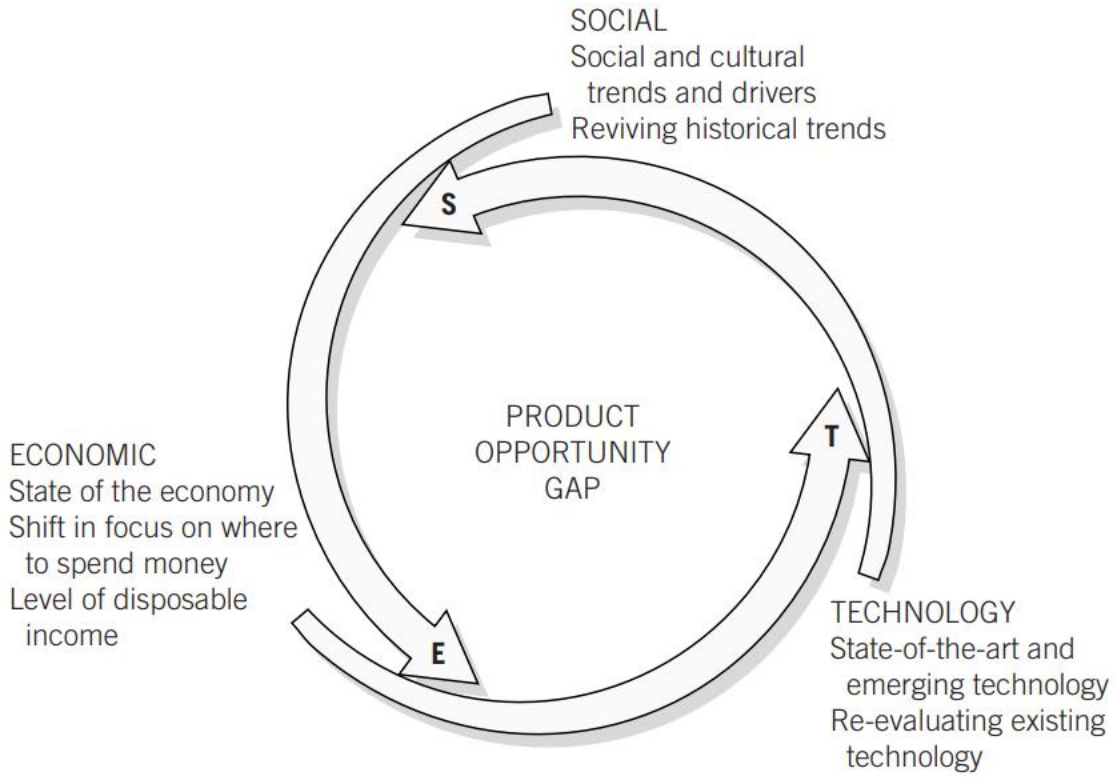


Figure 1.2 Scanning SET Factors leads to POGs.

Changes in the SET Factor(s) produce Product Opportunity Gaps (POGs).

Translate the POG into a new product or a significant modification of an existing product.

Combination of new aesthetic or new features

- Stemming from new technology
- Must match emerging shifts in consumer preference

POGs: Examples

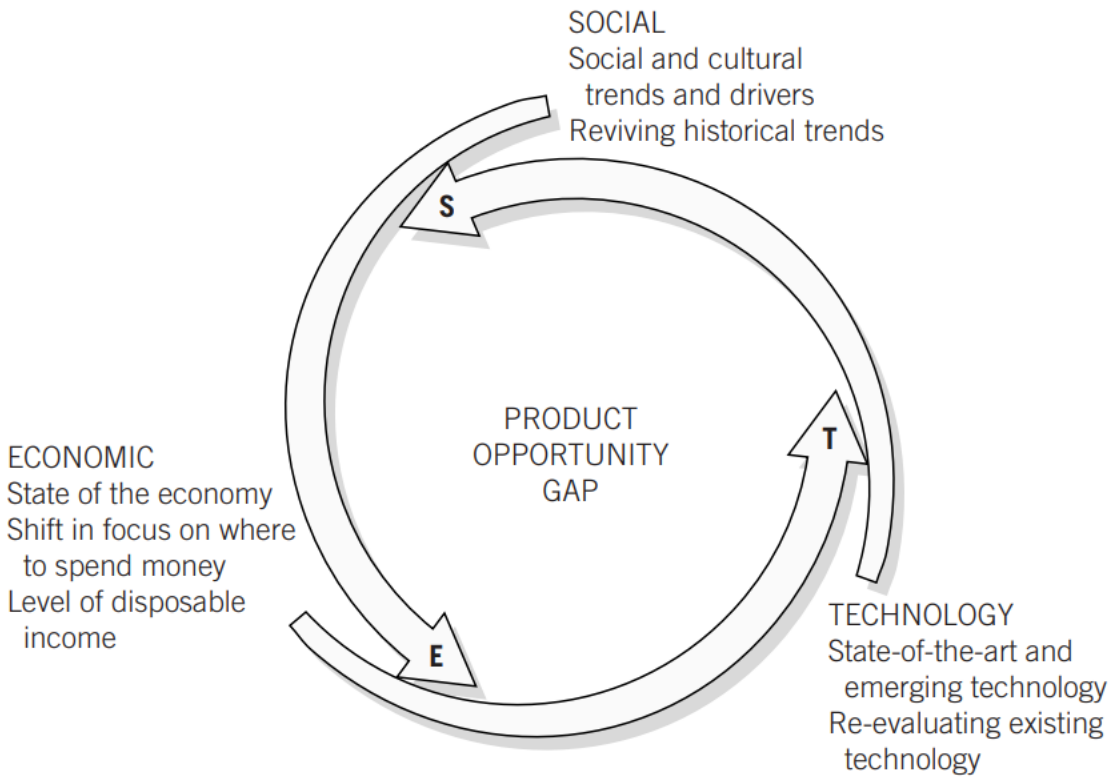
Standard peeler

1990s

What changes in SET Factors enabled this product opportunity gap?

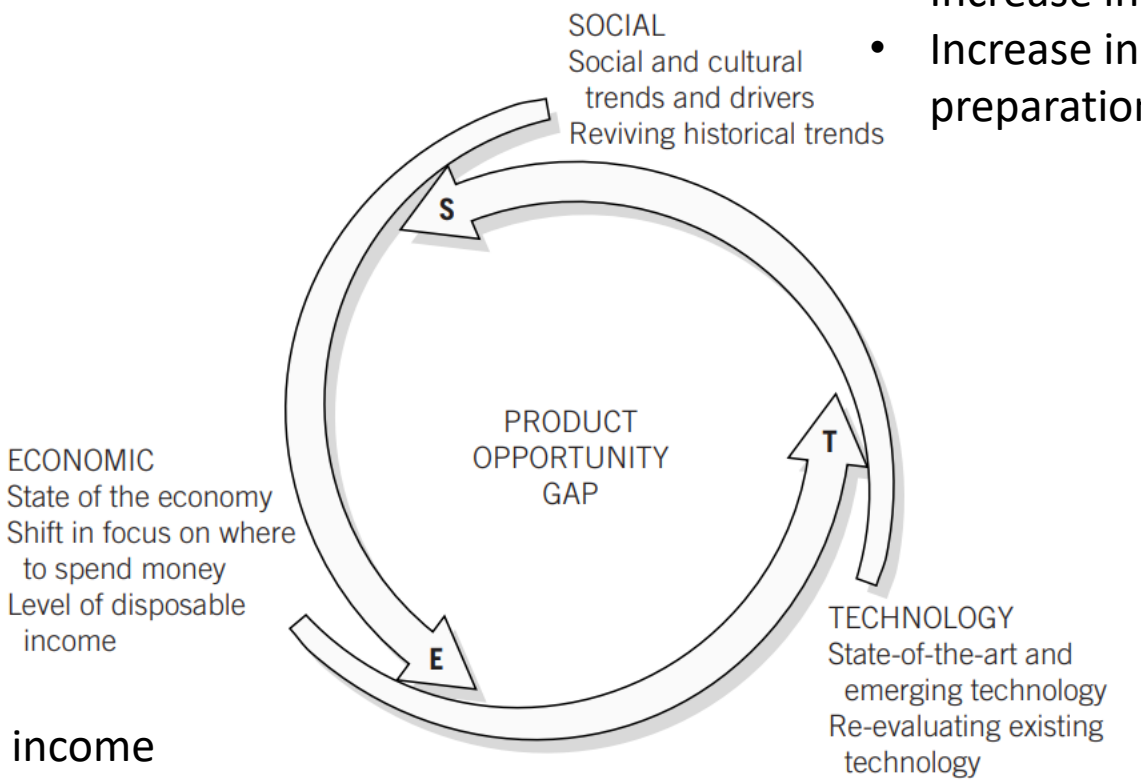
OXO Neoprene handle peeler

1990s


SOCIAL
Social and cultural trends and drivers
Reviving historical trends
S
PRODUCT OPPORTUNITY GAP
T
ECONOMIC
State of the economy
Shift in focus on where to spend money
Level of disposable income
E
TECHNOLOGY
State-of-the-art and emerging technology
Re-evaluating existing technology

1990s

- Increased awareness of needs for disabled
- Increase in population 65+
- Increase in home based food preparation



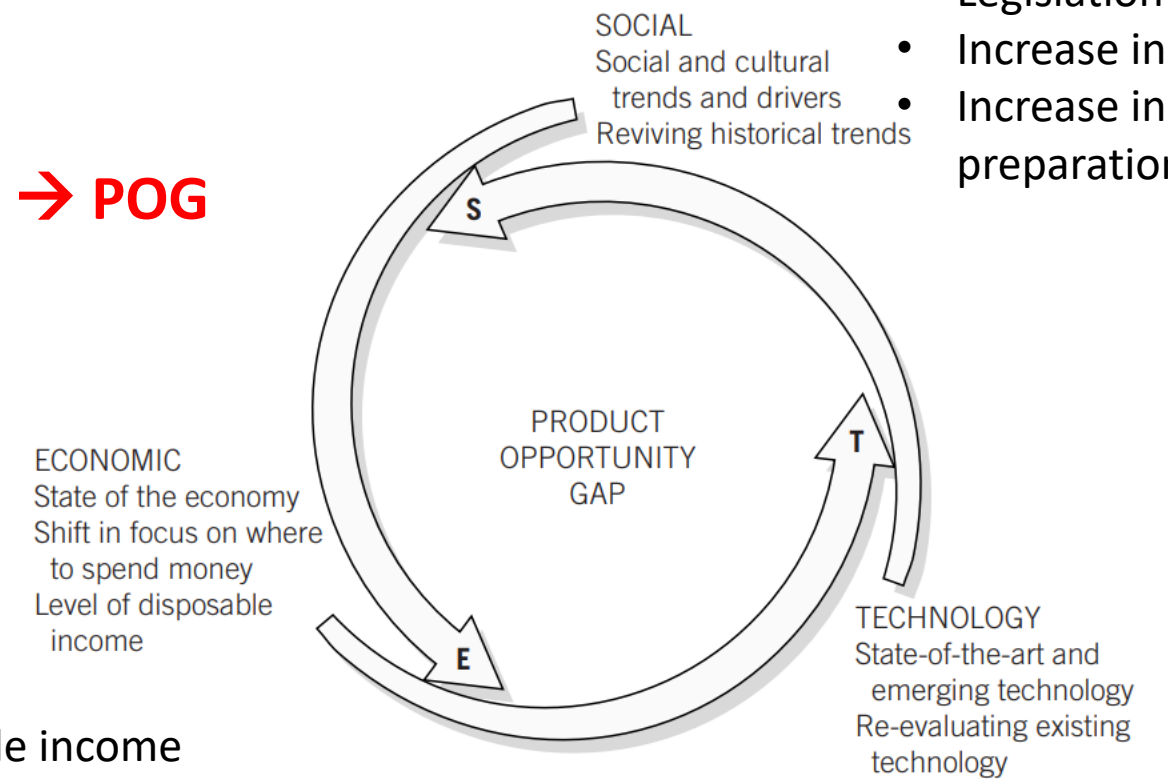
- Seniors have disposable income
- Increase in money spent in housewares
- Adult children buying aids for aging parents

- Neoprene
- New moulding techniques
- New capabilities for manufacturing tolerances

Trends had changed and people were able to recognize and were willing to pay for the value embedded in this product.

