



# LESGEVEN IN DE CHEMIE INNOVEREN MET SYSTEEMDENKEN

CHEMICAL SCIENCE & ENGINEERING (SCHEIKUNDIGE TECHNOLOGIE) AAN DE UT

WAAROM ZOULDEN JOUW LEERLINGEN DAAR VOOR KIEZEN?  
HOE SPREKEN WE ZE AAN?

Leonie Krab, opleidingsdirecteur en docent  
Albert Wong, onderzoeker en docent  
Arnoud Onnink, projectcoördinator en docent

Conferentie scheikundeleraren  
Woudschoten  
3 november 2023

UNIVERSITY  
OF TWENTE.

# 6 VWO → UNIVERSITEIT



- We hebben meer scheikundig ingenieurs nodig voor de uitdagingen van deze tijd
- We hebben ruimte op de UT voor meer studenten in de science-opleidingen
- We staan als internationale opleiding onder druk vanwege politieke initiatieven
- Waar blijven de meiden?!





# UNIVERSITY OF TWENTE

Wo 15 nov: Online Open Day  
Vr 22/za 23 maart: on campus

## Timetable Online Bachelor Open Day

14:00 - 16:30 | Live chat beschikbaar

14:00 - 14:30 | Waarom UT?

14:30 - 15:05 | Studiepresentatie 1

15:05 - 15:30 | Kies een sessie

15:30 - 16:05 | Studiepresentatie 2

16:05 - 16:30 | Live Q&A



# HOE ENTHOUSIASMEREN WE LEERLINGEN?

BSc Chemical Science & Engineering (CSE) aan de UT:

We doceren over relevante chemie en vaardigheden voor de toekomst:

- de energietransitie,
- alternatieve, duurzame processen,
- LCA,
- duurzame materialen
- essentiële vaardigheden, etc.

Jullie begrijpen hoe boeiend én belangrijk dat is!



- Kunnen we samen bereiken dat meer leerlingen kiezen voor een studie als deze?



# CSE CURRICULUM 2023-2024

YEAR 1

1 Chemistry	EC	2 Process Engineering	EC	3 Materials Science	EC	4 Equilibria & Electrochemistry	EC
Introduction to Mathematics & Calculus 1A	4	Mathematics: Calculus 1B	3	Mathematics: Linear Algebra	3	Mathematics: Calculus 2	3
Fundamentals of chemistry - (in)organ. structures - reaction categories - reaction mechanisms - polymers (synthesis) - project	8.5	Thermodynamics	4.5	Materials Science - quantum phenomena - inorg. mat. Science - polymers (physical prop.) - project	9.5	Equilibria - chemical equilibria - phase equilibria	5
		Process engineering - written test - distillation practicum - project	5			Think like a researcher (Electrochemistry) - electrochemistry (theory) - lab course & project	7
Lab course 1: Basic skills & Synthesis	2.5	Lab course 2: Energy & Process engineering	2.5	Lab course 3: Materials	2.5		

math  
 chemistry/ physics/ skills  
 lab



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# CURRICULUM SCHEIKUNDIGE TECHNOLOGIE

YEAR 2

5 Industrial processes	EC	6 Transport Phenomena	EC	7 Molecules & Materials	EC	8A Process design	EC	8B Materials Science & Technology	EC
Elective module: choose 8A or 8B									
Vector calculus	2	Numerical Methods	3.5	Organic and Bio-organic Chemistry incl. Lab course	8	Introduction Chemical Reaction Engineering (incl. process control)	4	Chemistry & Techn. of Inorganic Materials	4
Kinetics & Catalysis	4.5	Physical Transport Phenomena - fluid dynamics - heat transfer - mass transfer	7.5			Introduction Separation Methods	4	Chemistry & Techn. of Organic Materials	4
Industrial Chemistry & Processes	4.0			Interface Science incl. project	3	Project process design	7	Advanced Materials Science - materials S&T - project	7
Project Sustainable Industrial Chemistry and Essential Skills	4.5	Project Transport Phenomena	4	Characterization of Molecules & Materials Chemistry incl. Lab course	4				

[www.utwente.nl/onderwijs/bachelor/opleidingen/chemical-science-engineering/](http://www.utwente.nl/onderwijs/bachelor/opleidingen/chemical-science-engineering/)

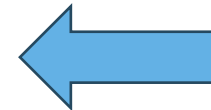
→ doorklikken naar “Studieprogramma”

Of stel een vraag: bachelor-cse@utwente.nl

Essential skills education in the bachelor's:

- a. Intellectual and practical skills
  1. Inquiry and analysis
  2. Critical thinking
  3. Creative thinking
  4. Written communication
  5. Oral communication
  6. Reading
  7. Quantitative literacy
  8. Information literacy
  9. Teamwork
  10. Problem solving
    - For CSE, this includes Design, and Modelling
- b. Personal and social responsibility
  11. Civic engagement – local and global
    - For CSE, this includes Sustainability awareness
  12. Intercultural knowledge and competence
  13. Ethical reasoning
  14. Foundations and skills for lifelong learning
  15. Global learning
- c. Integrative and applied learning
  16. Integrative learning

Ook veel aandacht voor essentiële vaardigheden!



