

Workshop Teaching Systems Engineering

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Abstract

Teaching systems engineering, a transdisciplinary field, requires a fitting pedagogic approach. Developing as a systems engineer requires on the job practice and life-long learning. This workshop addresses how can we facilitate learning through active learning and using a case.

Distribution

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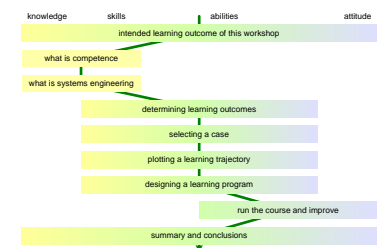
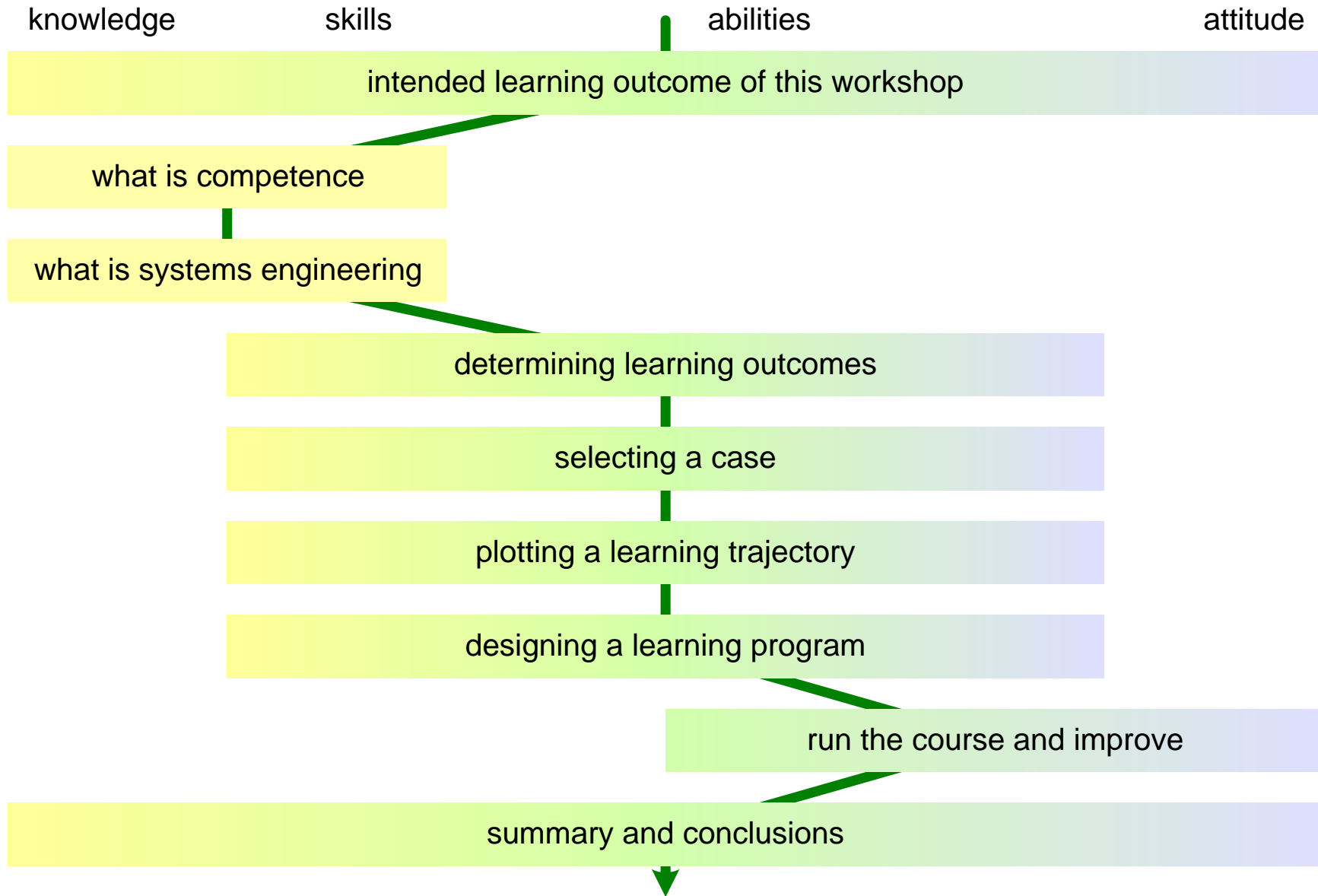


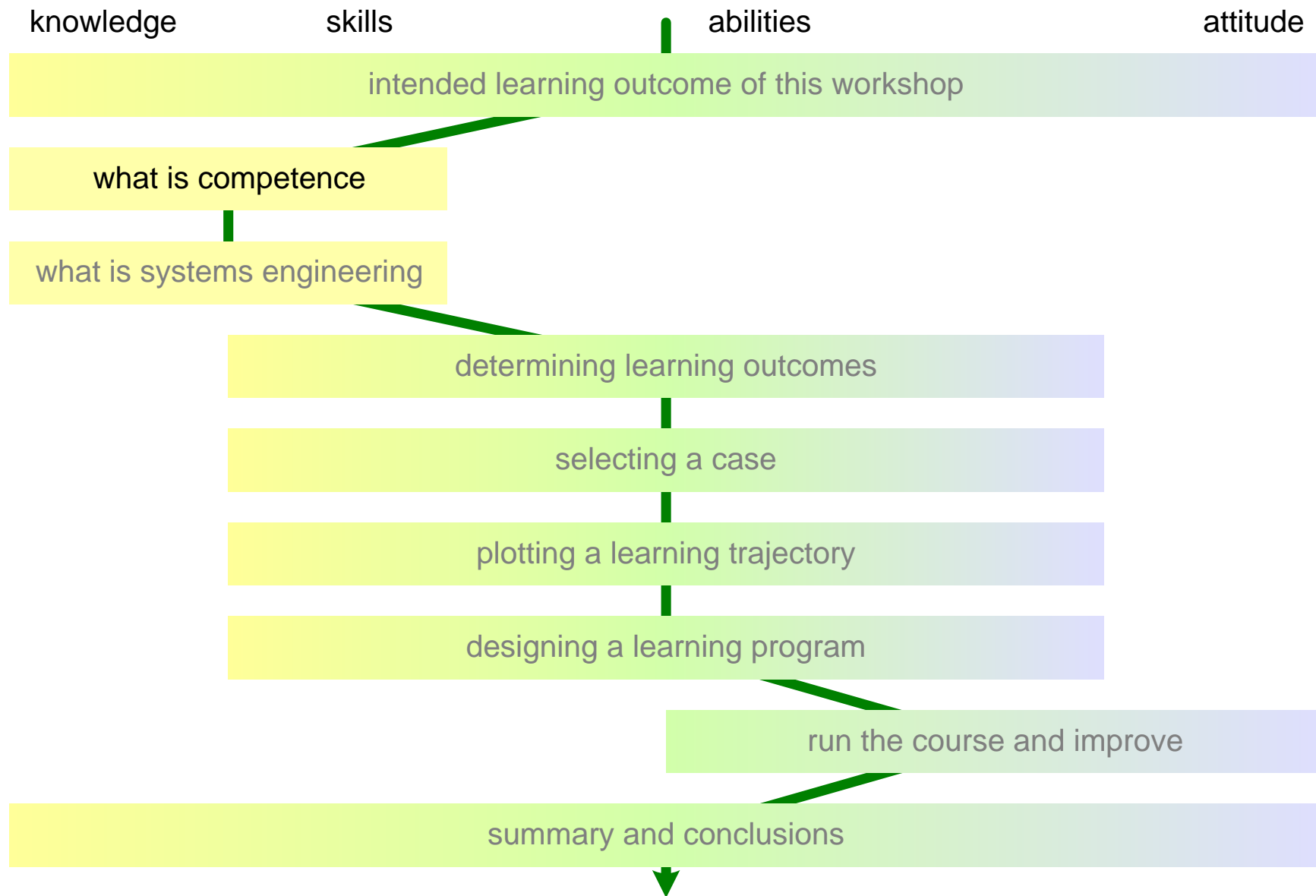
Figure of Content



Intended Learning Outcome of This Workshop

- How to develop an active-learning based course
- Suitable for systems engineering education
- Starting at the end:
 - H2 Determine desired learning outcomes
 - H2 to select a case?
 - Plot a learning trajectory in term of in-class assignments
 - Make a program with limited lecturing, assignments, discussions, and reflection
 - Plan a course ASAP, perform the course, evaluate often, and improve
- Some theory:
 - What is competence?
 - What is Systems engineering?

What is Competence?



Competency Layers Building on Each Other

Attitude (perseverance, faith, critical, constructive, etc.)

train

Ability (know when to use what skill and knowledge)

apply/use often, experience

Skills (calculate missing angle, calculate hypotenusa)

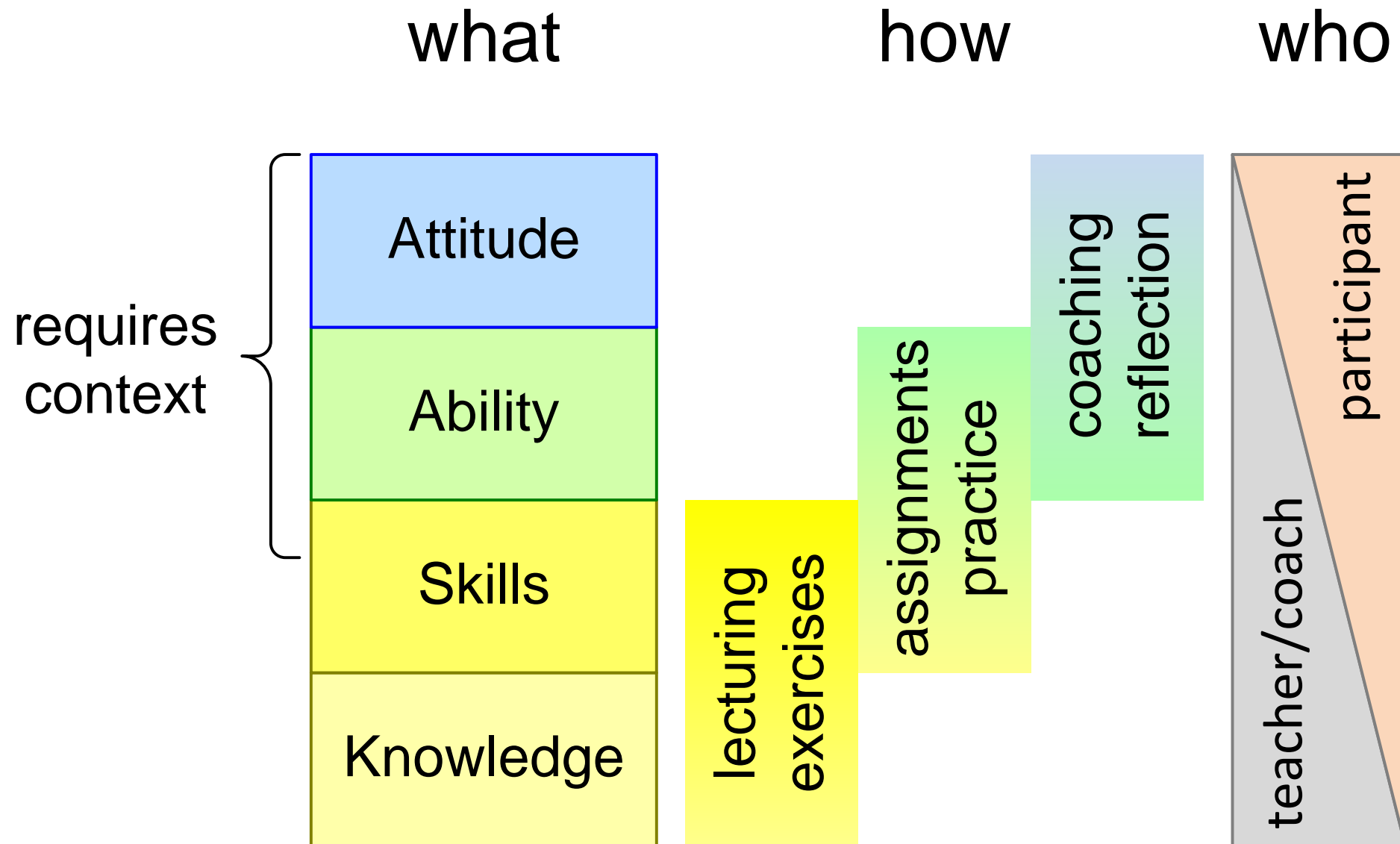
exercise

Knowledge (triangle has 3 corners, sum of angles is 180 degrees, Pythagoras $c^2 = a^2 + b^2$)