- Increased awareness of needs for disabled
- Legislation for
- Increase in population 65+
- Increase in home based food preparation

SET Factors Change → POG



- Seniors have disposable income
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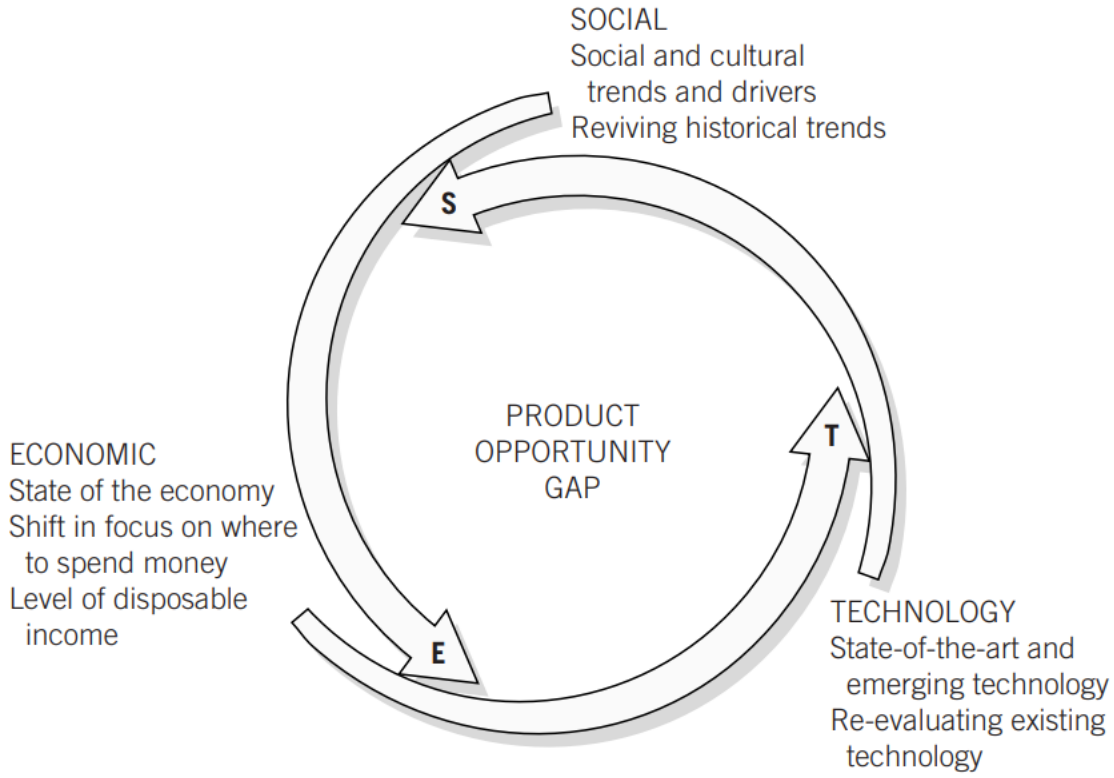
Starbucks

- An experience
- A brand
- Technology driven (water filtering, coffee machines, roasting facilities).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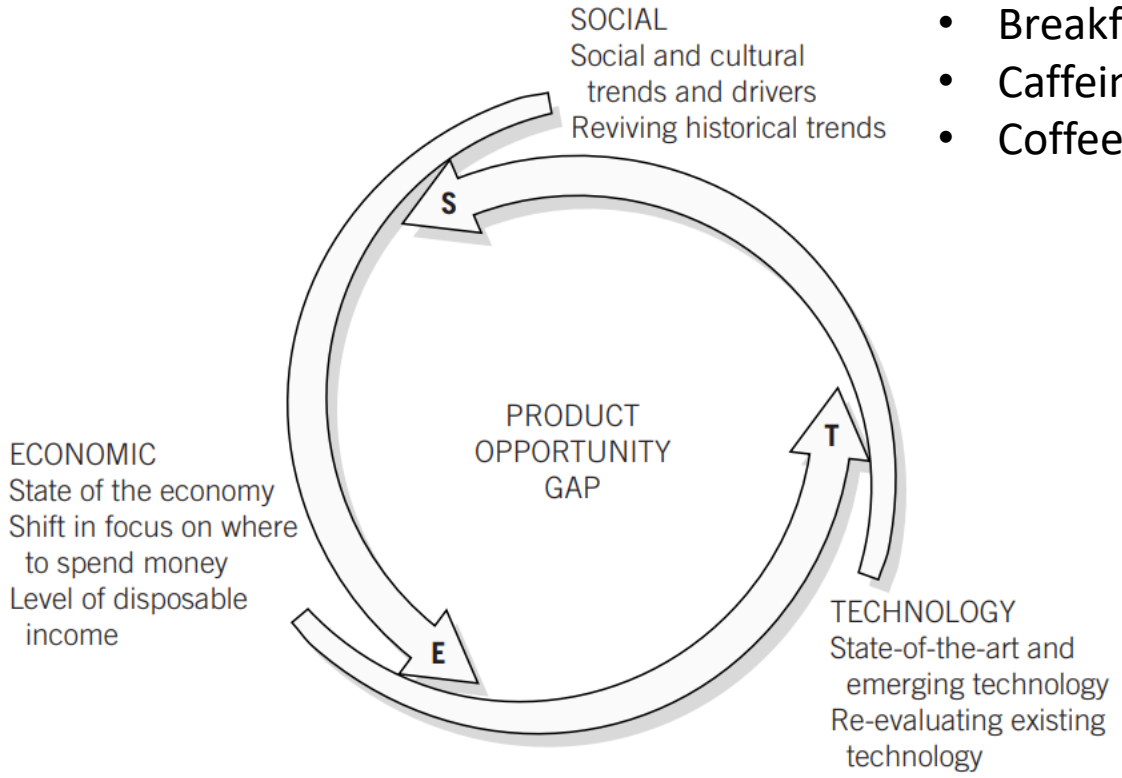
Shift in focus on where to spend money
Level of disposable income

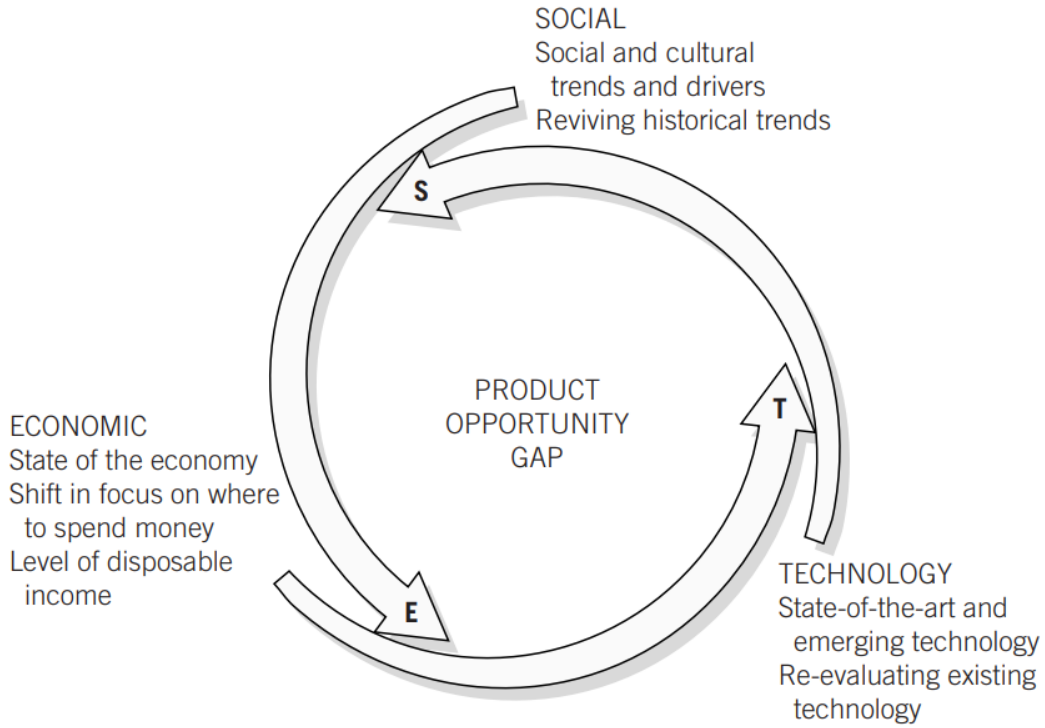
- Need for escape opportunities
- More free time
- Breakfast on the run
- Caffeine popular
- Coffee is a highlight of the day



- Expendable income
- Cost of eating on the run
- Value placed on high-quality intense breaks

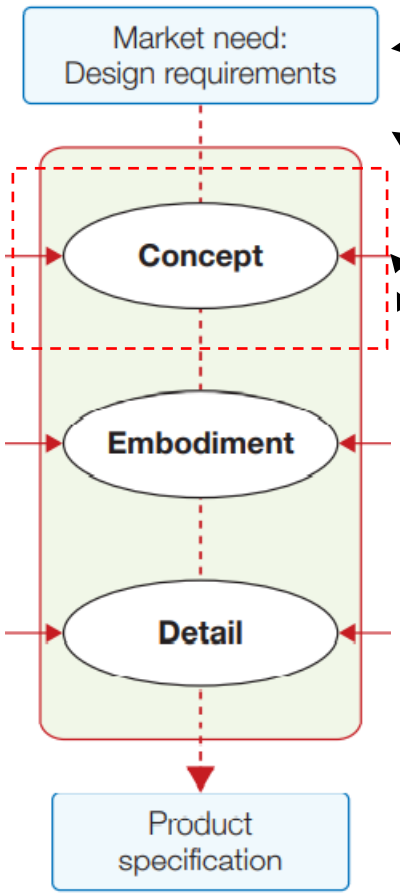
- Quality roasting and brewing process
- Systems approach to environmental design
- Water filtration technology

Identifying Product Opportunities: The SET Factors



SET Factors in at least 2, if not 3 areas leads to a product opportunity!

Recap: Stages of Design



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How do we build a specification from a market need?

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How do we decide which is the best solution?

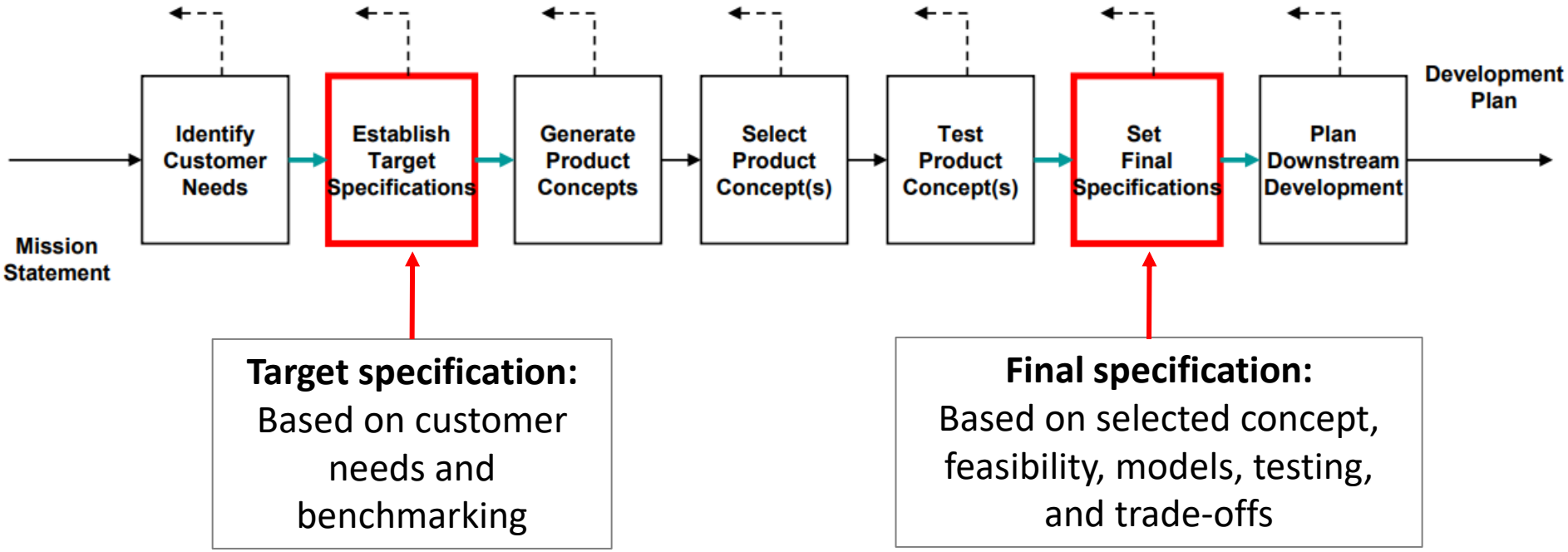
This is not just an engineering challenge, but also a challenge in understanding humans, and team work.

Developing a Specification

What is a specification?

- Specifications spell out in precise, measurable detail what the product has to do.
- Specifications represent an unambiguous agreement on what the team will attempt to achieve in order to satisfy the identified customer needs.
- Should include any regulatory and agency approval requirements

When do we form a specification?



- For simple products early in the development process, right after identifying customer needs
- For technology-intensive products: at least twice …

Forming (target) specifications

Form of a specification:

A ‘specification’ (sing.) consists of a metric and a value

Example:
metric → “Average time to assemble”
value → “less than 75 seconds”

Forming (target) specifications

Form of a specification:

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Example:
metric → “Average time to assemble”
value → “less than 75 seconds”

To form these specs:

- Prepare list of metrics, using the needs/metrics matrix.
- Collect benchmarking information.
- Set ideal and marginally acceptable target values for each metric.

Forming (target) specifications

Step 1: Convert needs from customer to specificiations

Needs captured from customer discussions

#	NEED		Imp
1	The suspension	reduces vibration to the hands.	3
2	The suspension	allows easy traversal of slow, difficult terrain.	2
3	The suspension	enables high speed descents on bumpy trails.	5
4	The suspension	allows sensitivity adjustment.	3
5	The suspension	preserves the steering characteristics of the bike.	4
6	The suspension	remains rigid during hard cornering.	4
7	The suspension	is lightweight.	4
8	The suspension	provides stiff mounting points for the brakes.	2
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5
10	The suspension	is easy to install.	1

How do we convert needs to metrics?

How do we generate metrics from needs?

- Metrics should be dependent, NOT independent, variables.
- Metrics should be practical.
- Some needs cannot be easily translated into quantifiable metrics (subjective needs).
- Metrics should include popular criteria used for ‘marketplace’ comparisons.
- Should be quantifiable

How do we generate metrics from needs?

What would appropriate metrics be for these needs?

#	NEED		Imp
1	The suspension	reduces vibration to the hands.	3
7	The suspension	is lightweight.	4
10	The suspension	is easy to install.	1

We can tabulate Needs vs. Metrics

	Need	Metric 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Attenuation from dropout to handlebar at 10 Hz	Spring preload	Maximum value from the Monster	Minimum descent time on test track	Damping coefficient adjustment range	Maximum travel (26 in. wheel)	Rake offset	Lateral stiffness at the tip	Total mass	Lateral stiffness at brake pivots	Headset sizes	Steertube length	Wheel sizes	Maximum tire width	Time to assemble to frame	Pedals compatibility
1	Reduces vibration to the hands	•		•	•												
2	Allows easy traversal of slow, difficult terrain		•														
3	Enables high-speed descents on bumpy trails	•		•	•												
4	Allows sensitivity adjustment					•											
5	Preserves the steering characteristics of the bike						•	•									
6	Remains rigid during hard cornering		•						•								
7	Is lightweight									•							
8	Provides stiff mounting points for the brakes										•						
9	Fits a wide variety of bikes, wheels, and tires											•	•	•	•		
10	Is easy to install															•	

- Some needs can have multiple metrics.
- Metrics can be used to assess multiple needs

Example: Needs & Metrics for a pen

Customer Need: – The pen writes smoothly

Assuming that smooth writing can be characterized by:

- N1: Good quality line
- N2: Preservation of line quality
- N3: Ease of use...