- math
- chemistry/ physics/ skills
- lab
- large projects
- minor

Curriculum B-CSE 2023-2024

YEAR 3

9 Minor 1	EC	10 Minor 2	EC	11 Intro Bachelor assignment	EC	12 Bachelor assignment	EC
Minor module - at the UT, or - exchange semester, or - getting teacher qualification	15	Minor module - at the UT, or - exchange semester, or - getting teacher qualification	15	Research	2.5	Bachelor assignment - lab work / simulations - interpreting results - report writing - final presentation	15
				Statistics	3		
				Ethics	2.5		
				Preparation Bachelor Assignment	2		
				Elective: Biochemistry / Bionanotechnol. / Process Equipment Design / Study Tour prep. / some Applied Physics courses / Other (Board of Examiners)	5		



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# LEERLINGEN ENTHOUSIASMEREN MET CREATIVITEIT!

- Creativiteit als motivator
- Hoe zetten we creativiteit door, als een leerlijn van basisschool via de middelbare school naar het hoger onderwijs?
- Hoe zetten we creativiteit slim in, zodat het bijdraagt aan oplossingen?



- Conceptueel modelleren en systeemdenken in ons onderwijs
- Masterclass: “Lesgeven in de chemie innoveren met systeemdenken”





# Workshop **Conceptual Modeling**



**Albert Wong &  
Arnoud Onnink**

M1 Fundamentals of Chemistry  
3 November 2023



# Masterpiece Gallery

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The Masterpiece Gallery is a celebration of the human imagination and the audacity of creation. It is a gallery dedicated to the LEGO builders of the world, featuring original works by multiple talents. The exhibited pieces have been handpicked by the gallery's curators and change on a regular basis, so most likely there will be something new on display for your next visit.

This is our tribute to our loyal fans around the world, and hopefully a great source of inspiration to everybody. Go create.





# Overview workshop Conceptual Modeling (CM)

## Learning Objectives

### Part I. Context: Why do I need CM?

- Understand the context of CM
- Acquaint with typical problems in chemistry

### Part II. Theory: What is a CM?

- Theoretical foundation of CM

### Part III. Applicability: How do I develop a CM?

- Practice developing a CM

## Lecture Format

- Lecture/Slides
- Poll questions (4)
- Group assignment (1)

## Post-Lecture

- Read suggestions literature (optional)
- Start your project; chose topic, contact tutor, and initiate literature search

1. York *et al.*, *J. Chem. Educ.* **2019**, 96, 2742–2751
2. M. Orozco, M. Boon & A. S. Arce, *Eur. J. of Eng. Edu.* **2022**
3. M. Boon & T. Knuuttila, *Philos. Sci.* **2009**