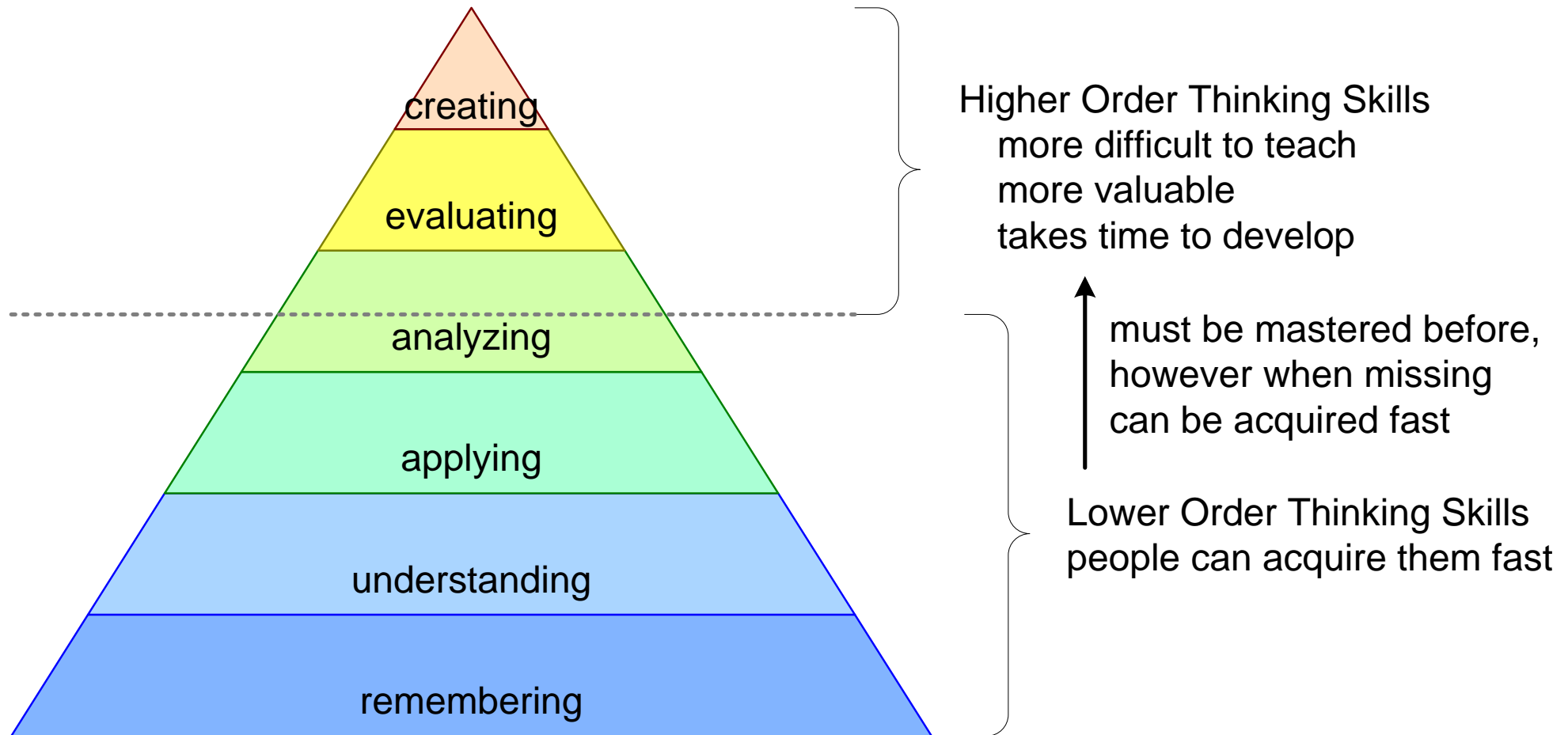
learn

Competence = Knowledge + Skills + Ability + Attitude

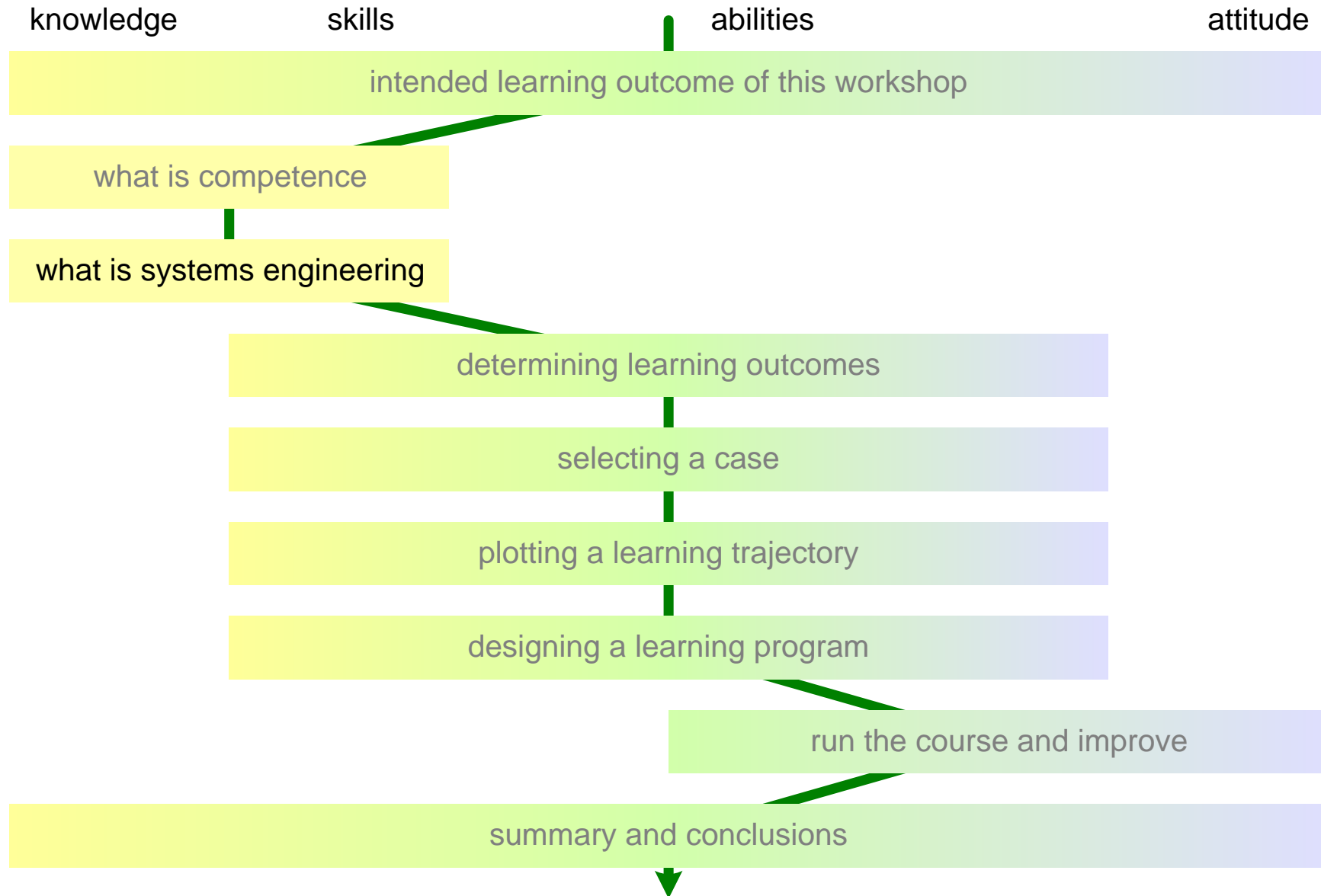
Life-Long Learning of SE Focuses on Attitude and Ability



Bloom's Taxonomy and Higher Order Thinking Skills



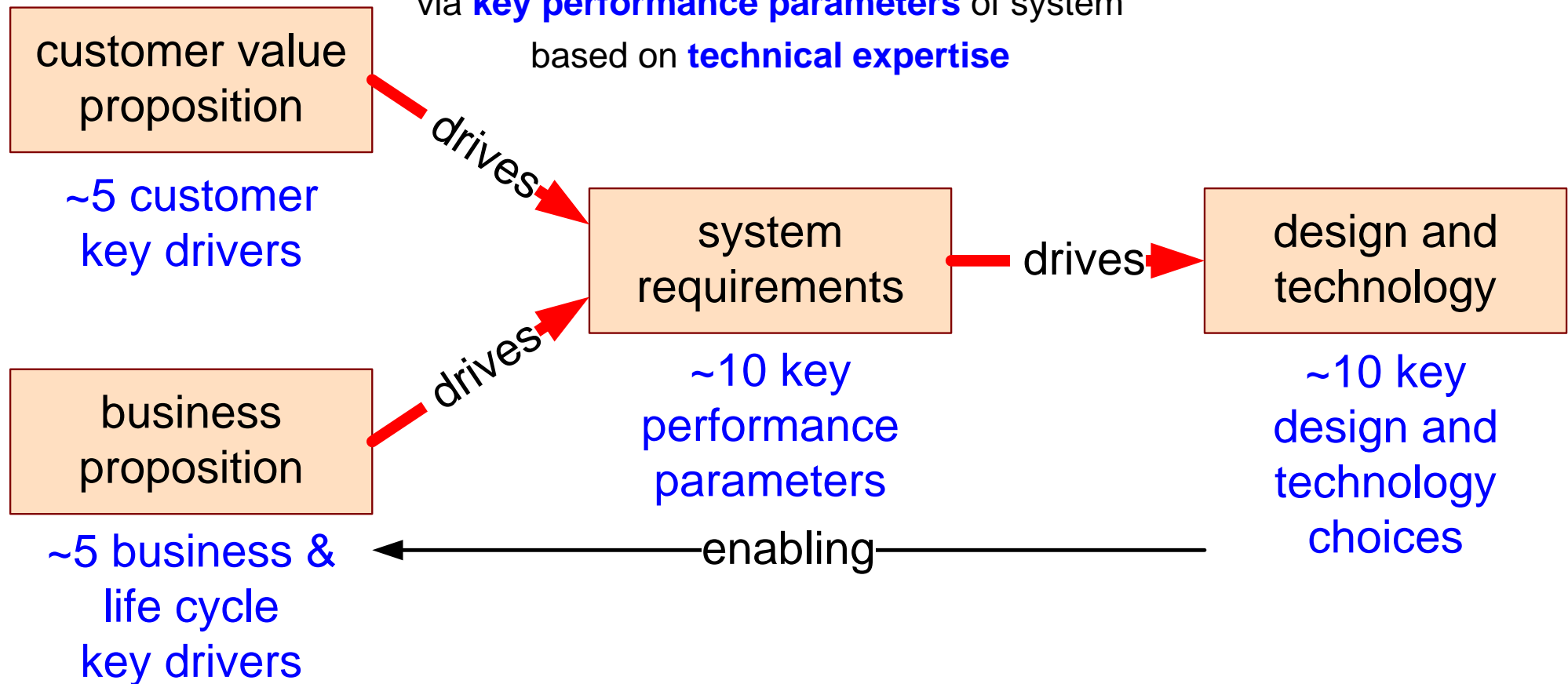
What is Systems Engineering?