Example: Needs & Metrics for a pen

Needs

- N1: Good quality line
- N2: Preservation of line quality
- N3: Ease of use...

Metrics

Example: Needs & Metrics for a pen

Needs

- N1: Good quality line
- N2: Preservation of line quality
- N3: Ease of use...

Metrics

1. Variation in line thickness (mm)
2. Variation in ink coverage (cc/mm 2)
3. Functional range of writing force (N)
4. Functional range of writing velocity (mm/sec)
5. Functional range of pen angle from vertical (deg)
6. Variation in resistance to translational motion (N)

Benchmarking

To form these specs:

- Prepare metrics
- **Collect benchmarking information.**
- Set ideal/marginal values

No product development team can expect to succeed without ‘benchmarking’ the project against competing products.

- Data in competitors’ catalogues and supporting literature may not be accurate.
- Values for key metrics should be verified by independent testing and observation.

Setting Target Values

To form these specs:

- Prepare metrics
- Collect benchmarking information.
- **Set ideal/marginal values**

The target value

Must satisfy, but not great

Set ideal and marginally acceptable target values for each metric.

– At least X
– At most X
– Between X and Y
– Exactly X
– A set of discrete values

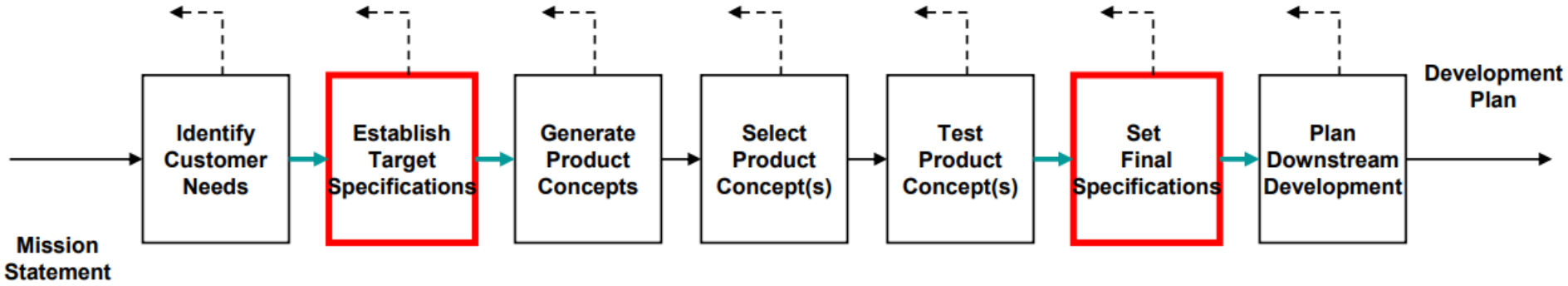
Setting Target Values

	Metric	Units	Marginal Value	Ideal Value
1	Attenuation from dropout to handlebar at 10hz	dB	>10	>15
2	Spring pre-load	N	480 - 800	650 - 700
3	Maximum value from the Monster	g	<3.5	<3.2
4	Minimum descent time on test track	s	<13.0	<11.0
5	Damping coefficient adjustment range	N-s/m	0	>200
6	Maximum travel (26in wheel)	mm	33 - 50	45
7	Rake offset	mm	37 - 45	38
8	Lateral stiffness at the tip	kN/m	>65	>130
9	Total mass	kg	<1.4	<1.1
10	Lateral stiffness at brake pivots	kN/m	>325	>650
11	Headset sizes	in	1.000 1.125	1.000 1.125 1.250
12	Steertube length	mm	150 170 190 210	150 170 190 210 230
13	Wheel sizes	list	26in	26in 700c
14	Maximum tire width	in	>1.5	>1.75
15	Time to assemble to frame	s	<60	<35

- Must have units!
- Marginal often a range, which includes the ideal value
- Try and be as specific as possible
- These target values could be conflicting (i.e. total mass and lateral stiffness)
- Remember, the specification could be updated later in the process.

Refining the Specification…

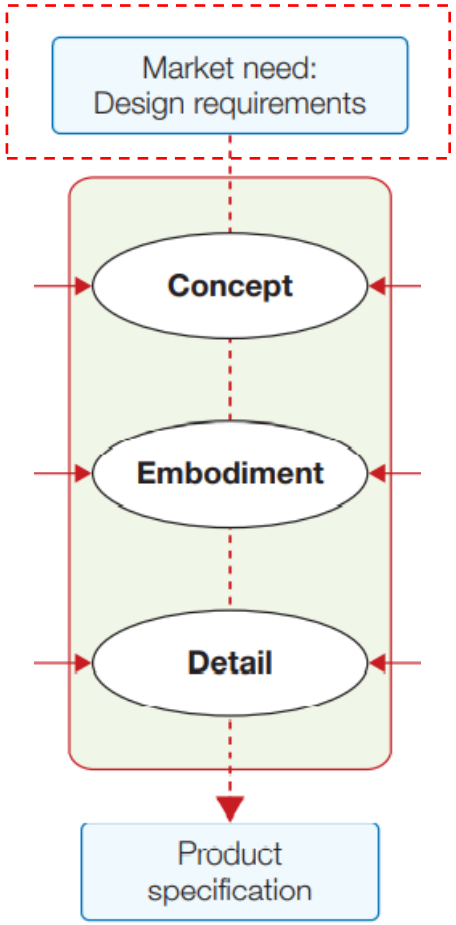
It might not be right the first time!



We may want to refine the specs later due to:

- Develop technical models of products and can improve
- Develop cost model which affects specifications
- Reflect on results and process.

Summary



- Customer needs expressed in the “language of the customer”
- First target specifications than final specs
- For target specifications:
  - Prepare the list of metrics
  - Collect benchmarking information
  - Set ideal and marginally acceptable values
  - Reflect on the results and the process
- Final specifications are developed by assessing the actual technological constraints and the expected production costs using analytical and physical models

Concept Selection (15% of Grade):

Due Week 5 October 9th, will also have a TA review with this document

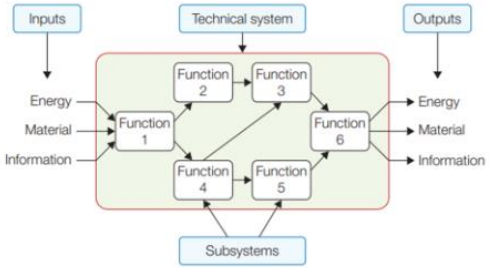
Concept Ideation & Selection

This report should be submitted as a single .pdf to Moodle, please use your group number as the file name. It should be a maximum of 8 pages, and contain the following. All group members should contribute.

Functional Diagram (1 page)

For your task, generate a functional diagram (1/2 page) which shows the inputs, systems and outputs and the different functions you choose to sub-divide it into.

To accompany the functional diagram provide a brief description of each of the functions required.



Some useful links on generating functional diagrams:

- About functional structure diagrams
- Conceptual example

Concept Generation (max. 5 pages, 1 concept per page)

Generate 4 different concepts and on each page provide a sketch of the design. This should include

https://flossy-quartz-a5a.notion.site/Concept-Ideation-Selection-f7ebd3d28b5a43e5bd80709233bce651?pvs=74

Project Details

Add description

List of available equipment

Table | Board | + | New

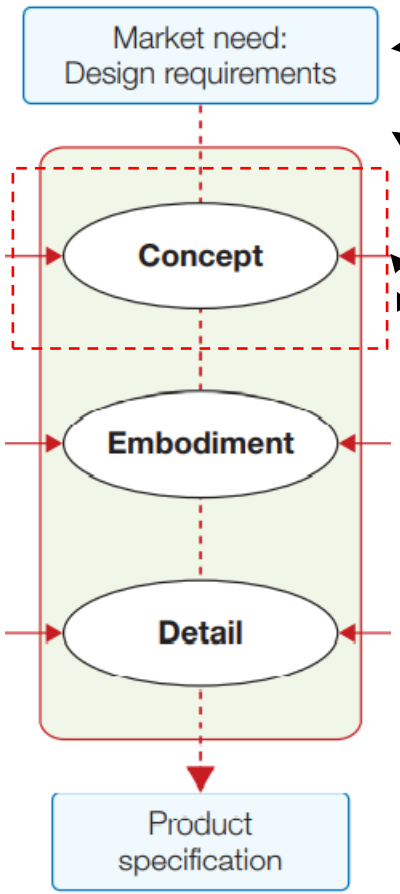
parts	category	description	in use by	available for ME320
Arduino Starter Kit	arduino, checked	Kit		☑
Mains 3-6V, 1A supply	power supply, checked	The white line indicates the +ve		☑
Servo (micro)	motor, checked	SD90 Micro Servo		☑
Servo (standard)	motor, checked	MG995 RC Servo Metal Gear Hi		☑
DC Motor Controller	(micro)controller, checked	Double H-bridge L298N		☑
Webcam	camera, checked	Cannot be used with Arduino -		☑
Load cell & Amplifier	sensors, checked	1kg load cell + amplifyer		☑
Light Dependent Resistor	sensors	5 – 10 K Ohms – Dark		☑
Limit switches	sensors			☑
Nuts (M2,M3,M4)	fasteners			☑
M2 Bolts	fasteners	Various lengths		☑
M3 Bolts	fasteners	Various lengths		☑
M4 Bolts	fasteners	Various lengths		☑
M4 Studding (Threaded Rod)	fasteners			☑
Light dependent resistors	sensors			☑

Project: Practical Steps to take

- Remember to add to the team list if not done so
- Complete the safety for SPOT (email was sent earlier in the week)

- Sign up for 3D printer training in the SPOT (your team will need this, to be able to prototype!) Slots may go quickly at the beginning of the semester

Recap: Stages of Design



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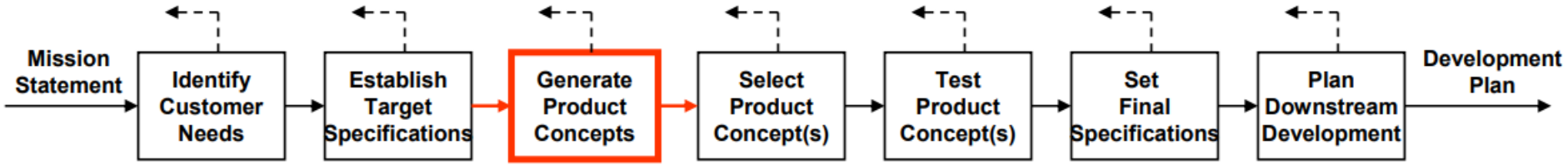
Concept Generation



- Concept generation is the process of creating ideas for designing a product based on the target specifications and requirements.
- These ideas describe the design and working principles of the product, along with how it can meet the customer requirements.
- Can be useful to graphically illustrate the proposed design as rough drawings, 3D model
- **Creativity and problem-solving skills are vital for this process.**

Concept Generation

The process should address:

- What existing solutions could be adapted for this application?
- What new concepts might satisfy these needs and specifications?
- What methods can be used to facilitate concept generation process?

…but it is not easy!

Concept Generation

Generate concepts in groups of 2-3 to the solve the need of:

- We want undamaged raspberries to eat
- There are not enough workers to harvest the raspberries

How did you approach the problem?

Concept Generation

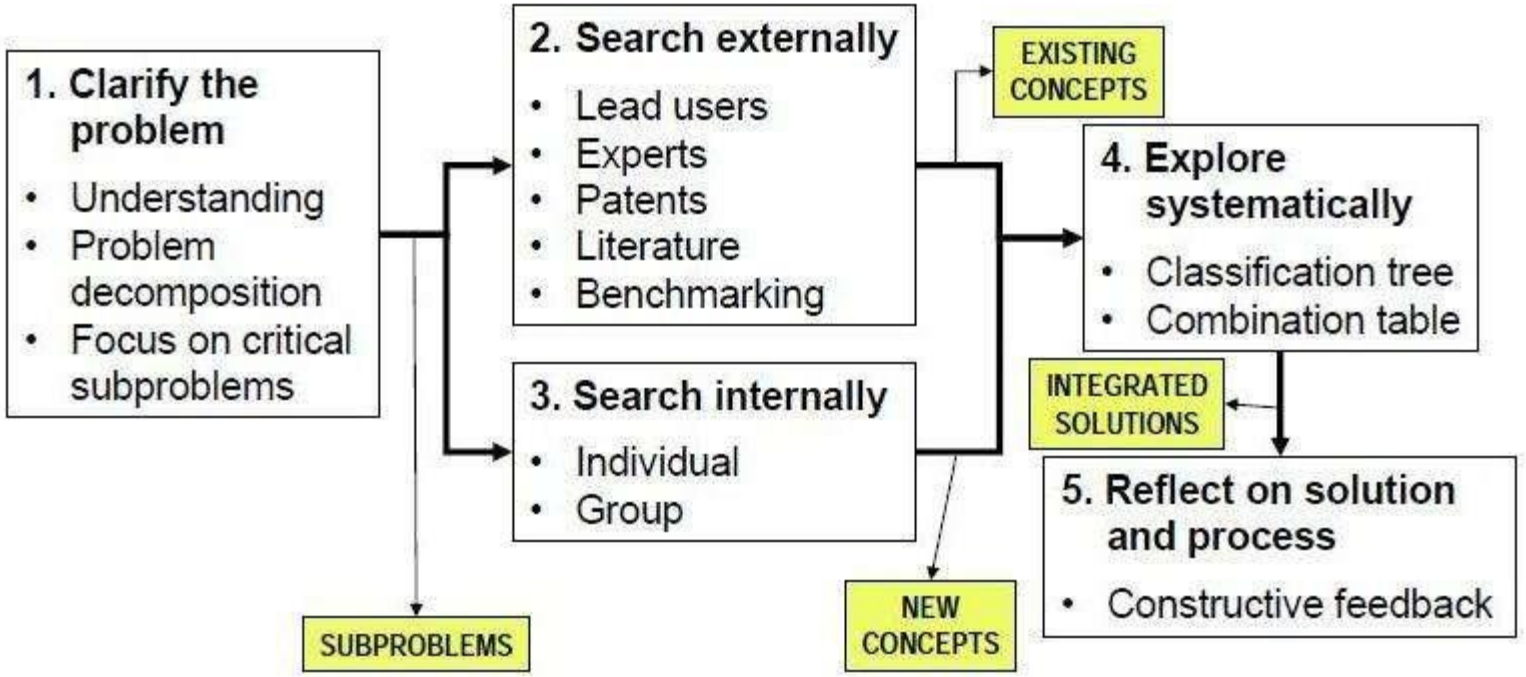
Concept generation can lead to poor outcomes when:

- Consideration of only a few concepts
- Failure to consider carefully existing solutions
- Involvement of only a few people → lack of confidence and commitment by others in the team
- Ineffective integration of promising partial solutions.
- Failure to consider entire categories of solutions.