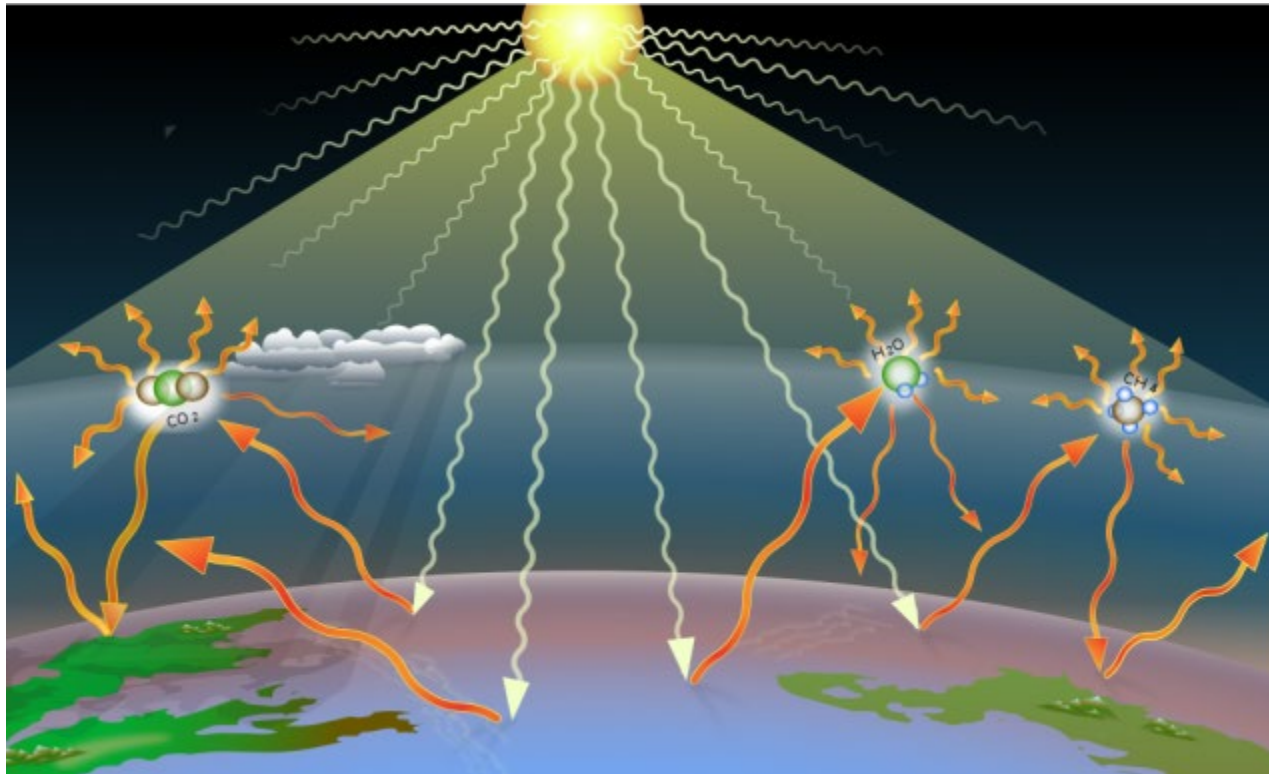
## References

# Part I. Context: Why do I need CM?

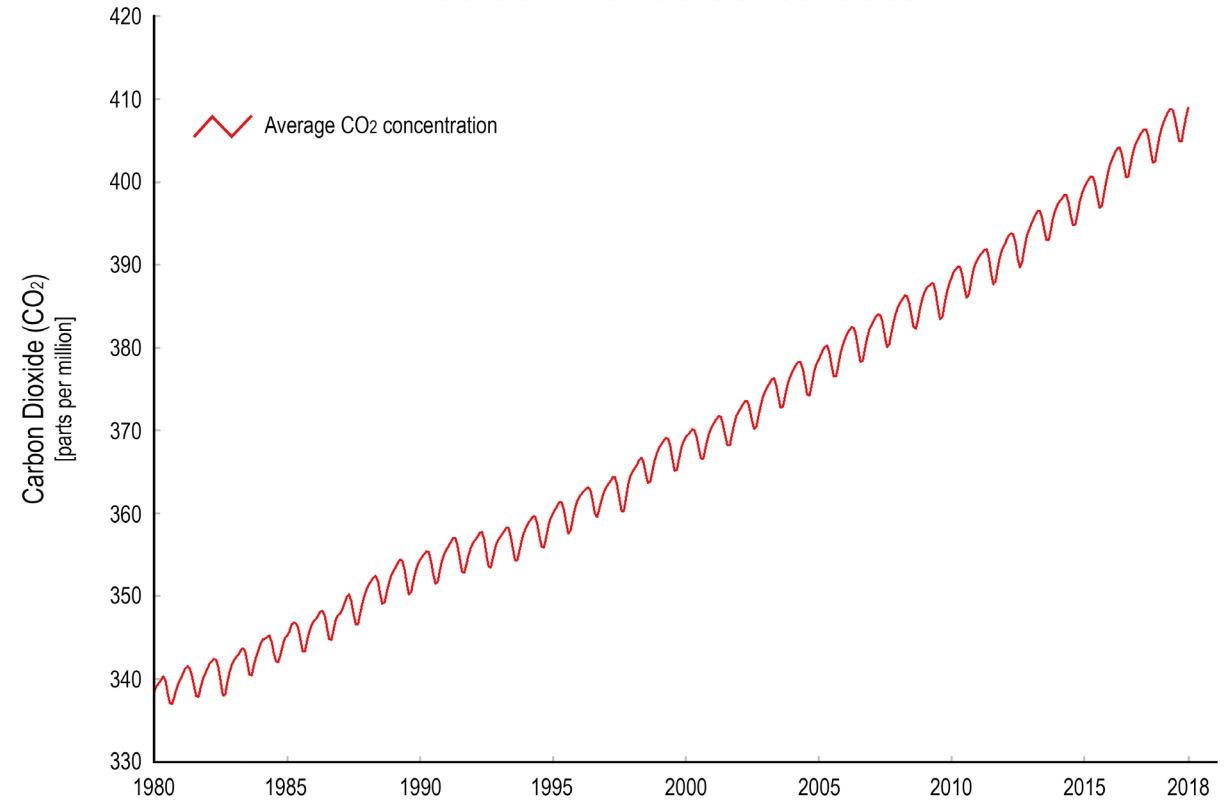