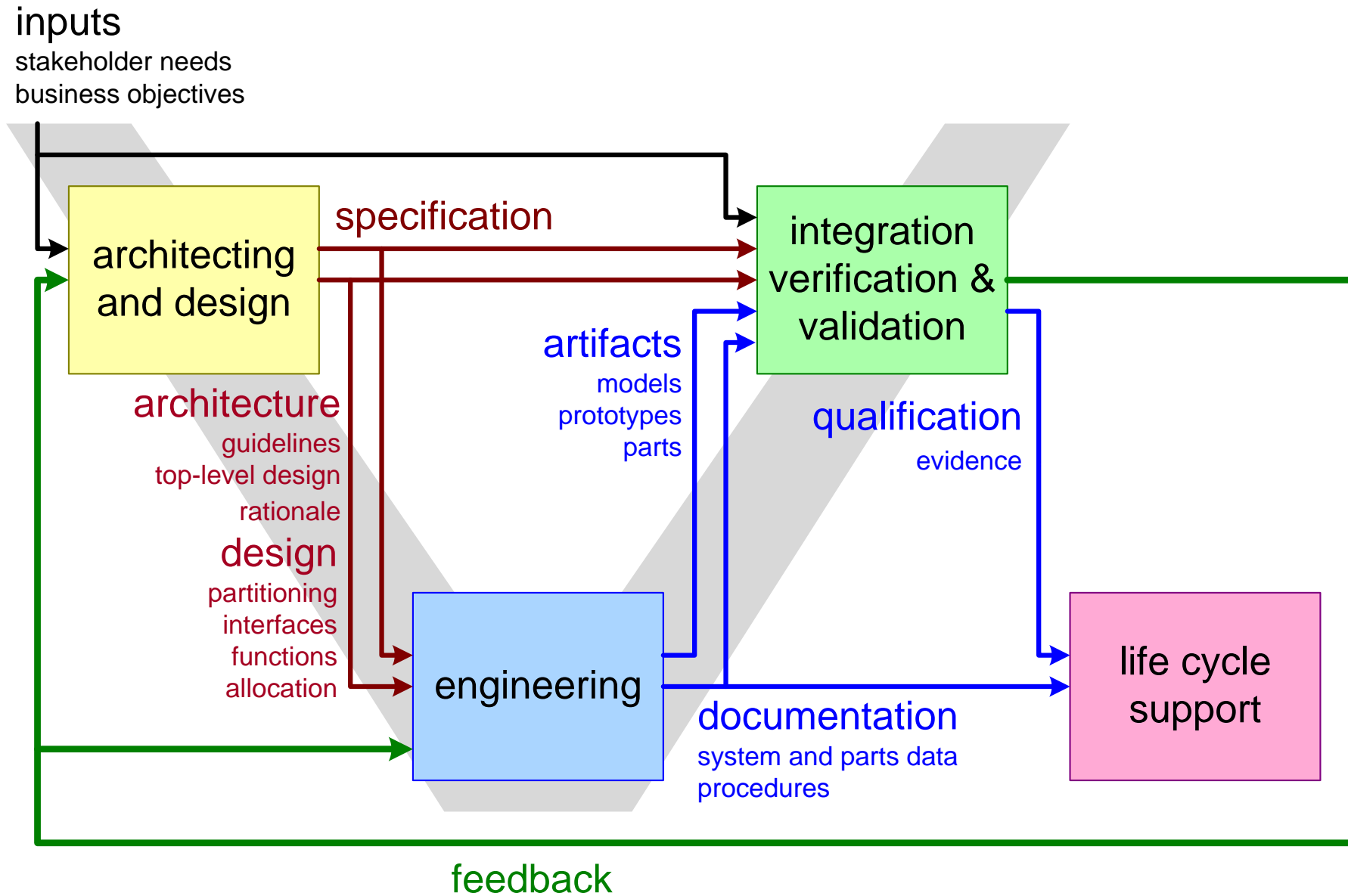
The Essence of Systems Engineering: Fitness-for-Purpose

Systems Engineering: *Fitness-For-Purpose*

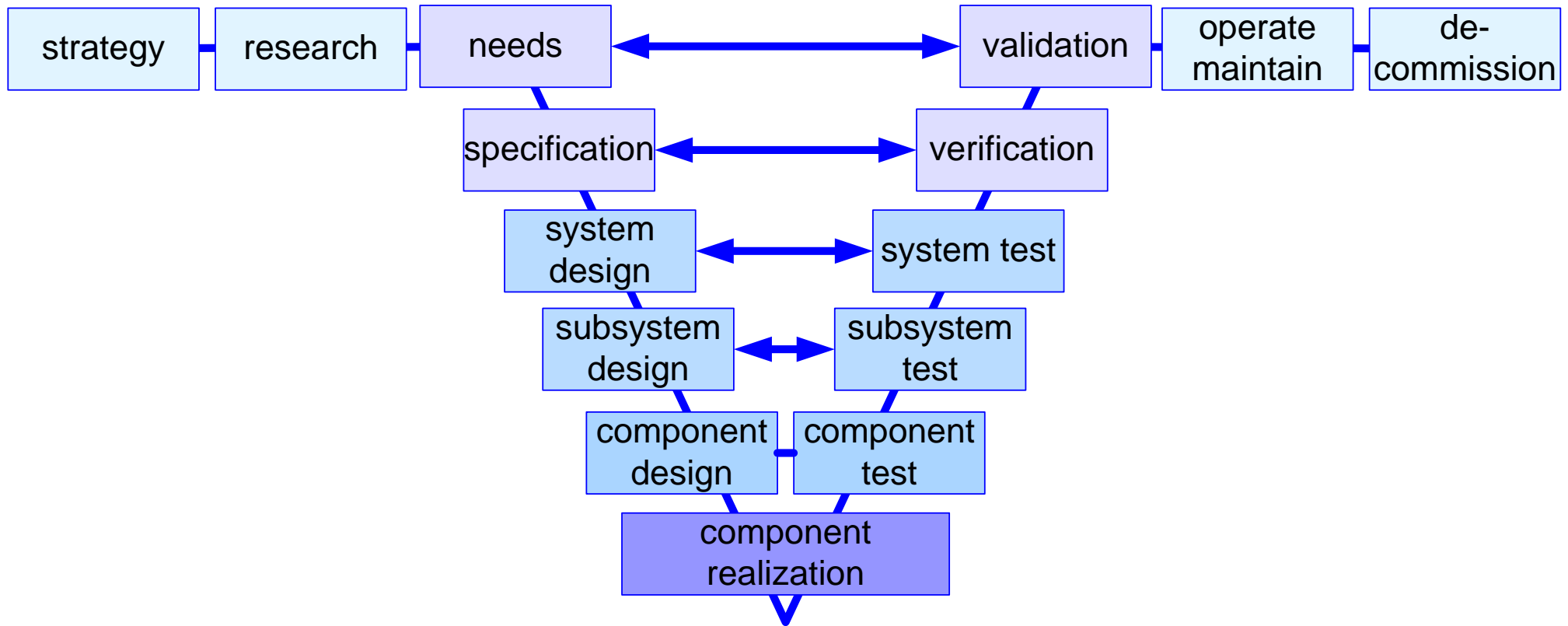
Achieving **customer** and **business key drivers**
via **key performance parameters** of system
based on **technical expertise**