Structured approaches reduce the likelihood of limited an inefficiently concept generation.

Concept Generation Process

A Five-Step Method



Concept Generation Process: Step 1

Step 1: Clarify the Problem

- Clarify understanding
- Problem decomposition
- Focus on critical sub-components

Review the need and understanding of the goal

Need: "Design a better vegetable peeler."
Feedback on existing ones: "none of the peelers works for everyone in every situation".

Concept Generation Process: Step 1

1. Customer comments (Feedback from user studies)
- "Carrots and potatoes are very different."
- "I cut myself with this one."
- "I just leave the skin on."
- "I'm left-handed. I use a knife."
- "This one is fast, but it takes a lot off."
- "How do you peel a squash?"
- "Here's a rusty one."
- "This looked OK in the store."

Customer Needs
- The peeler peels a variety of produce.
- The peeler works both right and left handed.
- The peeler creates minimal waste.
- The peeler saves time.
- The peeler is durable.
- The peeler is easy to clean.
- The peeler is safe to use and store.
- The peeler is comfortable to use.
- The peeler stays sharp or is sharpenable.

Metrics & Target Specifications
- Time to peel vegetables
- Life of the peeler
- Force exerted during peeling
- Time to clean the peeler

etc. etc.

We understand the problem ☺

Concept Generation Process: Step 1

Step 1: Clarify the Problem

- Clarify understanding
- Problem decomposition
- Focus on critical sub-components

Problem decomposition

• Decompose complex problem into simpler sub-problems. Many design challenges are too complex to solve as a single problem.

• Split a complex problem into simpler subproblems.(Problem decomposition)

Concept Generation Process: Step 1

Step 1: Clarify the Problem

- Clarify understanding
- Problem decomposition
- Focus on critical sub-components

Problem decomposition

• Decompose complex problem into simpler sub-problems. Many design challenges are too complex to solve as a single problem.

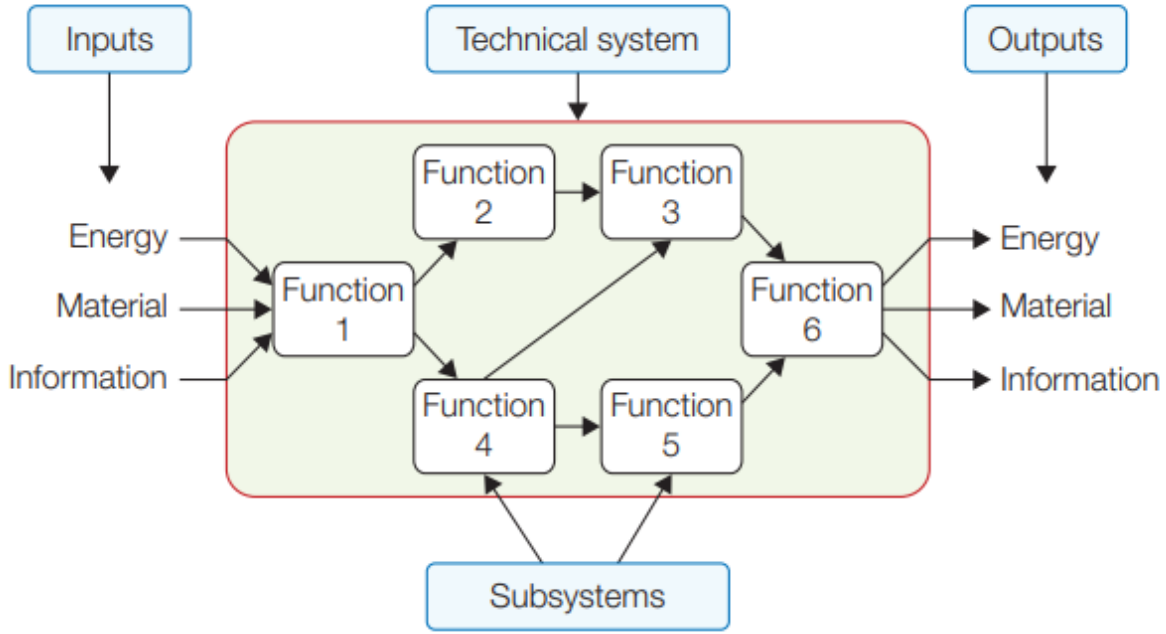
• Split a complex problem into simpler subproblems.(Problem decomposition)

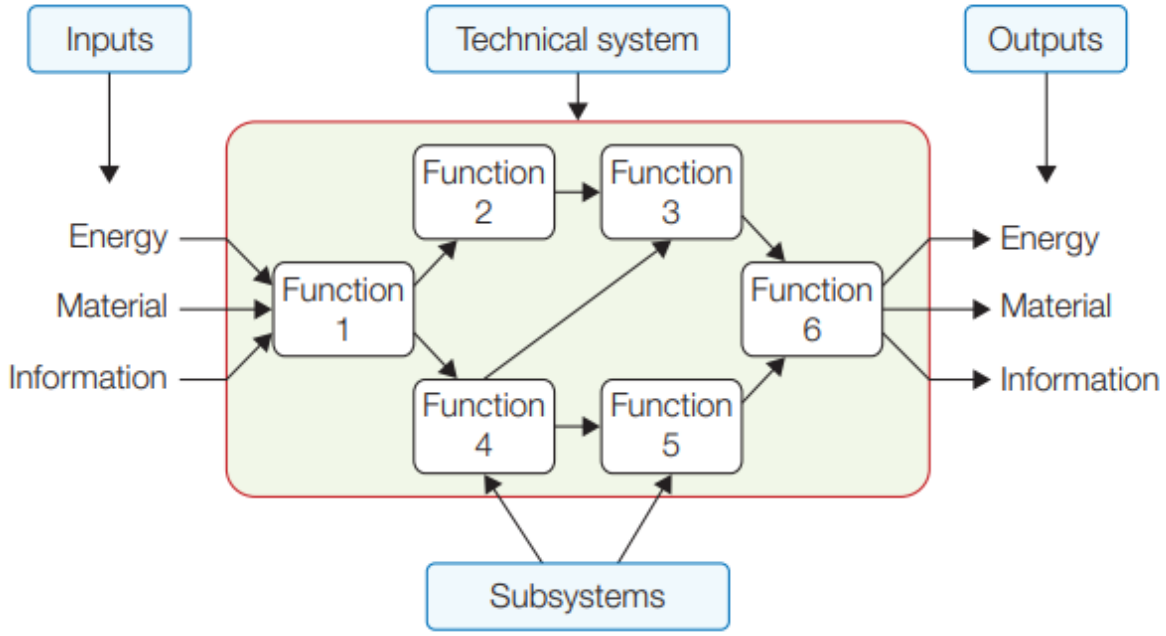
For example:

- *Printer* → Possible sub-modules: Document handler, Printing device, Paper feeder
- *Cup* → Possible sub-modules: Handle, Cup

Concept Generation Process: Step 1

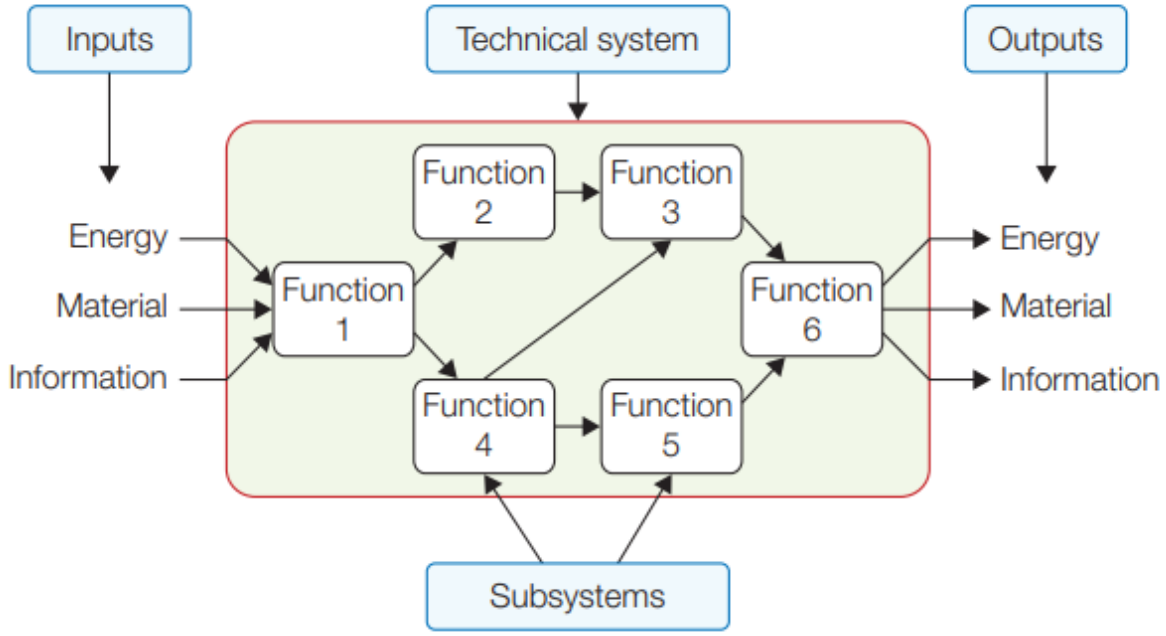
Problem Decomposition by Function





What are our input(s)?

What is our output(s)?



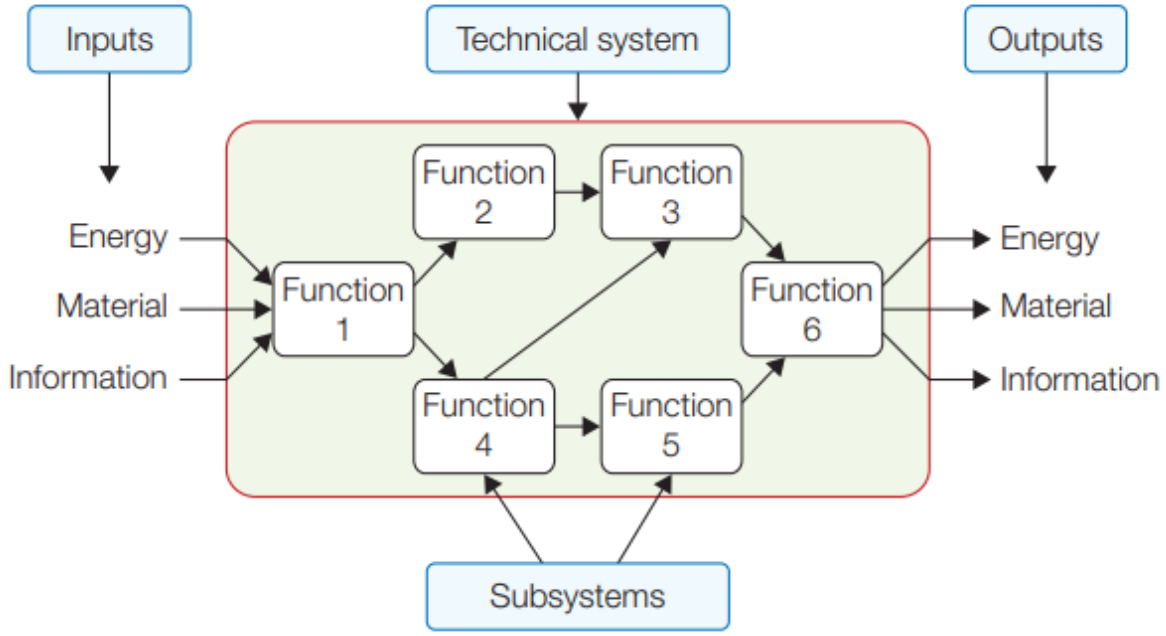
What are our input(s)?

Whole Vegetable

Hand Power

What is our output(s)?

Peeled Vegetable



What are our input(s)?

What functions are needed

What is our output(s)?

Whole Vegetable

Hand Power

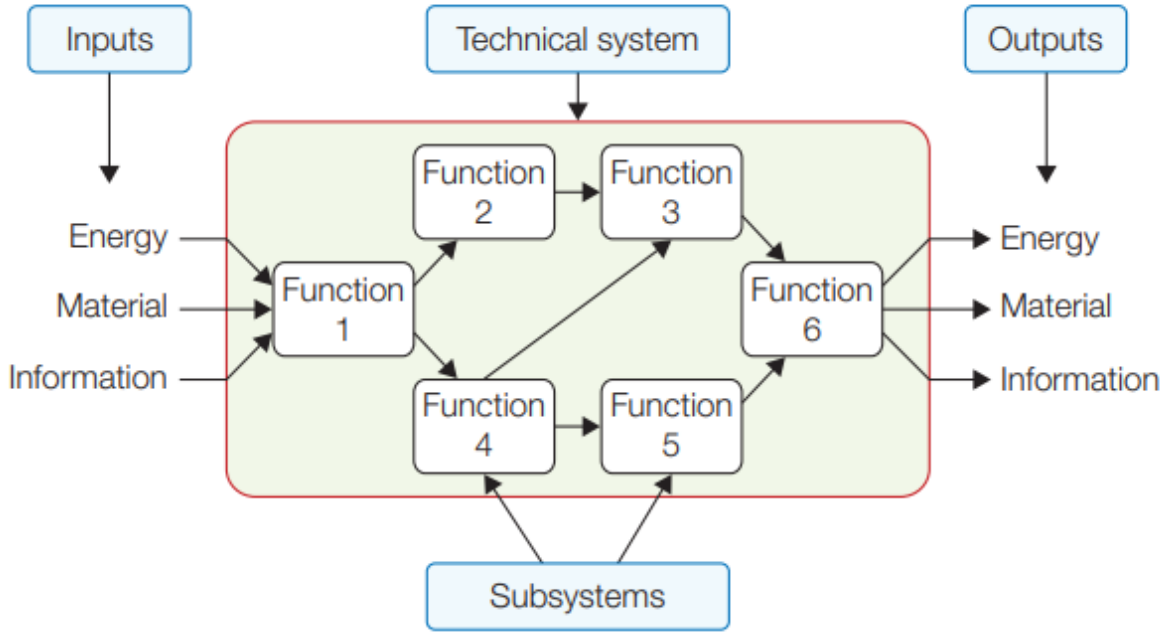
Manipulate Vegetable

Separate Skin

Discard Skin

Apply Hand Power

Peeled Vegetable



What are our input(s)?