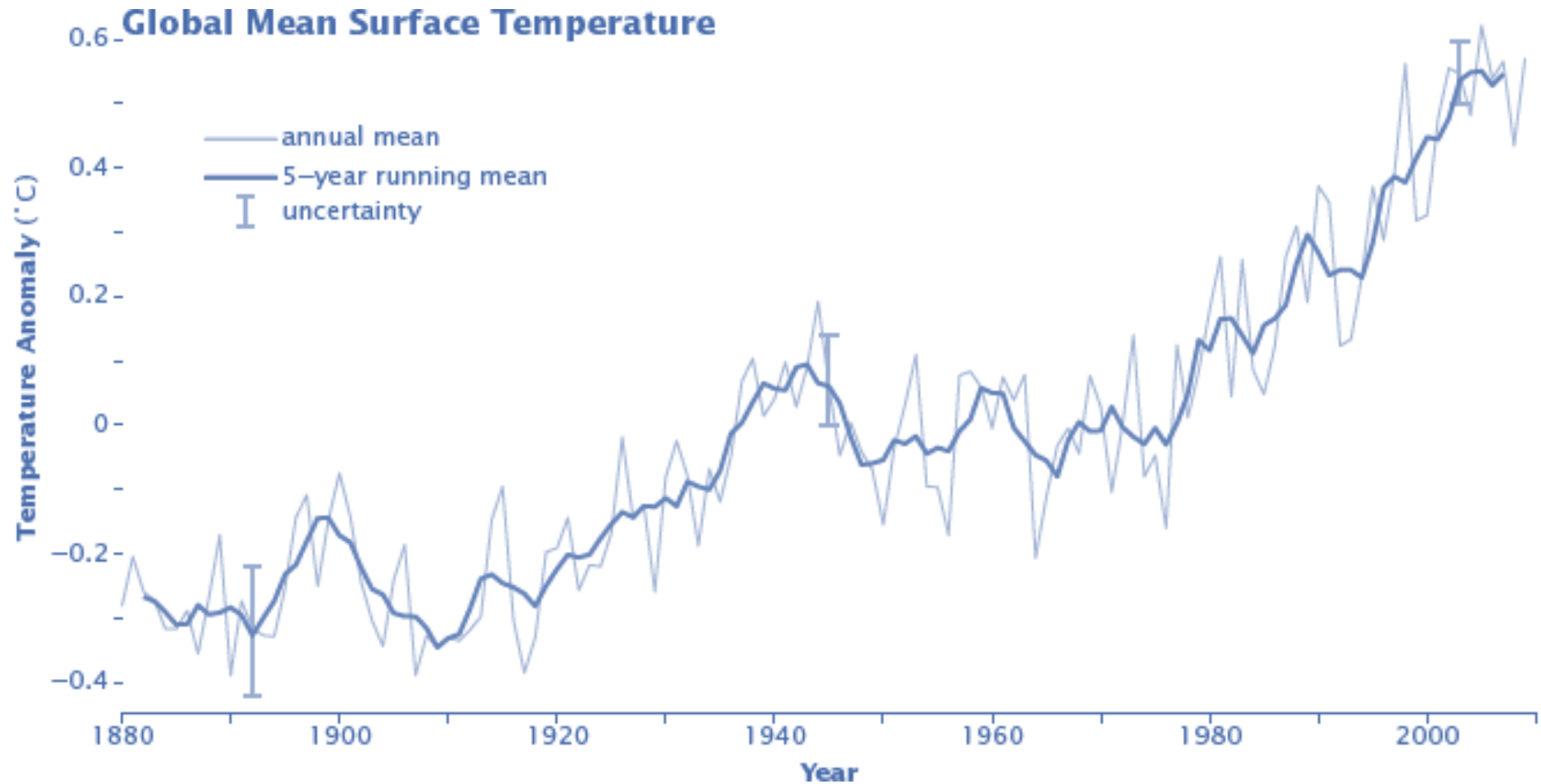
You probably will need to think of solutions related to sustainability!