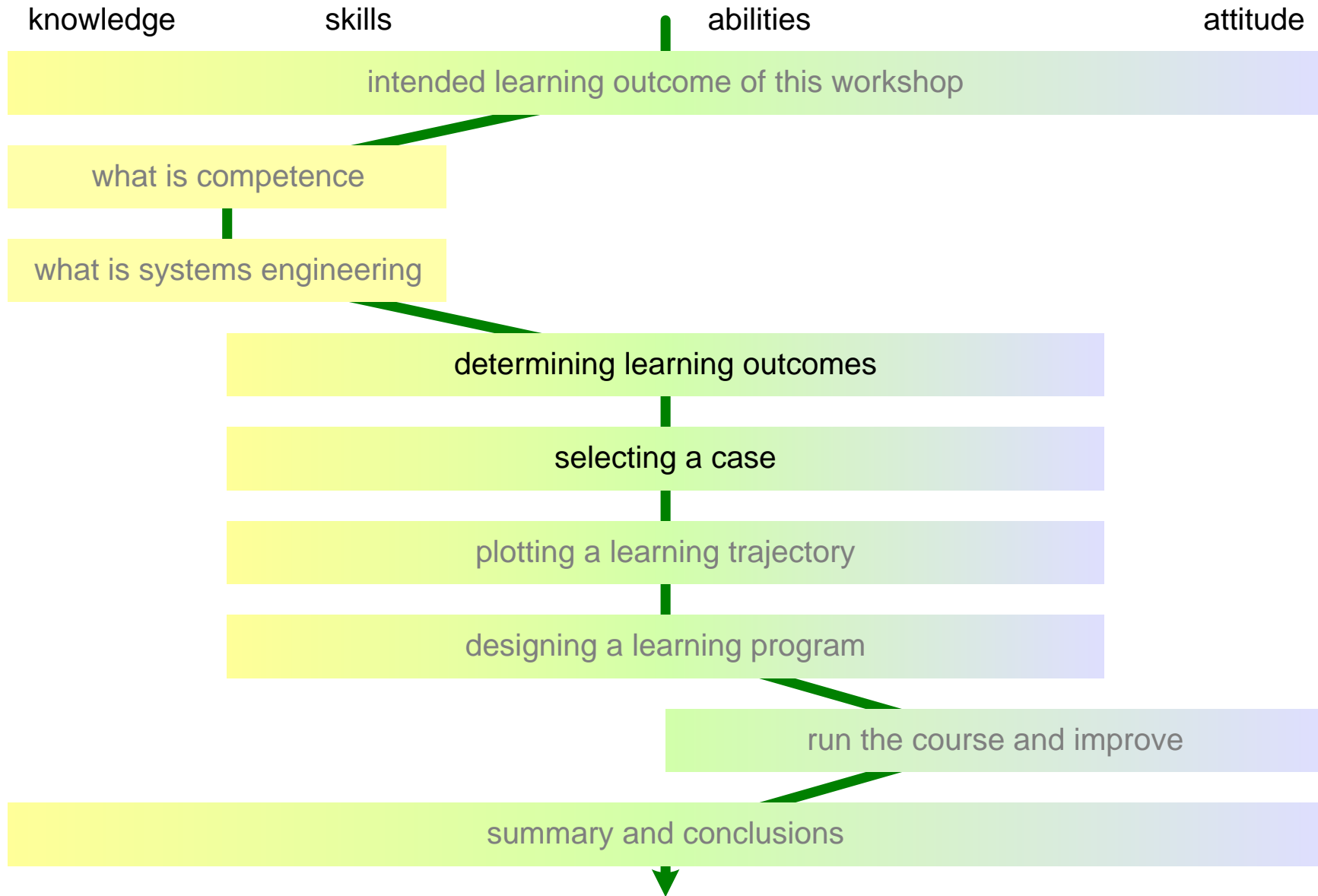
The simplified V-model



Extended V-Model is a Useful Framework



Determining Learning Outcomes and Selecting a Case



Determine the Desired Learning Outcomes

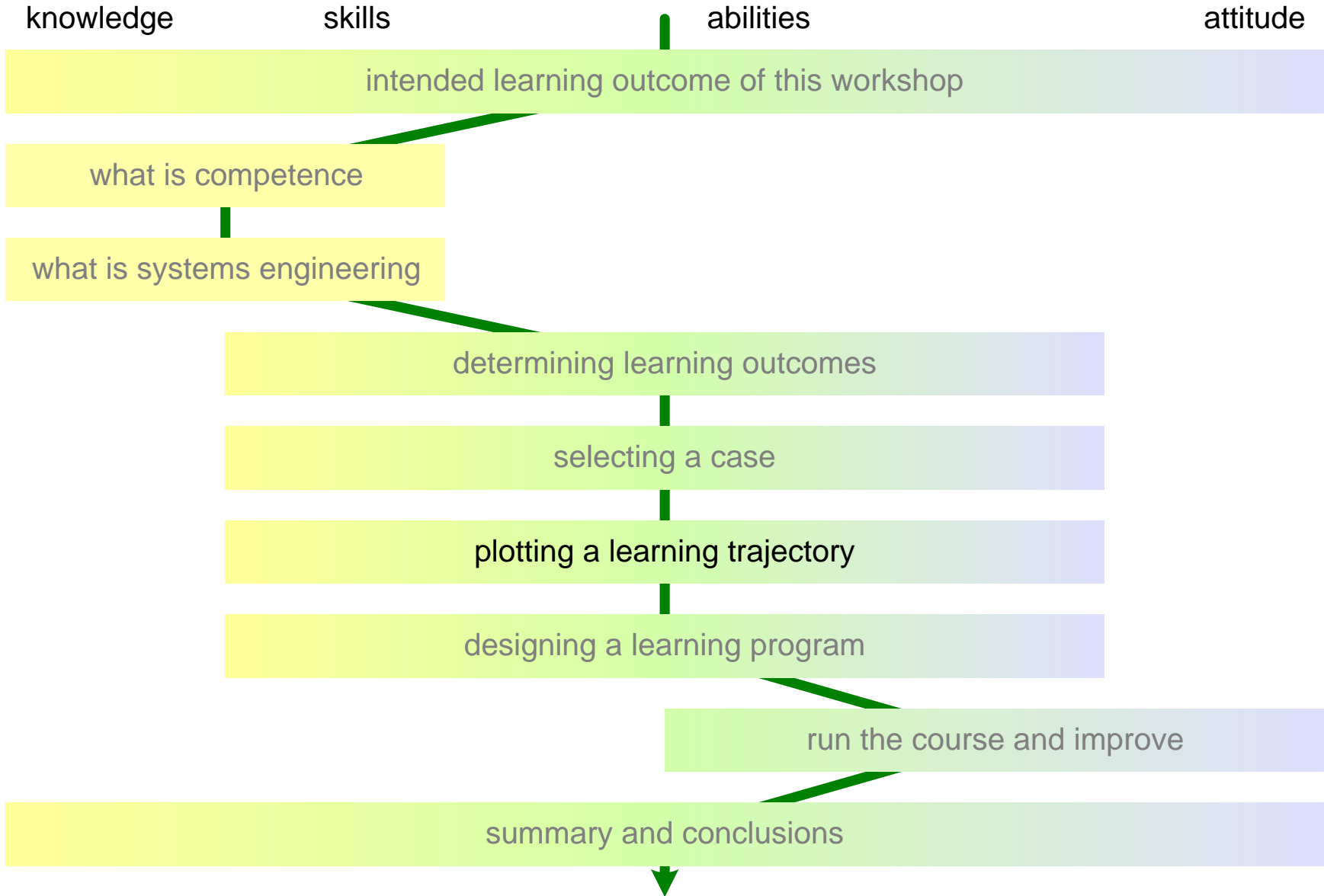
- What is the course topic?
- Who is the target audience?
- What learning outcomes do you want to achieve at the end of the course?
 - Knowledge
 - Skills
 - Abilities
 - Attitude
- Where do you want participants to be one year after the course?

Select a Case to Use as Learning Vehicle

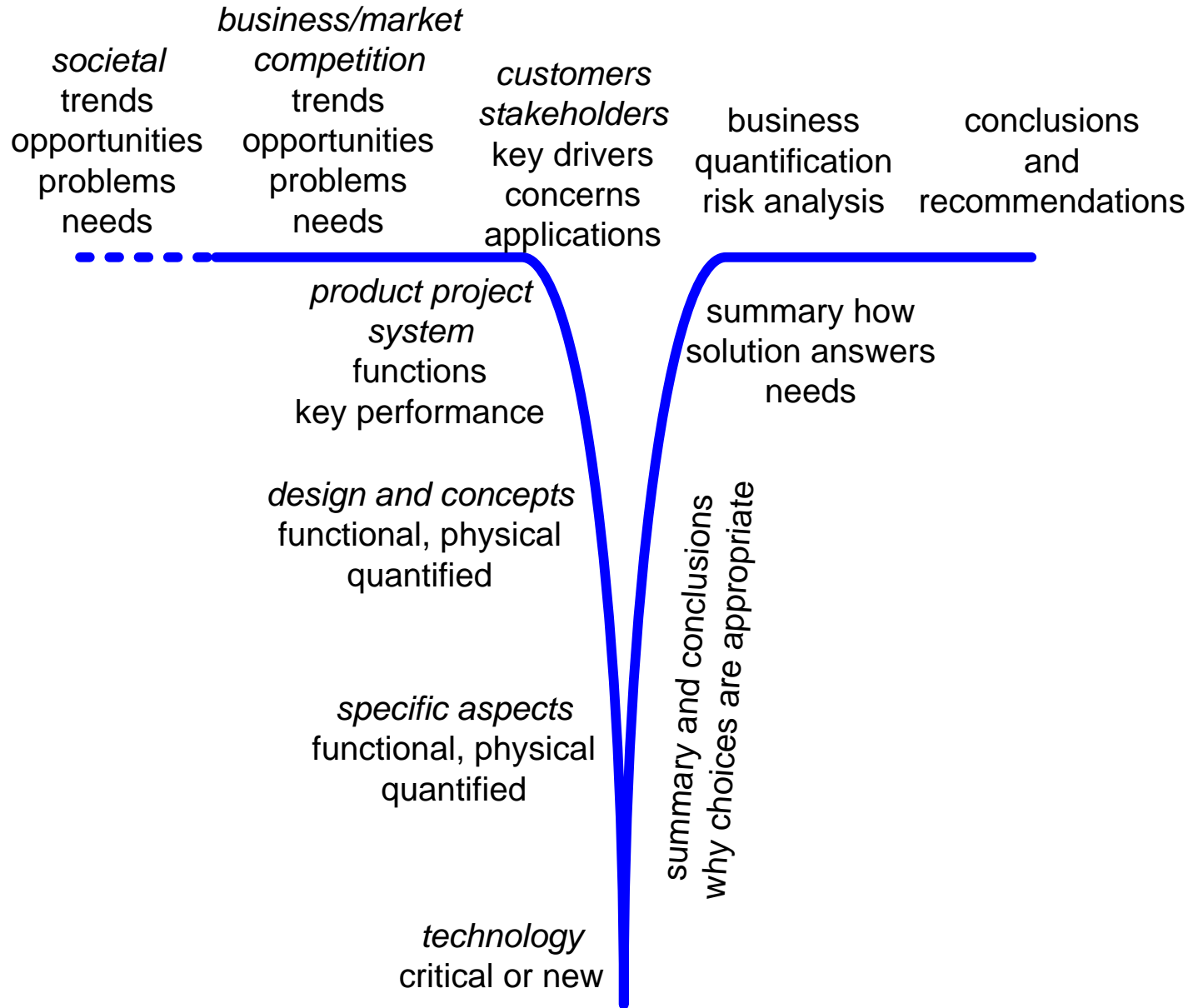
- What is close to the experience of the participants?
 - Participants shouldn't need much time to get domain knowledge, since they should focus on the competency rather than domain knowledge
- What case has the main pitfalls build-in?