What functions are needed

What is our output(s)?

Whole Vegetable

Hand Power

Manipulate Vegetable

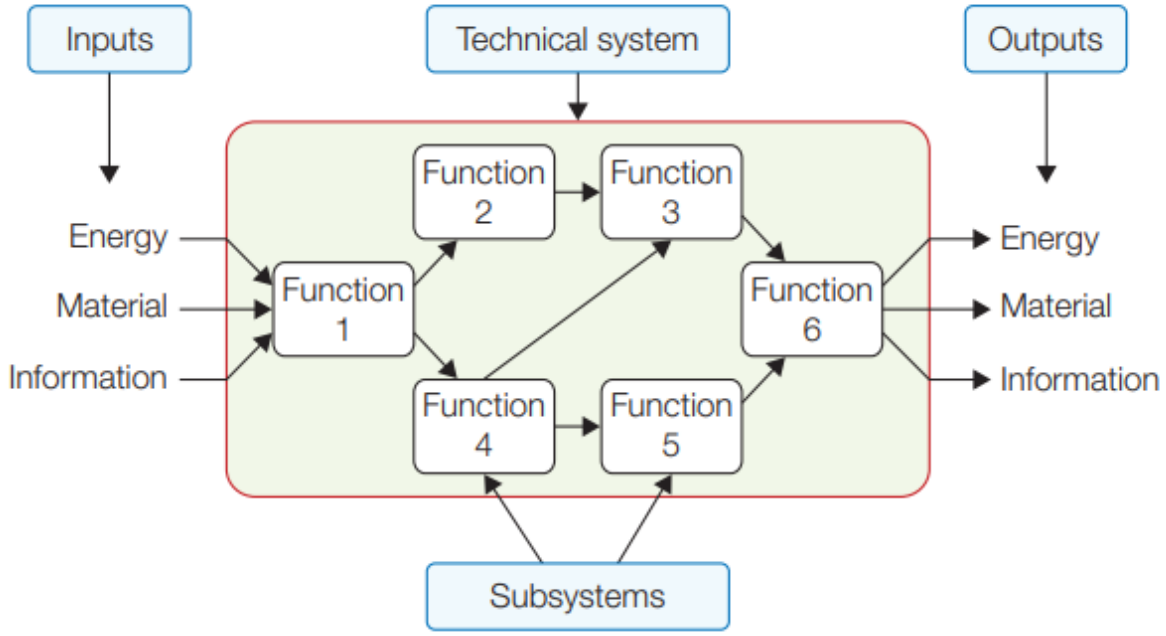
Separate Skin

Discard Skin

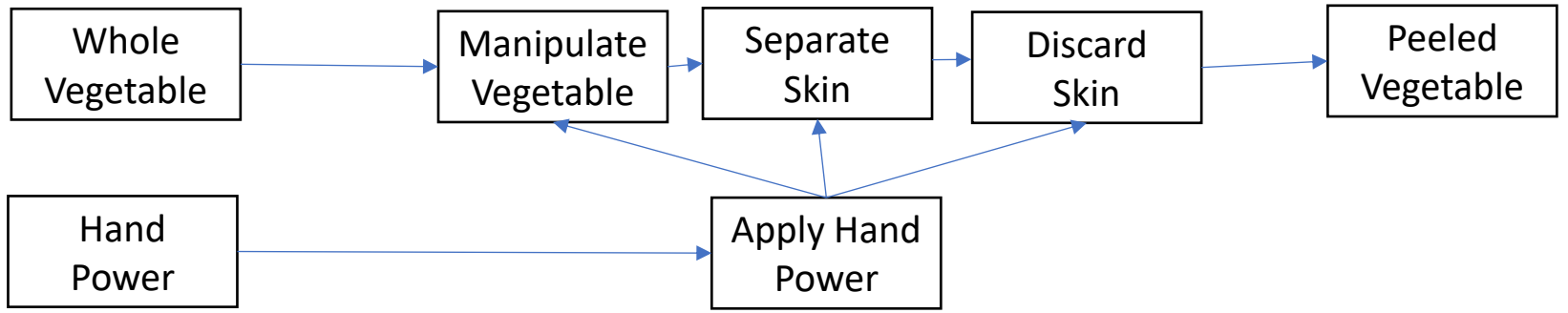
Apply Hand Power

Peeled Vegetable

How can they be connected



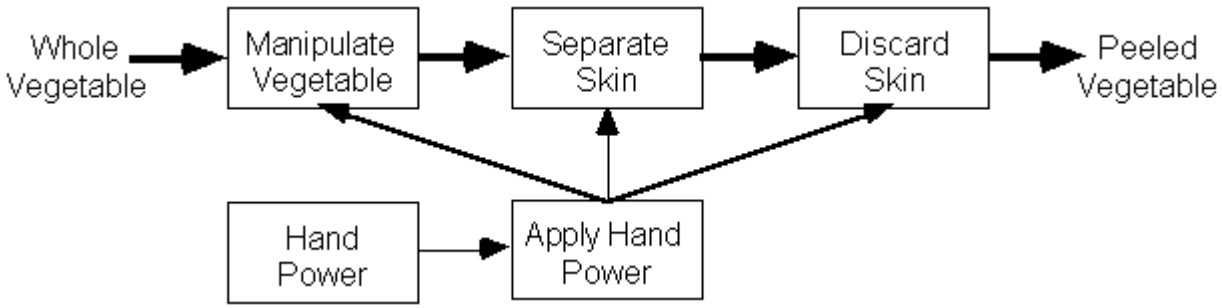
What are our input(s)? **What functions are needed** **What is our output(s)?**



How can they be connected

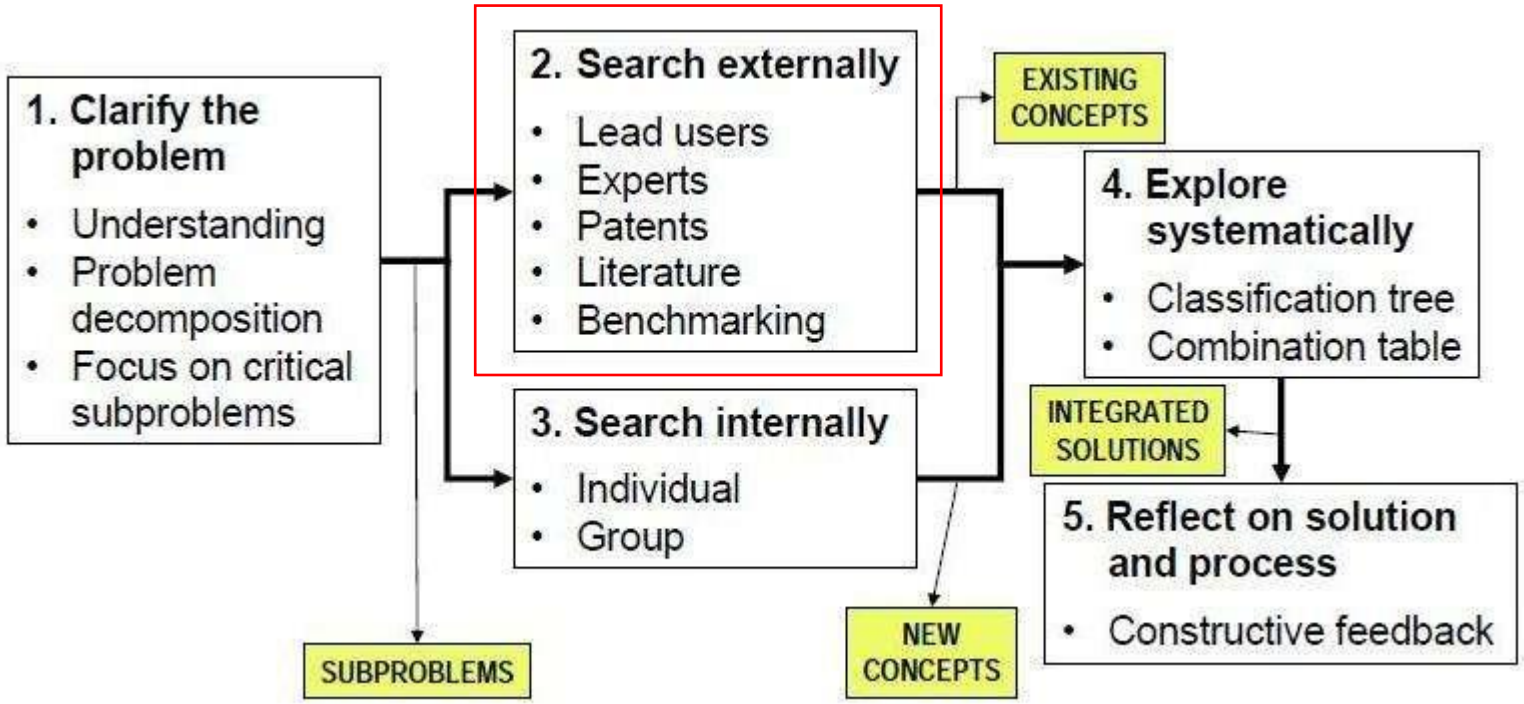
Concept Generation Process: Step 1

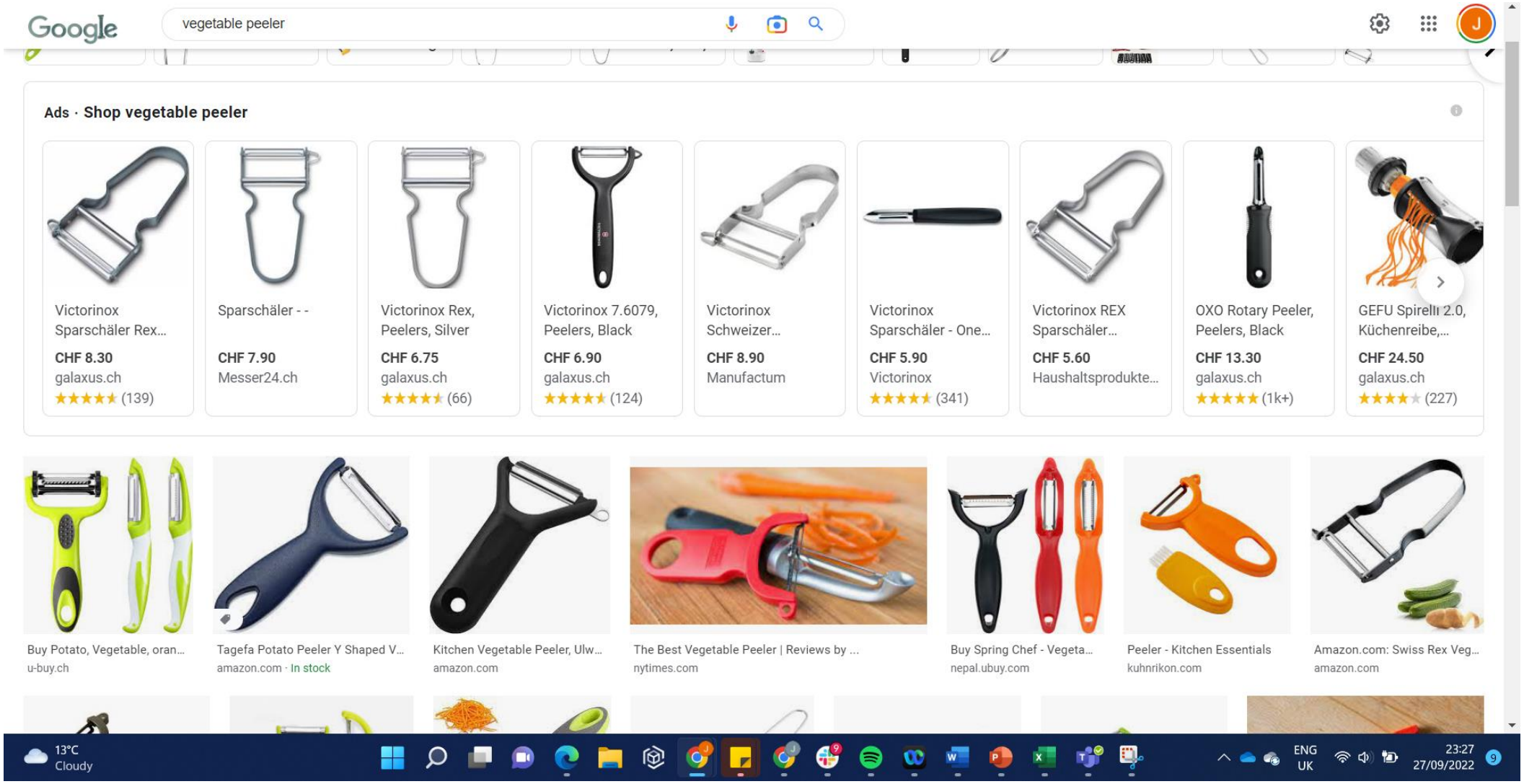
Functional Decomposition



Concept Generation Process: Step 2

Step 2: Search Externally




Google
vegetable peeler
Ads · Shop vegetable peeler
Victorinox Sparschäler Rex...
CHF 8.30
galaxus.ch
(139)
Sparschäler - -
CHF 7.90
Messer24.ch
Victorinox Rex, Peelers, Silver
CHF 6.75
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Victorinox 7.6079, Peelers, Black
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Victorinox Sparschäler - One...
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Victorinox REX Sparschäler...
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External and Internet Searches

Conduct external searches to find existing solutions to either the overall problem or a sub-problem identified during the decomposition step.

- Lead Users
  - see emerging needs before others
  - adopt and generate innovations first
- Benchmarking
  - competitive products
- Experts
  - technical experts
  - experienced customers
- Patents
  - search related inventions
- Literature
  - technical journals
  - conference proceedings
  - trade literature
  - government reports
  - consumer information

Try the European patent office:
http://ep.espacenet.com
• US patent office:
http://patft.uspto.gov

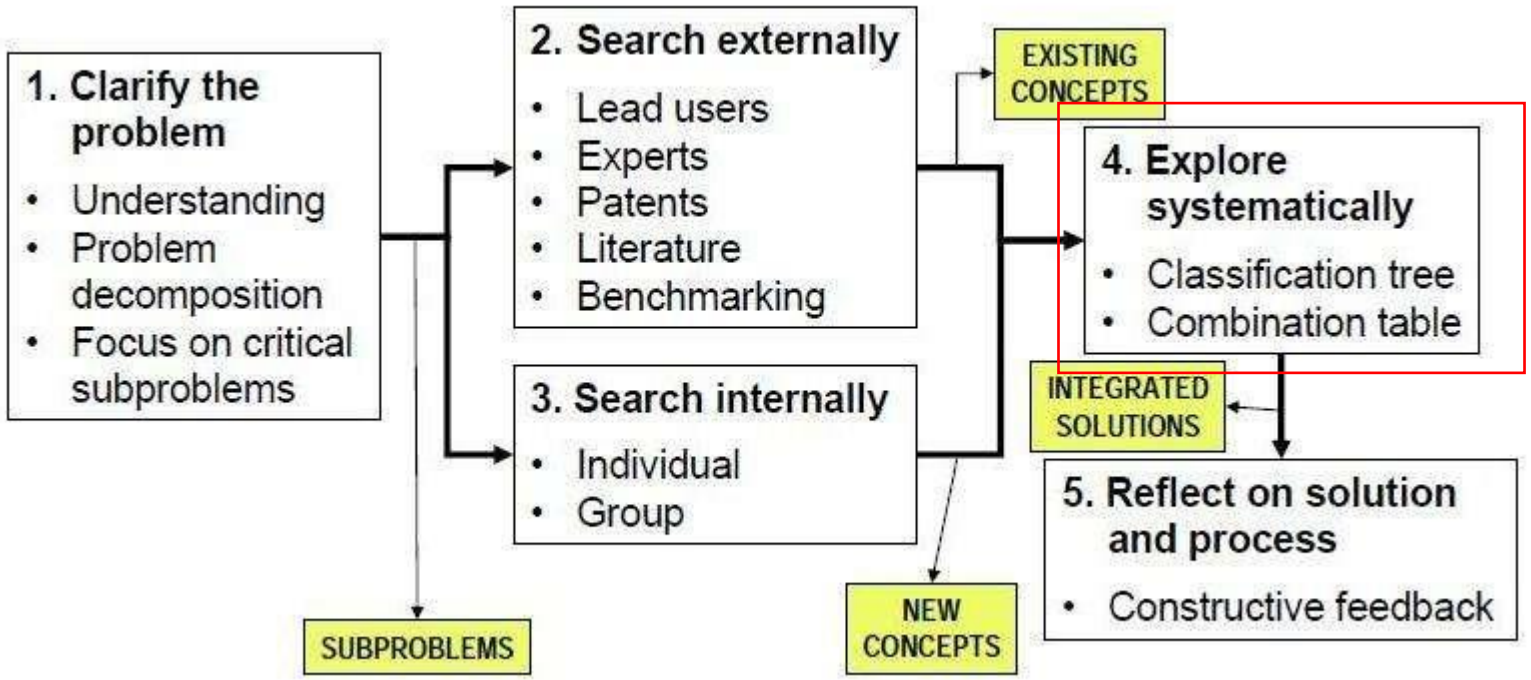
Concept Generation Process: Step 3

Search Internally (within your team): Practical Advice

- Suspend judgement – just ideate
- Generate lots of ideas (explore as much of the solution space as possible)
- Welcome ideas, even if they don't seem feasible
- Use graphical/physical means to discuss
- Make analogies (other designs/problems)
- Wish and wonder… I wonder what would happen if?
- Set quantitative goals – generate 20 concepts

Concept Generation Process: Step 4

Explore Systematically



Concept Generation Process: Step 4

Explore Systematically

After external and internal search there are probably tens or hundreds of solutions to subproblems, or concept fragments.

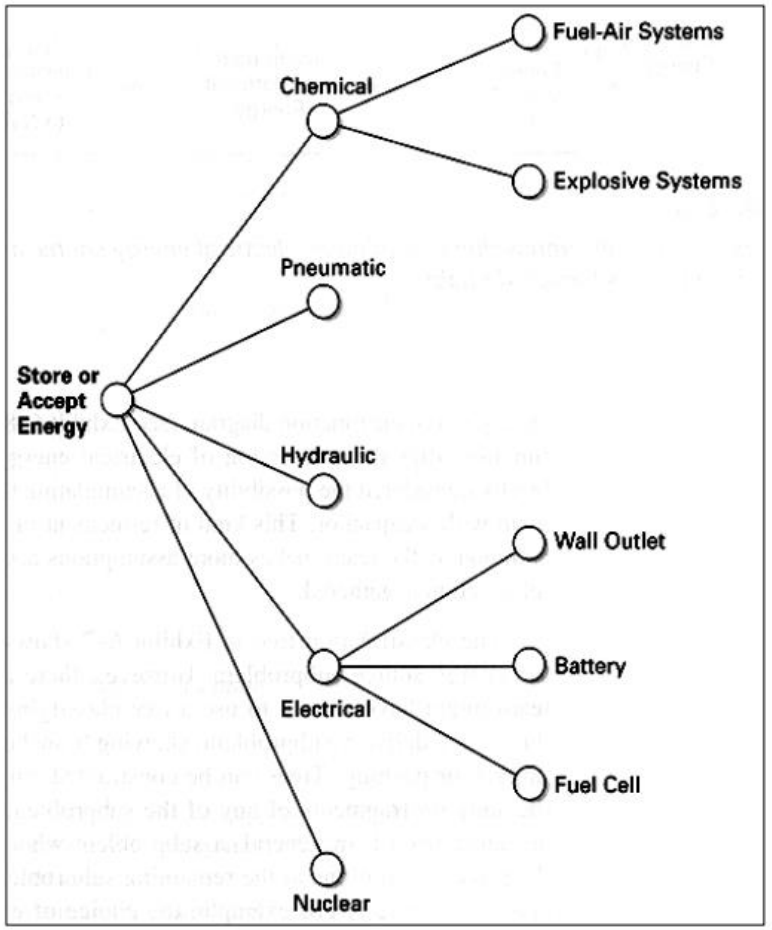
- Navigate the space of possibilities…
  - With the concept classification tree
  - With the concept combination table

Concept Generation Process: Step 4

Concept classification tree

- Prune less promising branches (carefully)
- Identify related verse independent approaches
- Highlight inappropriate emphasis (certain branches)
- Refine problem decomposition

For example, for an ‘electrically powered peeler’



Concept Generation Process: Step 4

Concept classification tree

- Prune less promising branches (carefully)
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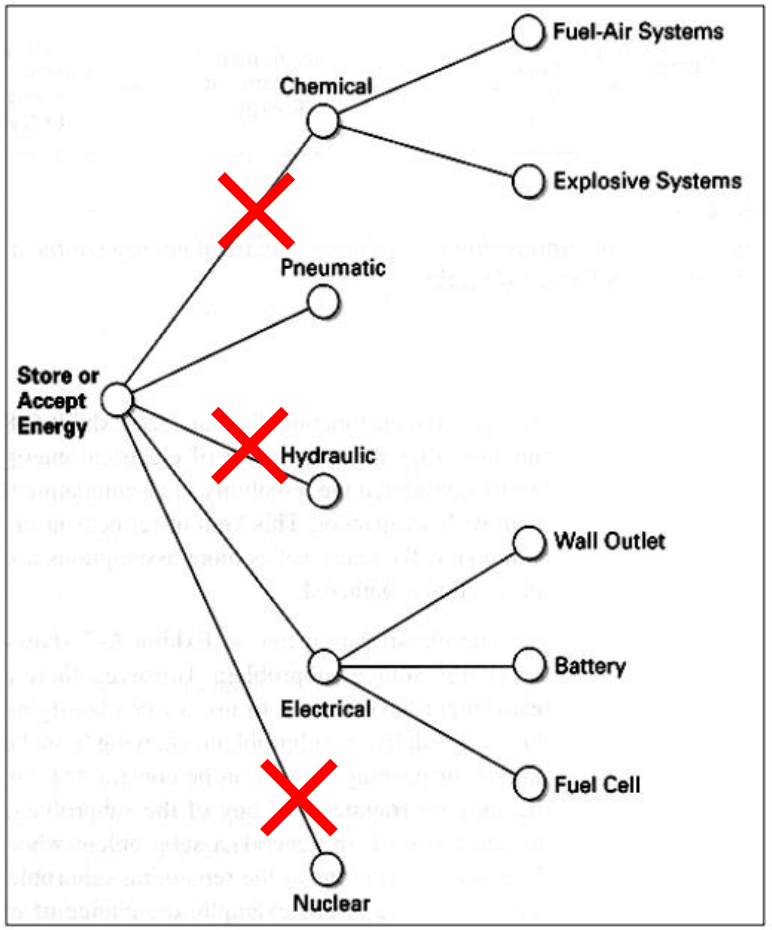
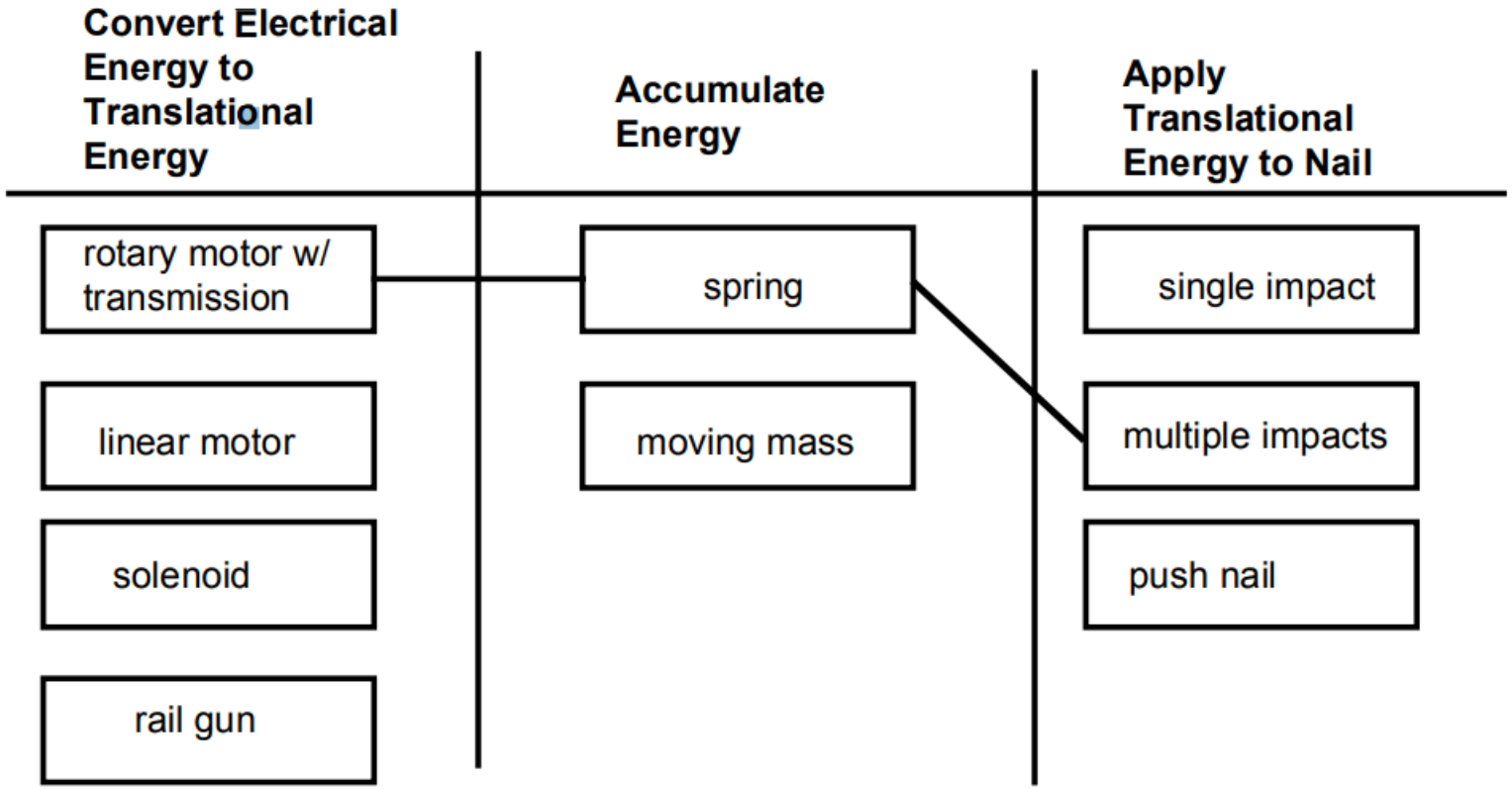
For example, for an ‘electrically powered nailer’