For examples of cases see the slides at the end of this presentation

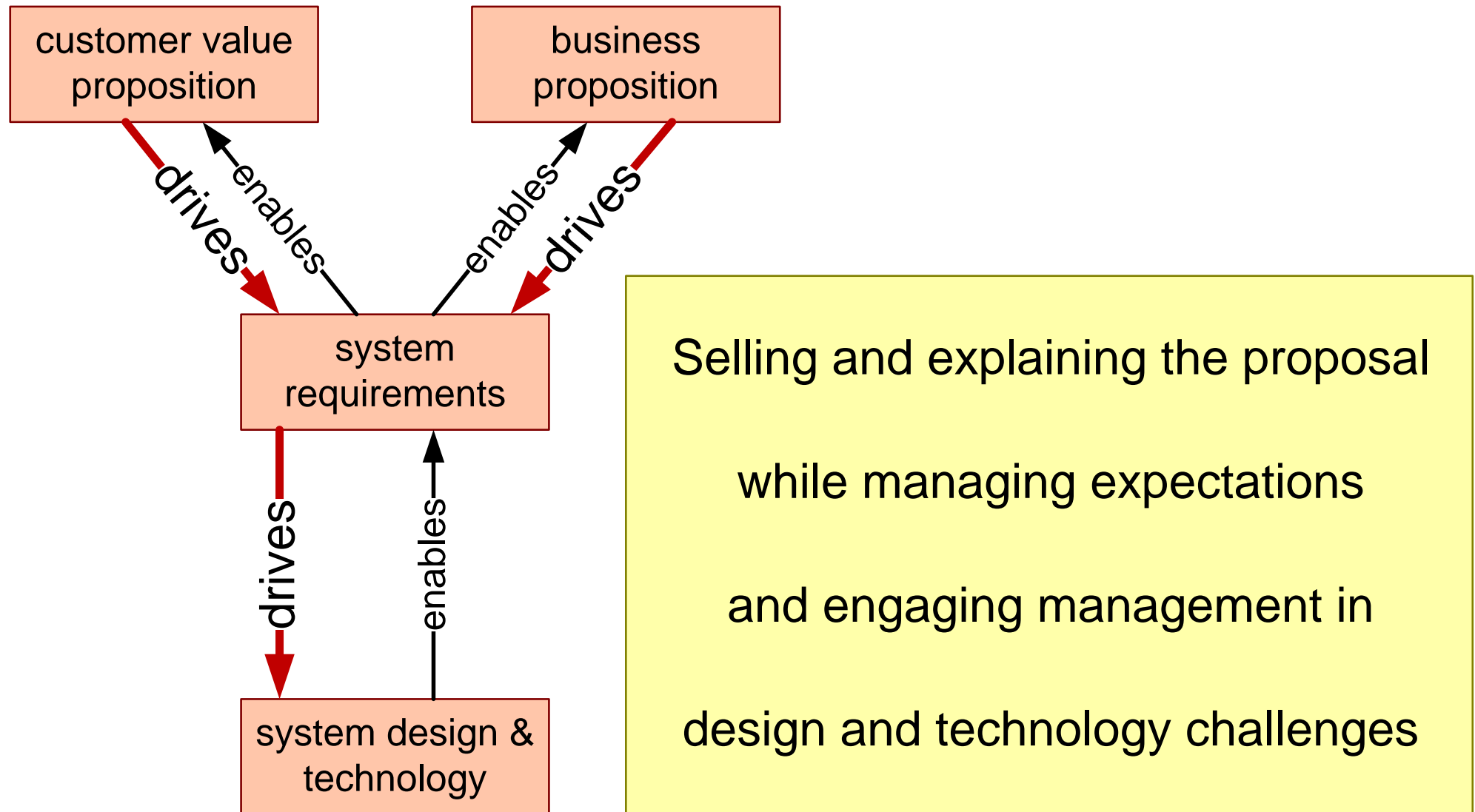
Plotting a Learning Trajectory



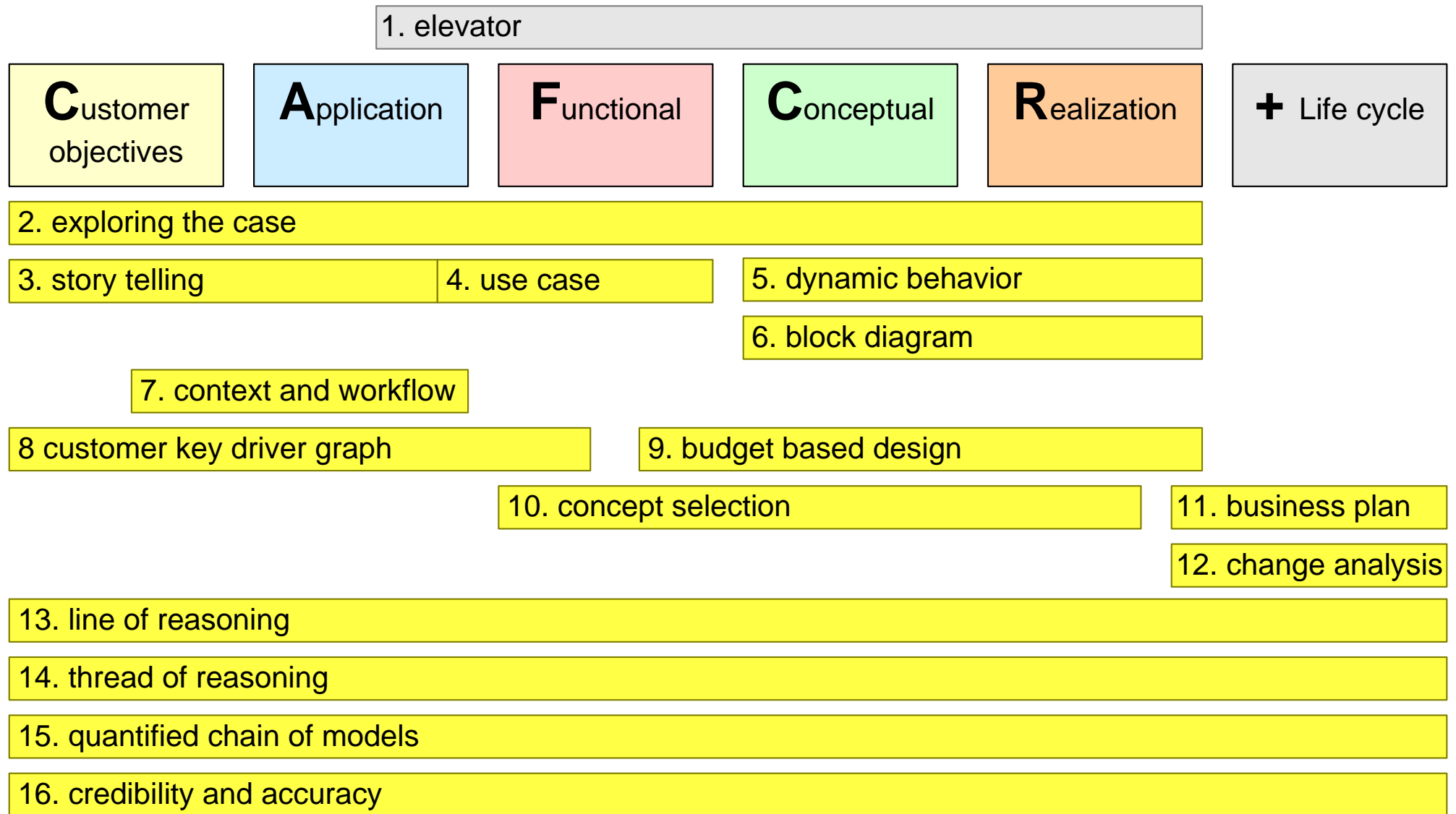
Example 1 SEMA, Final Deliverable: T-shaped Presentation



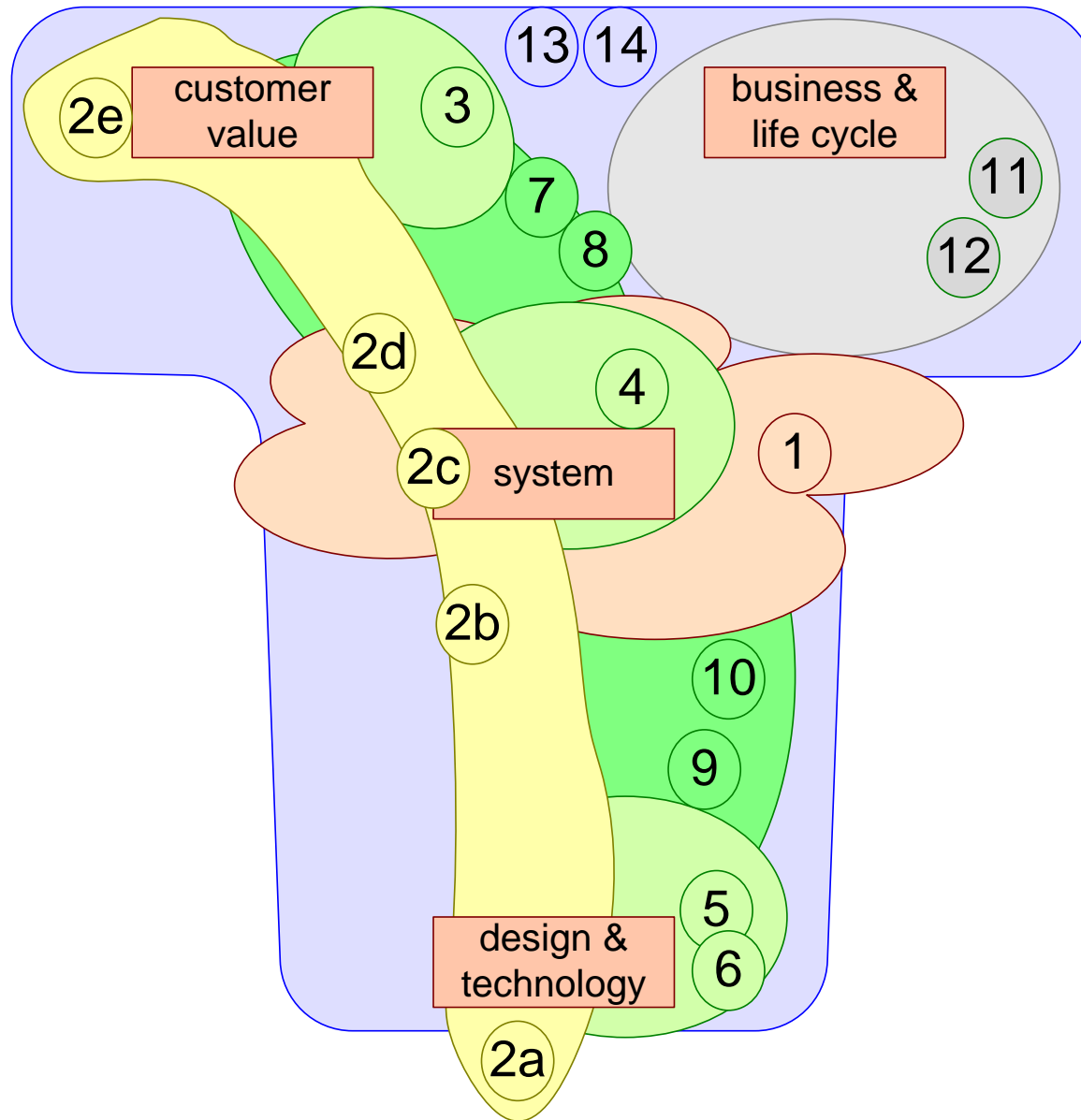
Final Course Week Deliverable: Elevator Pitch



Assignments during the Course



Classroom Assignments



Panorama Photo of Classroom



SEMA classroom September 2017, photo: Yang Yang Zhao

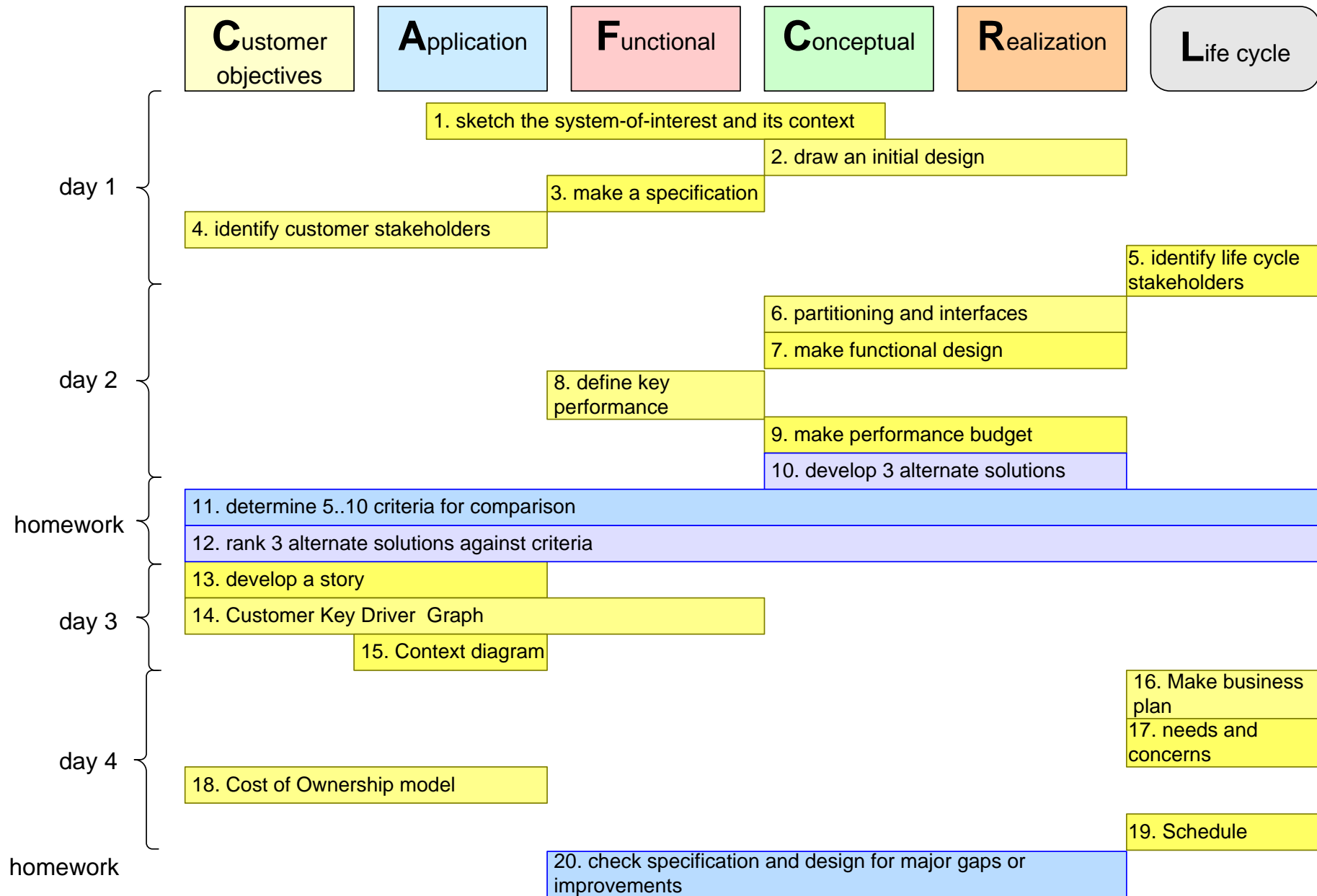
Homework Assignments

1/3: Capture course results as electronic visualizations
(PowerPoint/Visio)

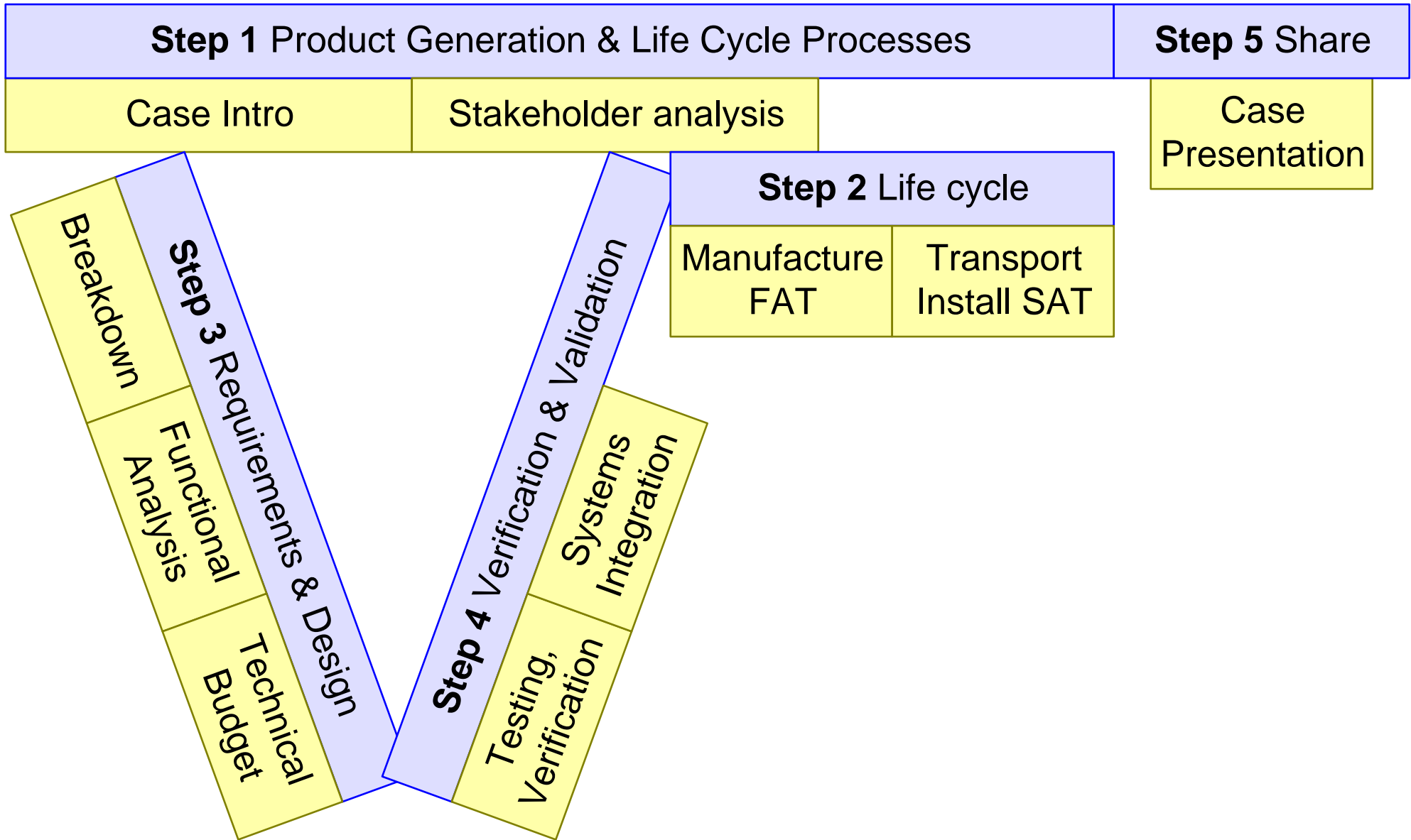
2/3: Transform into draft T-shaped presentation

final: T-shaped presentation
plus individual reflection

Example 2 Bachelor Architectural Reasoning



Example 3 Supplier Systems Engineering Course



Example 4 Systems Integration

System Specification

- determine **KPPs** and their quantified specification
- assess **risk** of KPPs caused by volatility, uncertainty, complexity and ambiguity
pick one **high-risk** KPP to elaborate
- describe **typical use** (including circumstances in the **context**) related to KPP

System design

- make system, SW, and HW **block diagrams** (parts, interfaces, connections)
- model **dynamic behavior** resulting in the KPP
- map **dynamic behavior** on **block diagrams** and **budget**: quantify contributions to KPP
- re-assess **risks** of KPP

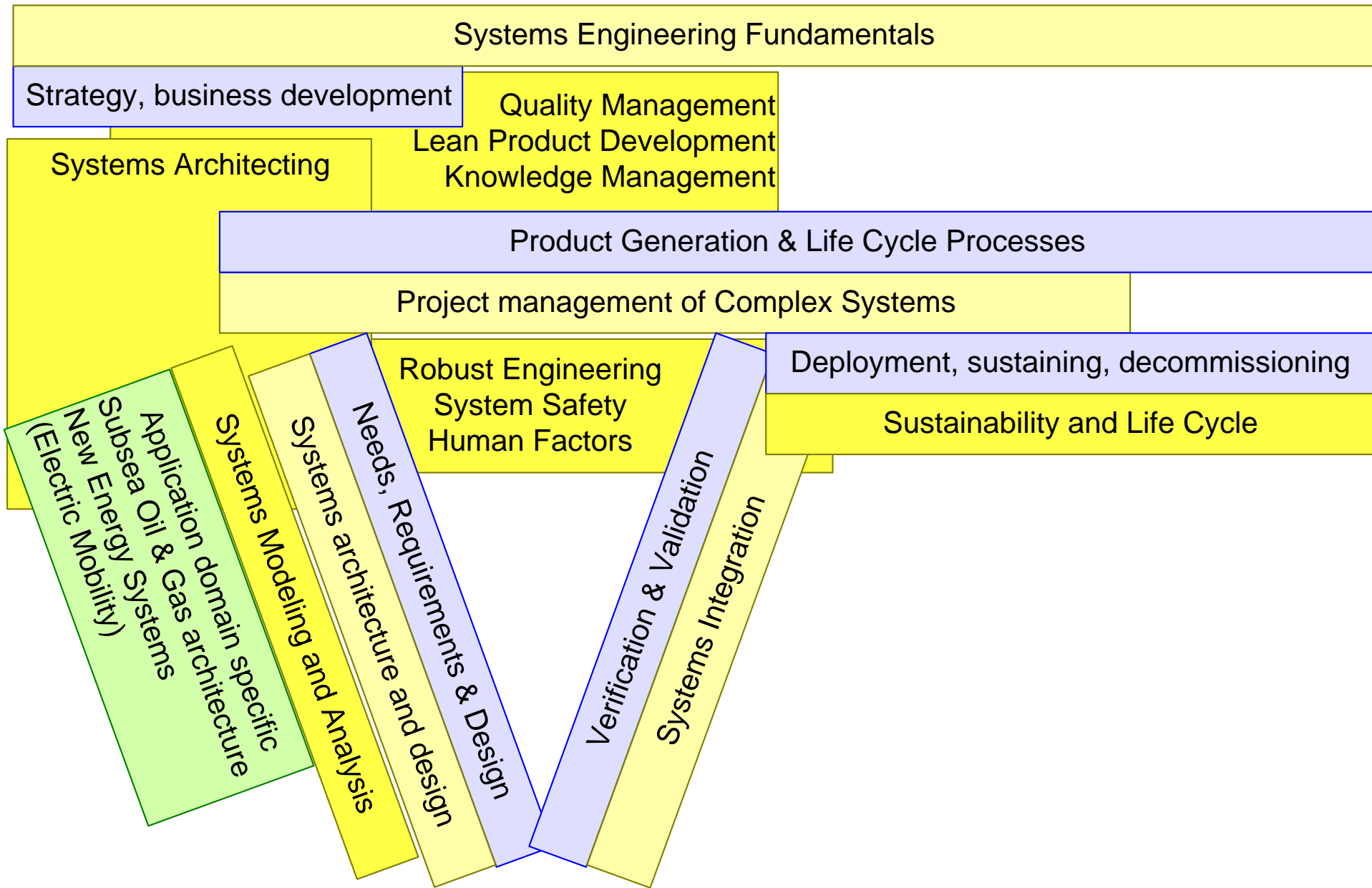
Systems Integration Plan

- determine an incremental **integration sequence** to measure the KPP as early as possible
- assess for the parts contributing to the KPP
 - **fitness for purpose** in customer context
 - **integration configurations** and **testware**
 - **supplier** and **logistics** status
 - **technology readiness**
 - **development** and **resource** status
- Identify **tensions** with development, logistics status, and availability of testware
and transform the sequence in a **(PERT) plan** with required resources and **integration configurations**
- assess **robustness** of the plan
- capture results in presentation

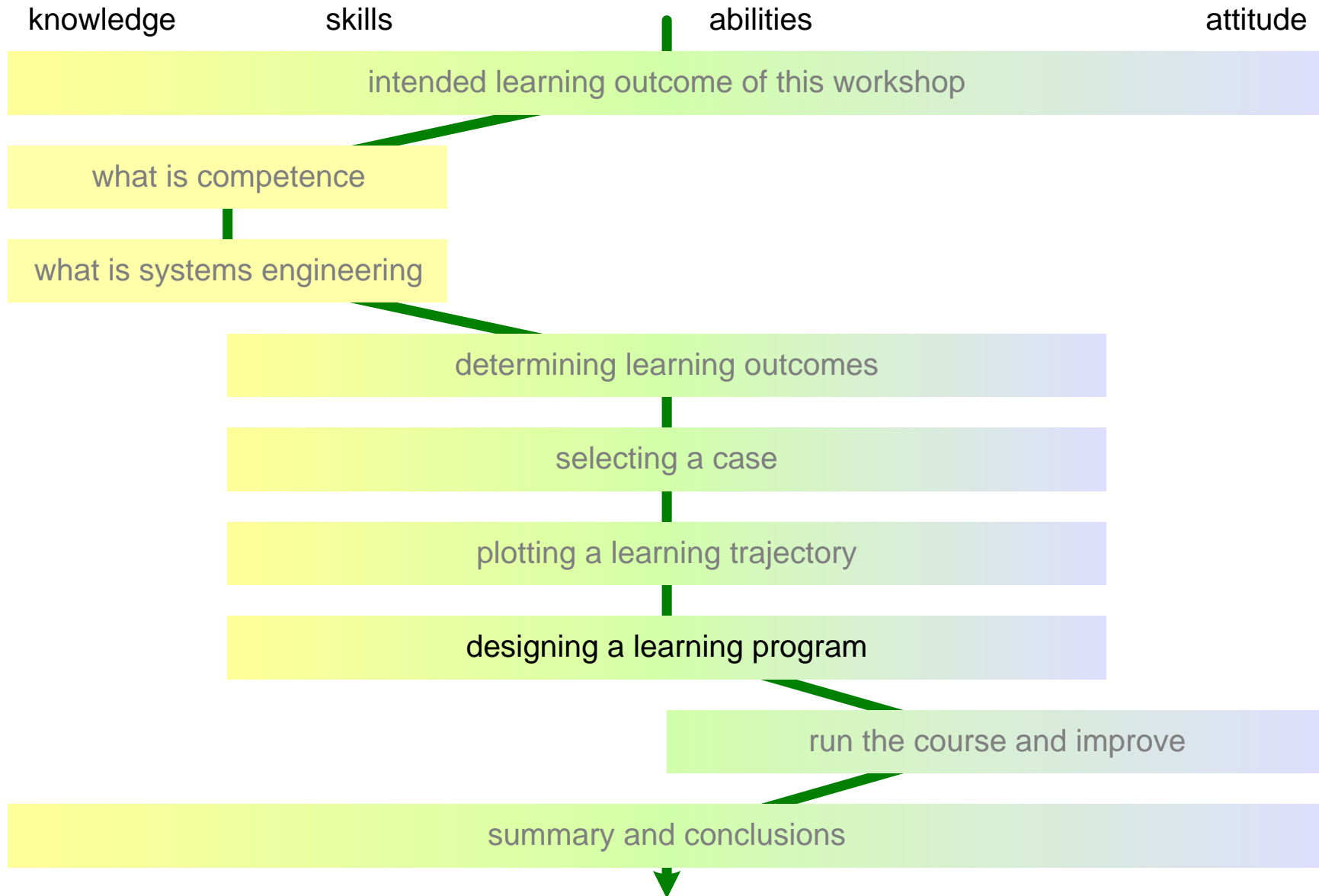
Reflection and Evaluation

- identify **tensions** or **gaps** in processes, organization, people, tools, instrumentation, context knowledge, etc. for executing the integration.