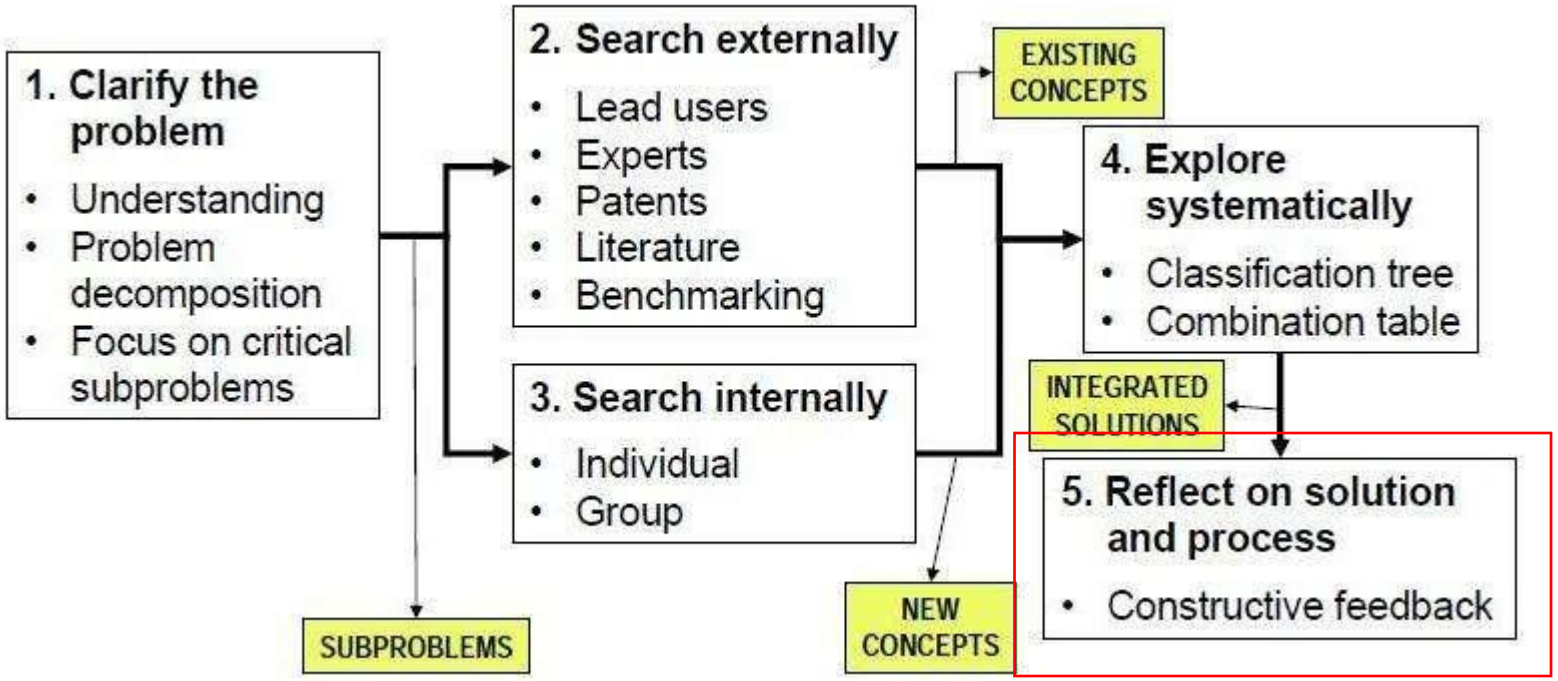
Concept combination table

Example for an ‘electrically powered nailer’



- Can systematically explore different combinations

Concept Generation Process: Step 5



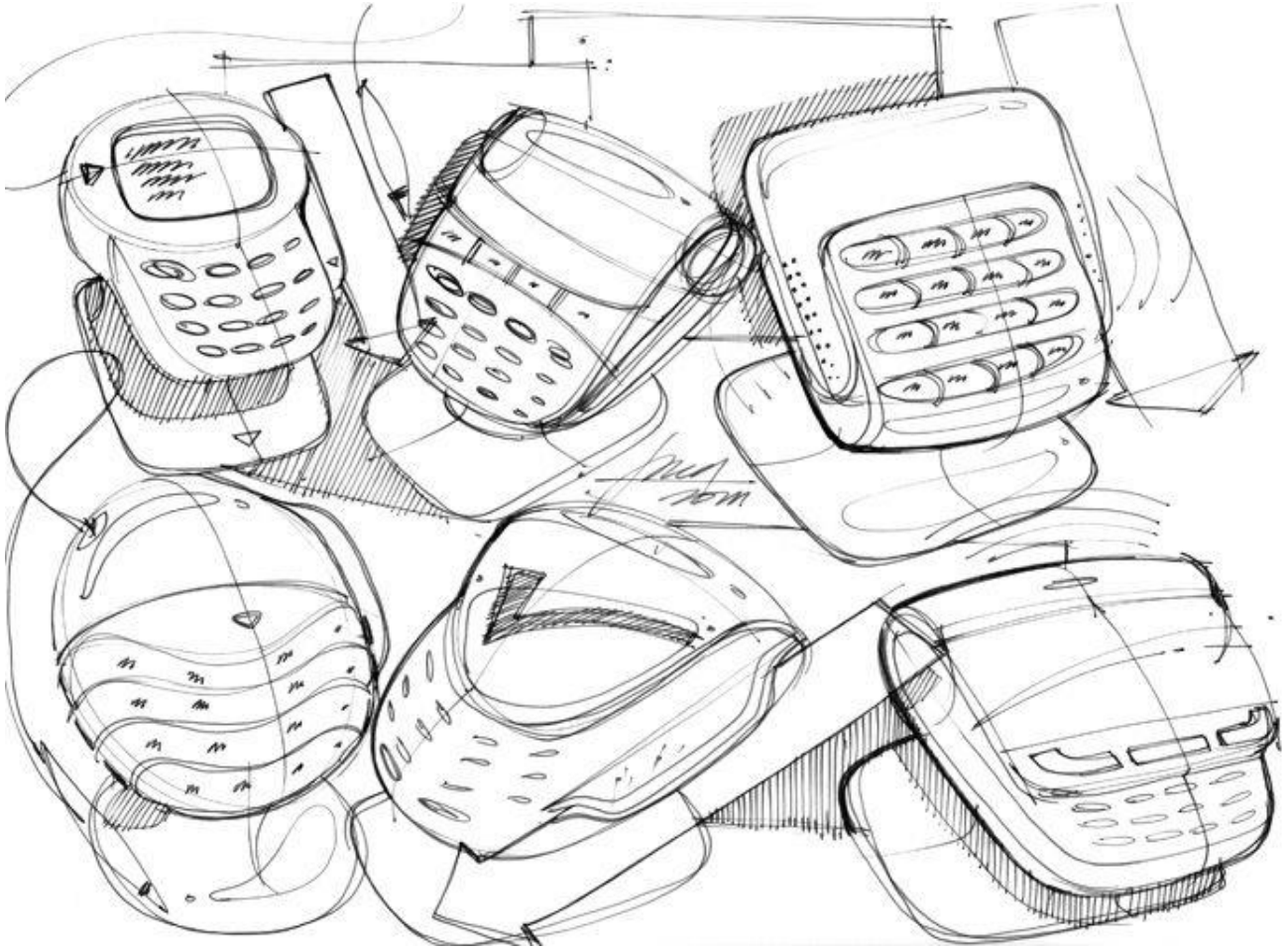
- Is the team developing confidence that the solution space has been fully explored?
- Are there alternative function diagrams?
- Are there alternative ways to decompose the problem?
- Have external sources been thoroughly pursued?
- Have ideas from everyone been accepted and integrated into process?

Concept Generation: Sketching

Product design sketching

Sketching **allows product designers to generate ideas quickly, without committing resources to any single idea**.
Allows for visual communication of an idea or a concept

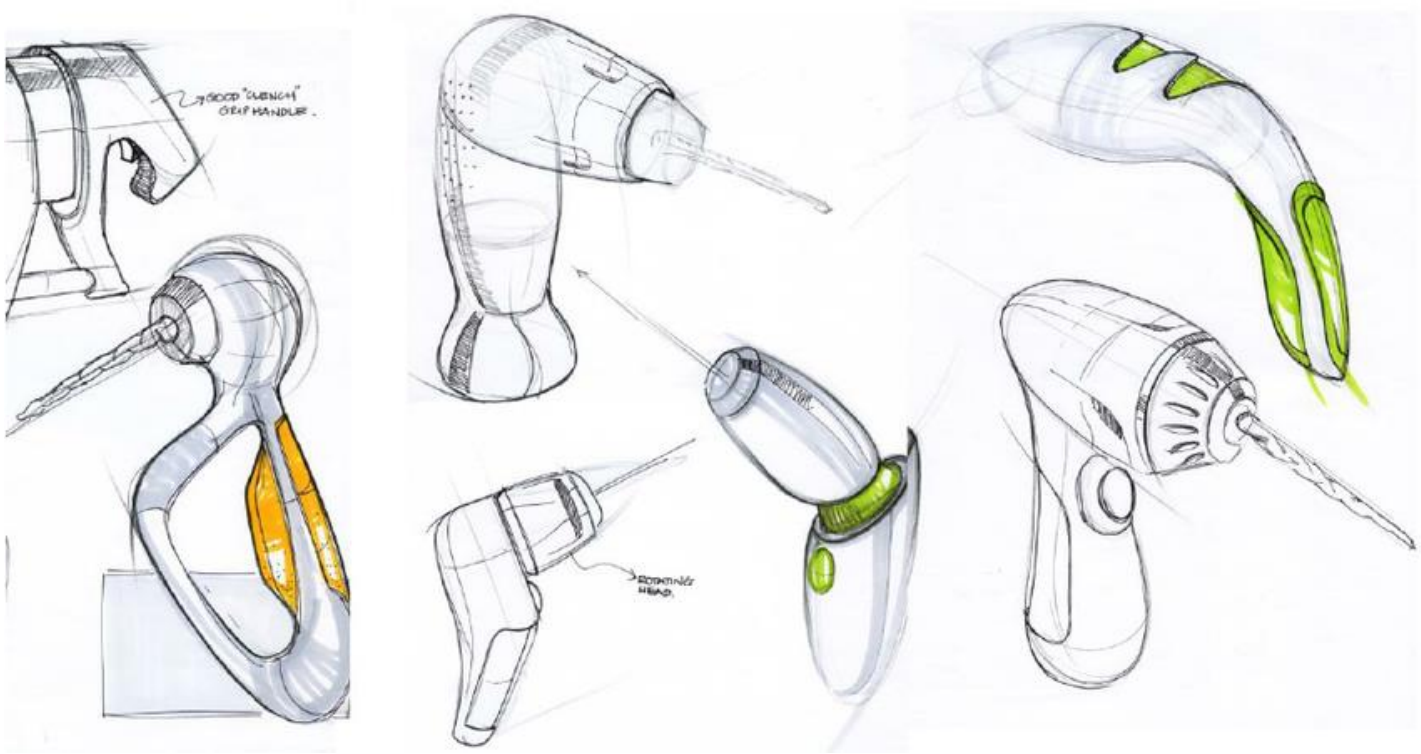
Illustrates concepts rapidly
Rapid Validation



Concept Generation: Sketching

‘Technical sketching’

- 3D can make it easier to convey an idea
- Clearly show function (or actuation) e.g. in another color
- Try using construction lines (light pencil), before then adding more dominant lines for the form
- Show multiple views
- Show exploded views

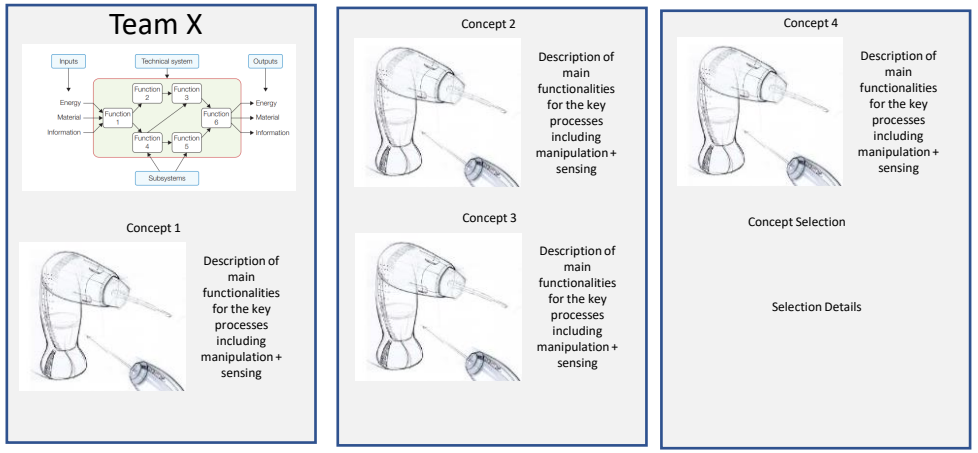


Project Work: Concept Generation & Selection

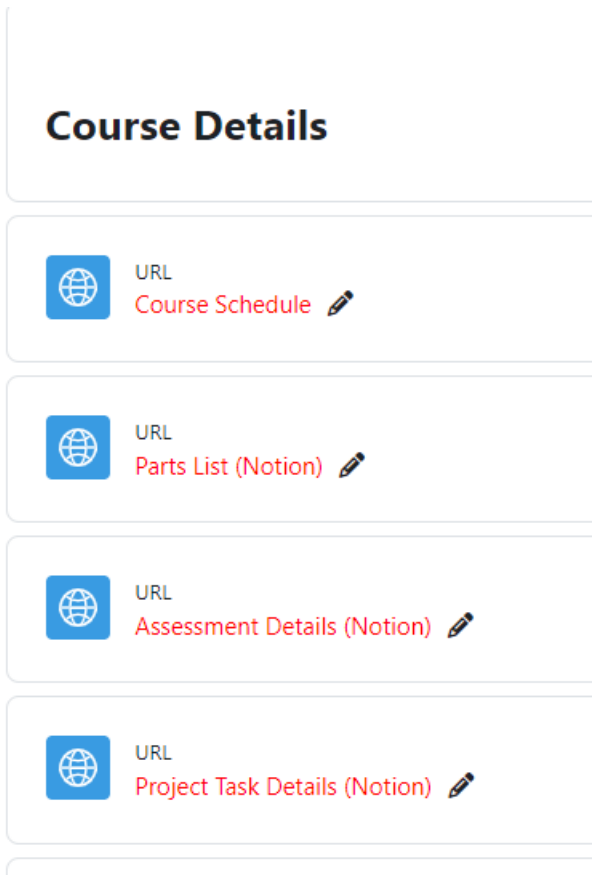
Break down the functionality you require in the gripper and represent in a functional diagram
Generate (lots of concepts within you team)
Evaluate and determine the best concept