Example Master Program Courses mapped on the V-model



Designing the Course



3-Day Face-to-Face Schedule Systems Integration

	day 1	day 2	day 3
9:00	course intro	early validation	integration strategy
10:00	systems integration intro	make system, SW, and HW block diagrams (parts, interfaces, connections)	determine an incremental integration sequence to measure the KPP ASAP
11:00	case discussion	dynamic behavior	project management
12:00	systems integration context	model dynamic behavior resulting in the KPP	assess integration configurations and testware, supplier and logistics status, technology readiness ,
13:00	determine KPPs and their quantified specification	lunch	lunch
14:00	reflection and discussion	reflection and discussion	and development and resource status
15:00	assess risk of KPPs caused by volatility, uncertainty, complexity and ambiguity	budgeting	reflection and discussion
16:00	describe typical use (including circumstances in the context) related to KPP	map dynamic behavior on block diagrams and budget : quantify contributions to KPP	identify tensions and transform sequence into a (PERT) plan
17:00	reflection and discussion	re-assess risks of KPP	present, discuss, reflection and discussion

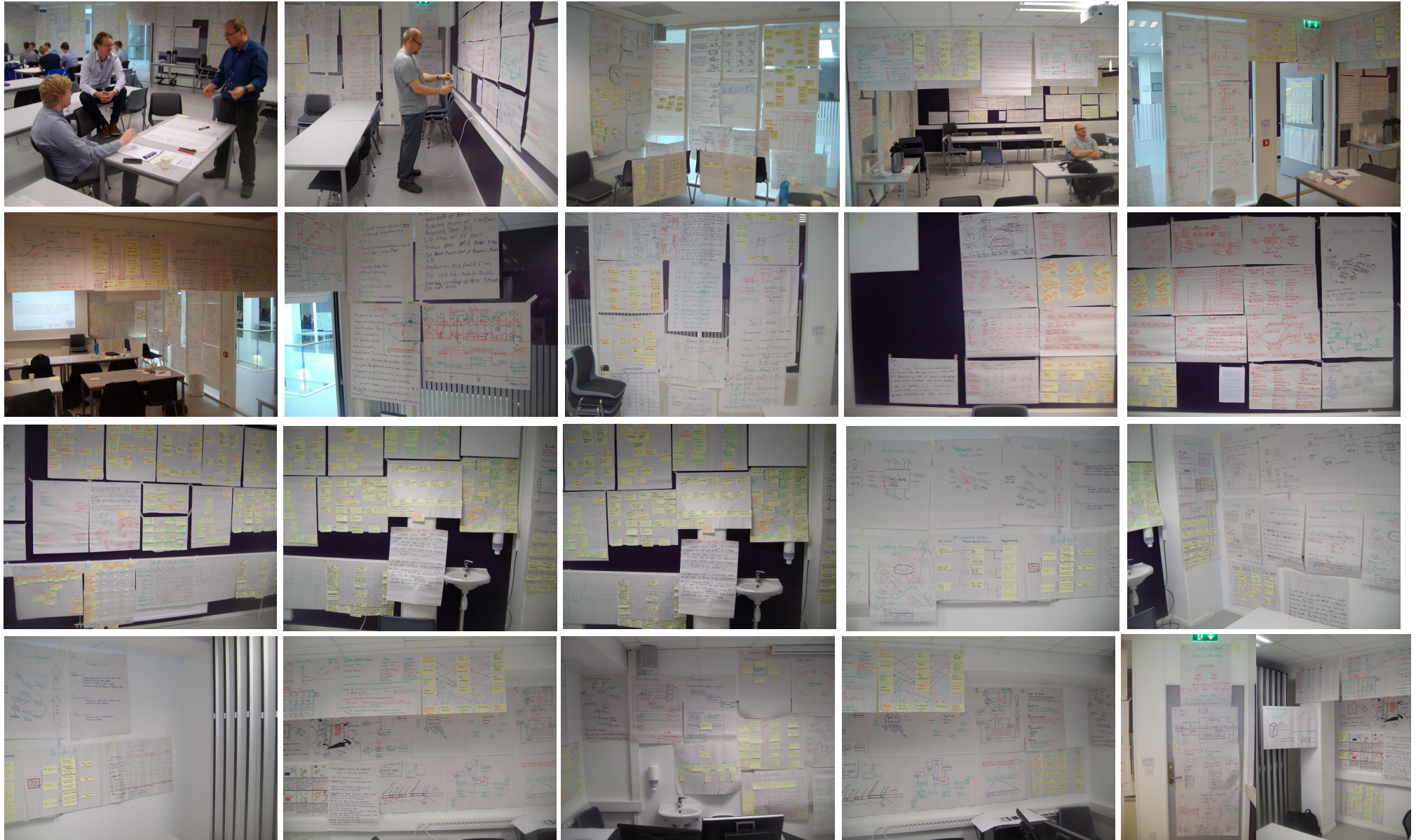
4-Day Face-to-Face Schedule Systems Integration

	day 1	day 2	day 3	day 4
9:00	course intro	early validation	project management	elective
10:00	systems integration intro	make system, SW, and HW block diagrams (parts, interfaces, connections)	re-assess risks of KPP	identify tensions and transform sequence into a (PERT) plan
11:00	case discussion	dynamic behavior	determine an incremental integration sequence to measure the KPP ASAP	elective
12:00	systems integration context	model dynamic behavior resulting in the KPP	readiness levels, systems of systems, elective	reflection and discussion
13:00	determine KPPs and their quantified specification	lunch	reflection and discussion	lunch
14:00	lunch	reflection and discussion	lunch	elective
15:00	reflection and discussion	integration strategy environments and configurations	assess integration configurations and testware, supplier and logistics status, technology readiness , and development and resource status	assess robustness of plan
16:00	assess risk of KPPs caused by volatility, uncertainty, complexity and ambiguity	map dynamic behavior on block diagrams and budget : quantify contributions to KPP	elective	make and give presentation to management
17:00	describe typical use (including circumstances in the context) related to KPP	elective	reflection and discussion	reflection and discussion
	reflection and discussion	reflection and discussion		

<i>people, process, and organization</i> <ul style="list-style-type: none"> • human aspects • process and integration • organization 	<i>technical</i> <ul style="list-style-type: none"> • budgeting • testing • systems of systems 	<ul style="list-style-type: none"> • architecting for integration • impact of change • software and integration product families, platforms
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electives

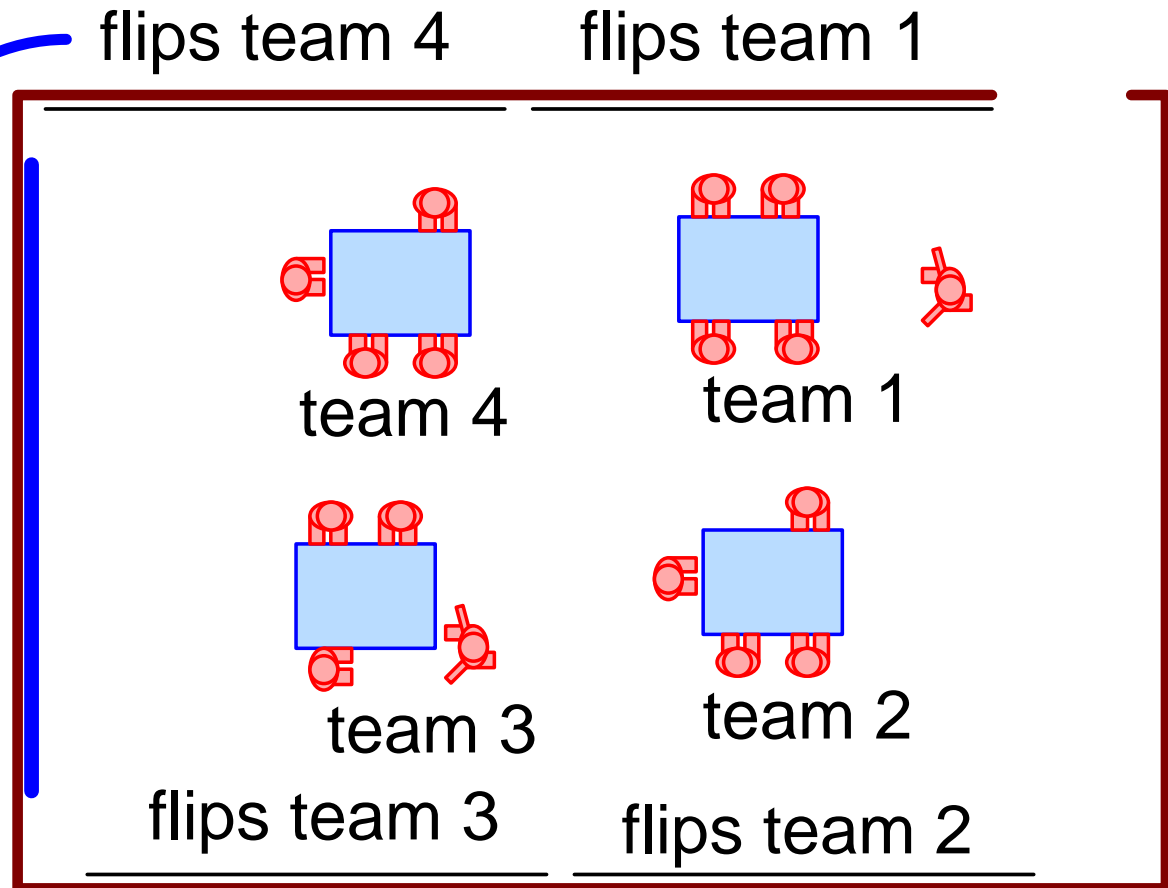
The Wall with Sheets is the Group's Memory



Design the Physical Space too

mental switch
from problem/system
to “meta”
how, what, why?