You will need to hand in:

→ Functionality diagram
→ Examples of four concepts you have generated (mini sketch + short description)
→ Evaluation of which one you have chosen and why



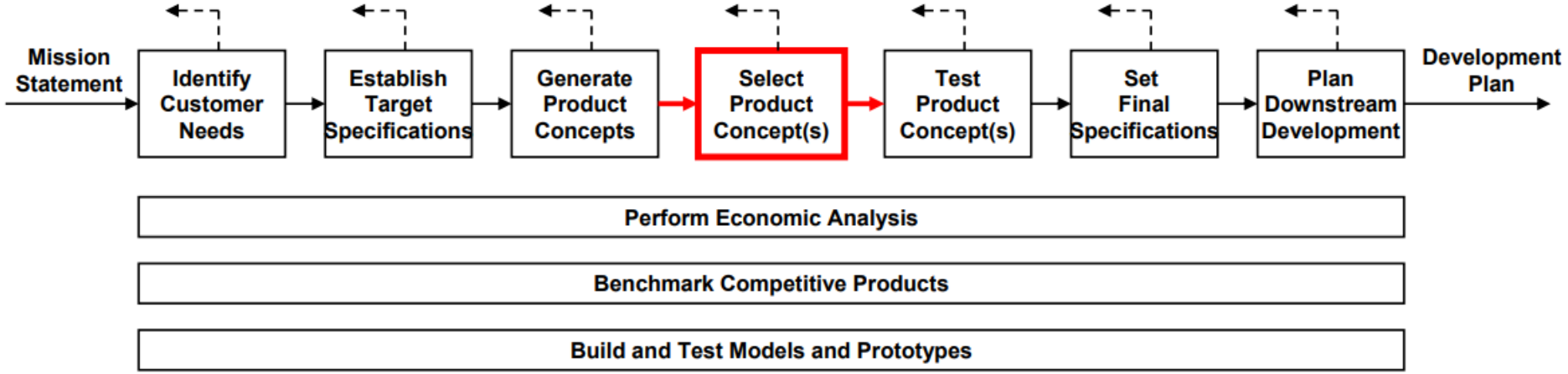
Project Details



Assessment Details:
https://flossy-quartz-a5a.notion.site/Assessment-Details-1923ea02ed1746bd84b0eaecaa62f9a1

Parts List:
https://flossy-quartz-a5a.notion.site/d5eb659cb9ed46ffba1ae9eb213a3da2?v=30835a3e1f104f6e8c3aa486966e6a46

Concept Selection



What concept(s) should be taken further?

Concept Selection: The methodology

- The concept selection process is based on two methodologies:

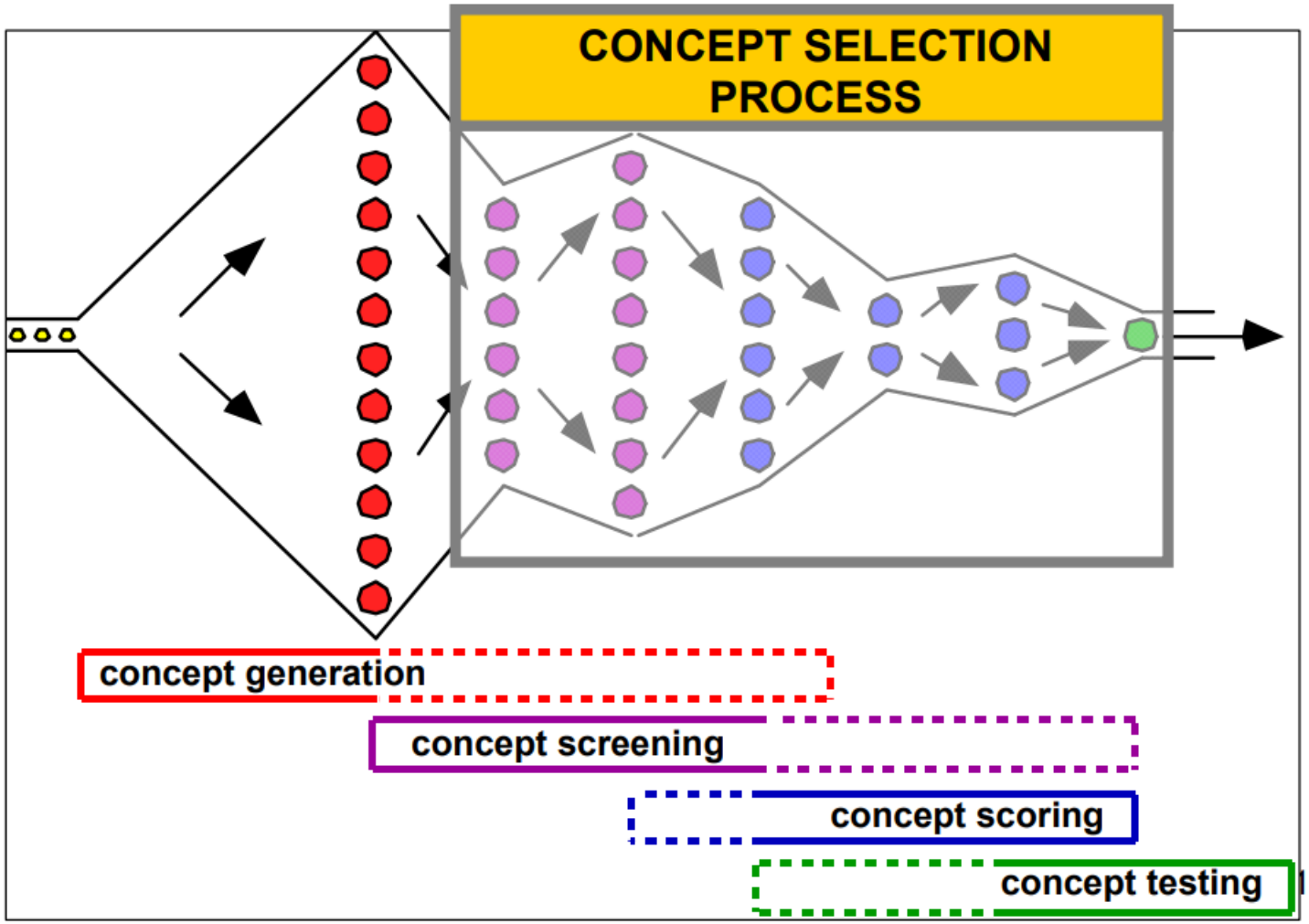
  - Concept Screening
  - Concept Scoring

To reduce the best concepts to refine further. Or to generate additional concepts

Select the final solution

- Concept screening is just for narrowing the number of concepts
- For a small number of concepts, go directly to concept scoring

Concept Selection Funnel



Concept Screening

Often called P**ugh Concept Selection**. The purpose is to narrow the number of concepts and improve the concepts.

- Step 1: Prepare the selection matrix
- Step 2: Rate the concepts
- Step 3: Rank the concepts
- Step 4: Combine and improve the concepts
- Step 5: Select one or more concepts
- Step 6: Reflect on results and process

Concept Screening

- Step 1: **Prepare the selection matrix**
  - *Enter **concept variants***
    - The same level of detail
    - Graphical and/or textual representation

SELECTION CRITERIA	CONCEPT VARIANTS							
	A	B	C	D	E	F	G	REF.
Ease of Handling								
Ease of Use								
Number Readability								
Dose Metering								
Load Handling								
Manufacturing Ease								
Portability								

Concept Screening

- Step 1: **Prepare the selection matrix**
  - *Choose **selection criteria***
    - Consider use of primary customer needs
    - Consider use of enterprise needs (price, manufacturability, etc.)
    - Choose criteria that differentiate your concepts
    - List criteria of similar importance
    - Do not list unimportant criteria

SELECTION CRITERIA	CONCEPT VARIANTS							
	A	B	C	D	E	F	G	REF.
Ease of Handling								
Ease of Use								
Number Readability								
Dose Metering								
Load Handling								
Manufacturing Ease								
Portability								

Concept Screening

- Step 1: **Prepare the selection matrix**
  - *Choose **reference concept***
    - Could be industry standard, best-in-class benchmark, top seller, an early concept, a new concept or one of the considered concepts
    - Pick a reference that will allow you to <u>differentiate</u> your concepts

	CONCEPT VARIANTS							
SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
Ease of Handling								
Ease of Use								
Number Readability								
Dose Metering								
Load Handling								
Manufacturing Ease								
Portability								

Concept Screening

- Step 2: **Rate the concepts**
  - Rate the concepts - assign relative scores
    - "better than" (+)
    - "same as" (0)
    - "worse than" (-)
  - Use objective metrics if possible

	CONCEPT VARIANTS							
SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0

Concept Screening

- Step 3: **Rank the concepts**
  - The sum of all the “better than” “same as” and “worse than”

SELECTION CRITERIA	CONCEPT VARIANTS A	B	C	D	E	F	G	REF.
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0
PLUSES	3	2	2	1	2	2	2	
SAMES	4	3	1	5	5	2	3	
MINUSES	0	2	4	1	0	3	2	
NET	3	0	–2	0	2	–1	0	
RANK	1	3	7	5	2	6	4	
CONTINUE?	Yes	Yes	No	No	Yes	No	Yes	

Concept Screening

Is there a concept that is generally good but degraded by one bad feature?

Can a minor modification improve the overall concept while remaining distinct from the other concepts?

Are there two concepts which can be combined to preserve the “better than” qualities while eliminating the “worse than” qualities?

- Step 4: Combine and improve the concepts

	CONCEPT VARIANTS							
SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0
PLUSES	3	2	2	1	2	2	2	
SAMES	4	3	1	5	5	2	3	
MINUSES	0	2	4	1	0	3	2	
NET	3	0	–2	0	2	–1	0	
RANK	1	3	7	5	2	6	4	
CONTINUE?	Yes	Yes	No	No	Yes	No	Yes	

- Combine D + F = **DF**
- Improve G = **G+**

Concept Screening

- Step 5: **Select one or more concepts**
  - The number of concepts selected for further review will be limited by team resources (personnel, money, and time)
  - The team must clarify which issues need to be investigated further before a final selection can be made.
    - Another round of concept screening?
    - Will concept scoring be applied next?

The goal of concept selection is not to → Select the best concept.
The goal of concept selection is to → Develop the best concept.
….So remember to combine and refine the concepts to develop better ones

Concept Scoring

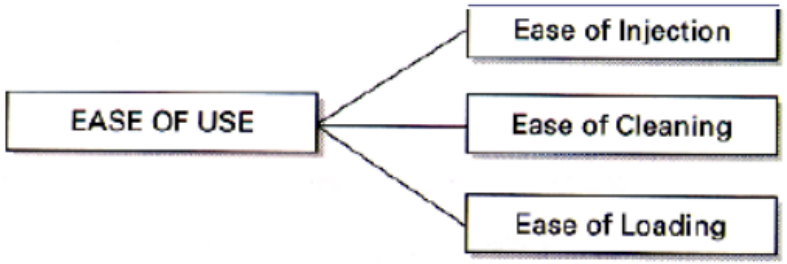
- Used when increased resolution (detail) will better differentiate among competing concepts
- A more quantitative version of concept screening

- Step 1: Prepare the selection matrix
- Step 2: Rate concepts
- Step 3: Rank concepts
- Step 4: Combine and improve concepts
- Step 5: Select one or more concepts
- Step 6: Reflect on results and process

Relative Performance	*Rating*
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Concept Scoring

- Step 1: **Prepare the selection matrix**
  - *Choose **selection criteria***
    - Consider more detailed selection criteria



  - *Include **importance weights** for the criteria*
    - 1 to 5
    - allocating 100% among all
  - *Choose **reference concept***
    - Different reference concepts may be used for each criterion to avoid scale compression
    - Average performance concept, benchmarked concept, target values for product specifications

Concept Scoring

- Step 2: **Rate the concepts**
  - *Choose **scale*** (1 to 5, or 1 to 9)
    - Reference point is in the middle

Relative Performance	*Rating*
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

  - Assign relative scores to the concepts
    - For each criterion consider the performance of each concept relative to the reference point

Concept Scoring

- Step 3: **Rank the concepts**
  - Calculate weighted scores by multiplying the raw scores by the criteria weights

$$S_j = \sum_{i=1}^{n} r_{ij} w_i$$

where

r_{ij} = raw rating of concept j for the ith criterion
w_i = weighting for ith criterion
n = number of criteria
S_j = total score for concept j

		Concepts							
		A Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of Handling	5%	3		3		4		4	
Ease of Use	15%	3		4		4		3	
Readability of Settings	10%	2		3		5		5	
Dose Metering Accuracy	25%	3		3		2		3	
Durability	15%	2		5		4		3	
Ease of Manufacture	20%	3		3		2		2	
Portability	10%	3		3		3		3	

Concept Scoring

		Concepts							
		A Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of Handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of Use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of Settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose Metering Accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of Manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
Total Score		2.75		3.45		3.10		3.05	
Rank		4		1		2		3	
Continue?		No		Develop		No		No	

Concept Scoring

Step 4: Combine and improve the concepts

- Look for changes and combinations that improve the concept

Step 5: Select one or more concepts

- Check sensitivity of selection to the importance weightings and ratings.
- Consider uncertainty about ratings

The goal of concept selection is not to → Select the best concept.
The goal of concept selection is to → Develop the best concept.
….So remember to combine and refine the concepts to develop better ones

What happens after concept selection?

What happens after concept selection?

Product Generation & Prototyping!

Engineering Design:

- Actuators
- Mechanism
- Sensors
- Control

Practical Implementation (aka how to..):

- Fabricate/3D print
- Use microcontrollers
- Prototype

Project Work

Component	% of grade	Deadline
0. Teams & DLL Safety	-	Week 2
1. Concept Section & Gantt Chart	20%	Week 5
2. Drawings & Schematics, Patent & Literature Review	20%	Week 14
3. One minute pitch video	10%	Week 13
4. Gripper Performance (Competition)	30%	Week 14
5. 2 Page Final Report	20%	2 weeks later
Returning of parts	-20%	

Deadlines are Tuesday midnight for that week unless stated otherwise