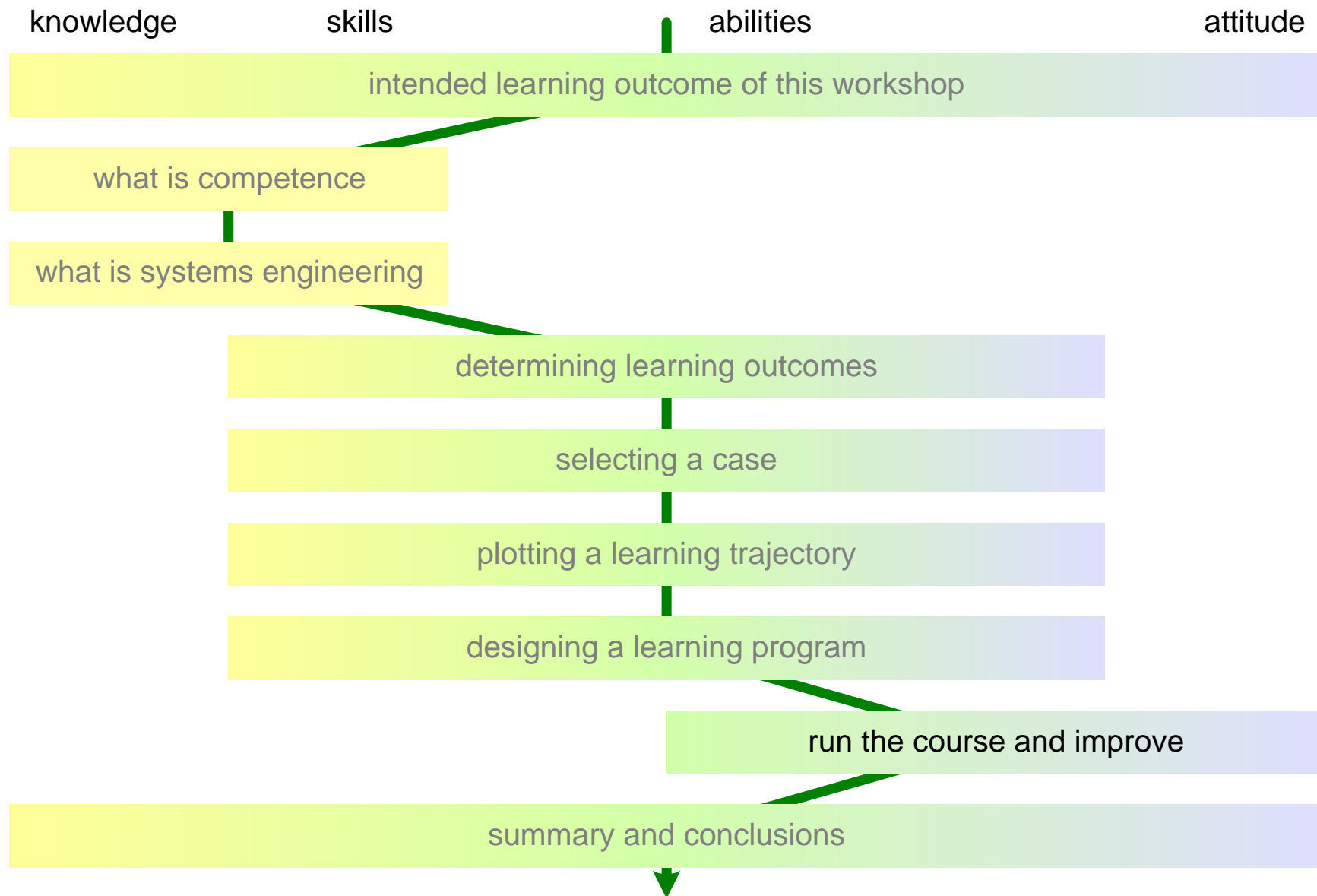
reflection
wall



Transform the Trajectory into a Program; Elements are:

- (Check in)
- Limited lecturing
 - an alternative is to use a flipped class room, using “nuggets” (max 6 minute video lectures, plus a few questions)
- Working in groups on the case
- Discussion and feedback
- Reflection

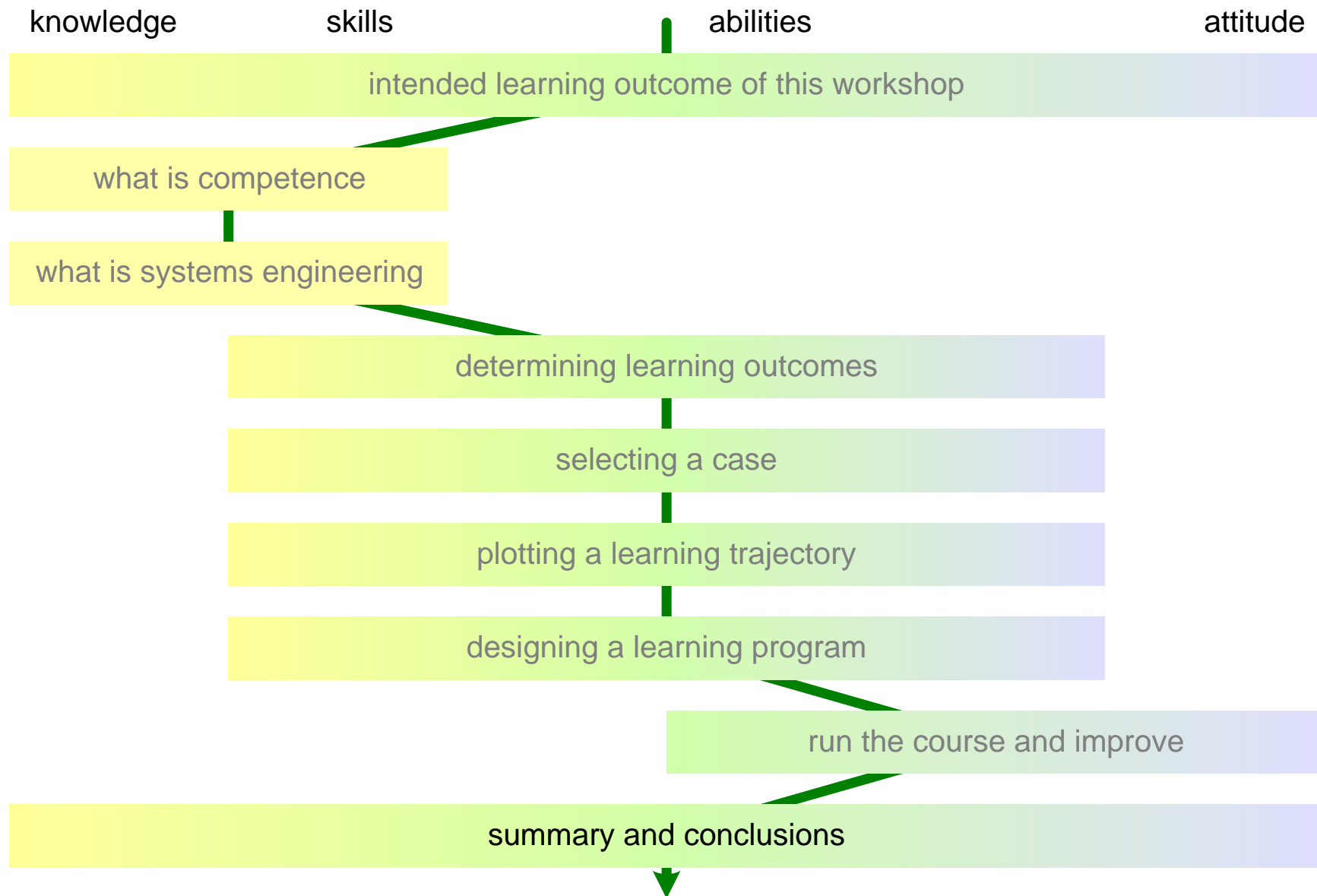
Summary and Conclusions



Mindset: Improve by Doing

- Perfect is the enemy of Good
- Schedule a first course execution ASAP
- Obtain feedback from participants during and after the course
- Think on your feet, reflect before, during, and after teaching
- Teachers also make mistakes; just avoid fatal (or huge) mistakes
- Cope with your own uncertainty
- Have confidence in your own competency and authority

Summary and Conclusions



I Hope that You Learned

- How to develop an active-learning based course
- Suitable for systems engineering education
- Starting at the end:
 - H2 Determine desired learning outcomes
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 - Plot a learning trajectory in term of in-class assignments
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- Some theory:
 - What is competence?
 - What is Systems engineering?

Your Feedback Please: Benefits and Concerns

Please write

- at least 1 sticky note with benefits of this workshop
- at least 1 sticky note with concerns about this workshop

Attach them on the Benefits & Concerns flip-over sheet

Specify and design

an **Intelligent Pest Control Robot**.

Climate change will cause the migration of many animals that are disease carriers, e.g. ticks, mosquitos, bats. The goal is to mitigate health risks. You may determine your own scope, such as clients,

location, and application

e.g., Kongsberg
Viken
Norway
Europe

e.g., mosquito control,
rat control

e.g., civilians,
government agencies,
pest control companies,
municipalities

Example Case

Specify and design

a **Drone Interception System**.

The goal is to prevent drone misuse, e.g. paparazzi's, terrorist attacks, etc.

You may determine your own scope, such as clients,

e.g., celebrities,
festivals, oil companies

location, and application

e.g., Kongsberg

Viken

Norway

Europe

e.g., security

counterintelligence

Specify and design

a **Smart Covid Test Collecting and Handling System.**

The goal is to achieve good and actual insight in infections.

You may determine your own scope, such as clients,

e.g., children,
employees,
or elderly

location, and application

e.g., Kongsberg

Viken

Norway

Europe

e.g., screening

diagnosis

monitoring

tracing

Specify and design

a **Smart Waste System**.

The goal is to achieve sustainability, where resources are fully recycled.

You may determine your own scope, such as type of waste,

e.g., plastic
metals

location, and application

e.g., Kongsberg
Viken
Norway
Europe

e.g., residential
industrial
agricultural

Example Case

Specify and design

a Smart and Sustainable, e.g. energy neutral etc., House or Building for Norway,

which will be comfortable, attractive and affordable

Example Case

Specify and design

an autonomous waste collector.

This collector finds and removes waste from the environment.

Example Case

Specify and design

an autonomous track/road maintainer for elderly Norwegians.

This robotic vehicle, amongs others, keeps the drive to their home fully operational (in winter).

Specify and design an
Unmanned Humanitarian Response/Support Vehicle,

which will be able to reach locations with
poor, bad, or destroyed access.

Specify and design
a full-electric
TukTuk
(versatile, urban, no emission)



http://en.wikipedia.org/wiki/Auto_rickshaw#mediaviewer/File:DKoehl_colombo_auto_rickshaw.JPG
by Dan Koehl, license: <http://creativecommons.org/licenses/by/3.0/>

Specify and design
a full-electric
drive-by-wire
race kart



photo <http://nl.wikipedia.org/wiki/Bestand:Outdoor-karting.jpg>

Tree Cutting Robot

background:

Less young people are willing to work in the wild and mountainous areas in Norway, Canada, or USA to cut trees for wood production.

product:

Robot that supports the cutting and processing of trees so that less people are needed

Explorer Inaccessible Spaces

background:

When renovating houses and buildings the builder needs to know the construction and the position of infrastructure

product:

Robot that is flexible and remotely operated that can explore inaccessible spaces in houses and buildings

and more Example Cases

apple, tomato, or strawberry plucking robot

apple, tomato, or strawberry sorting robot

tree cutting robot

spinach or lettuce harvesting robot

robot that removes or kills lice, wasps, or mosquitos

communication device for elderly people (80+ years old)

automated loader for Electric Vehicle

robot to help builders to look in inaccessible places

robot to install cables in tunnels

device to assist elderly people (80+ years) with washing, clothing, eating, drinking, getting in and out bed