Global Monthly Average Carbon Dioxide Concentration



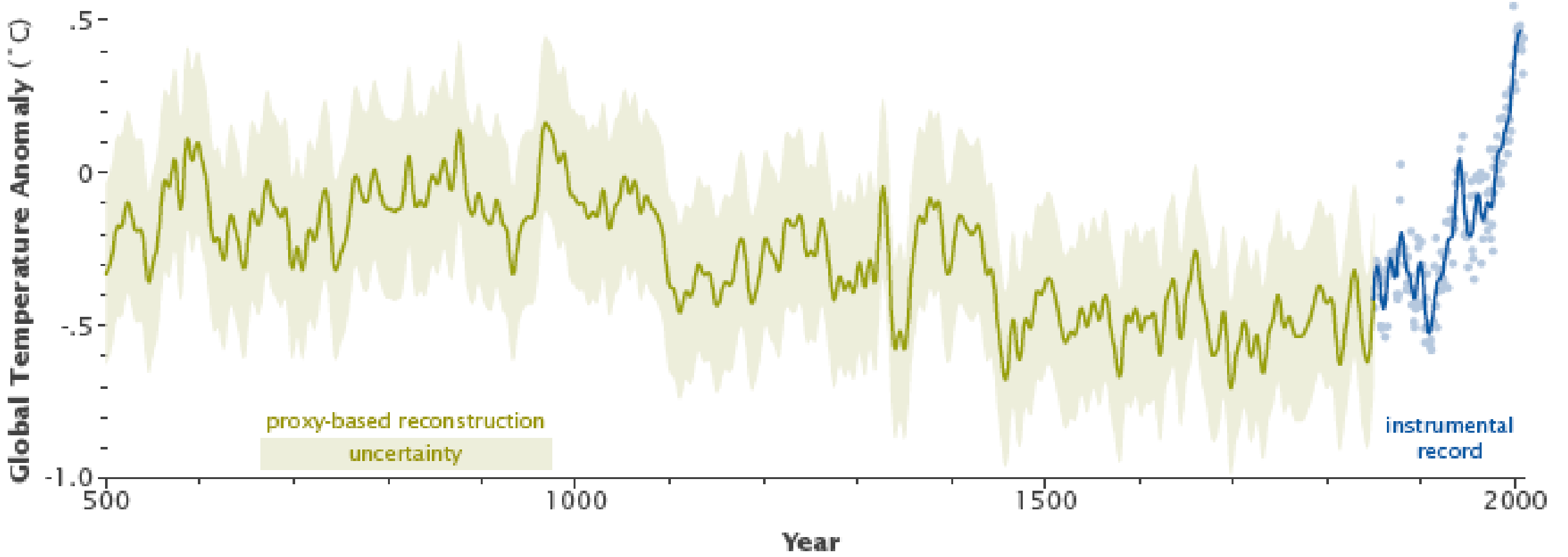
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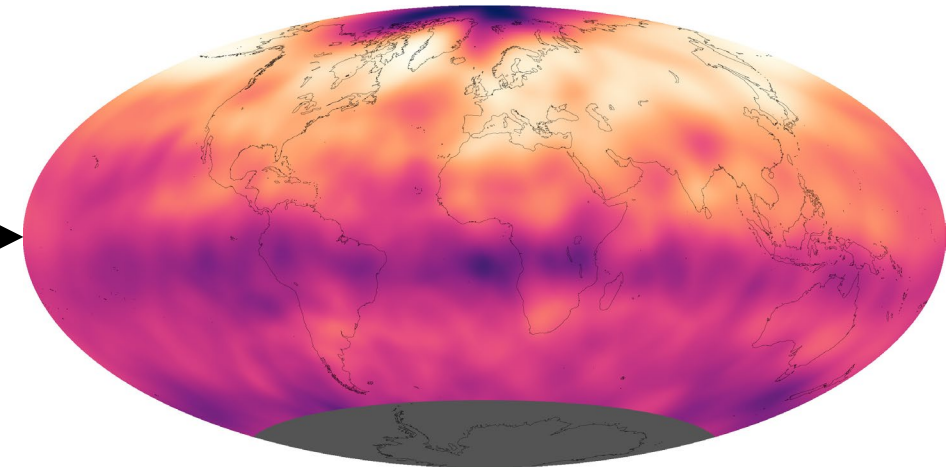
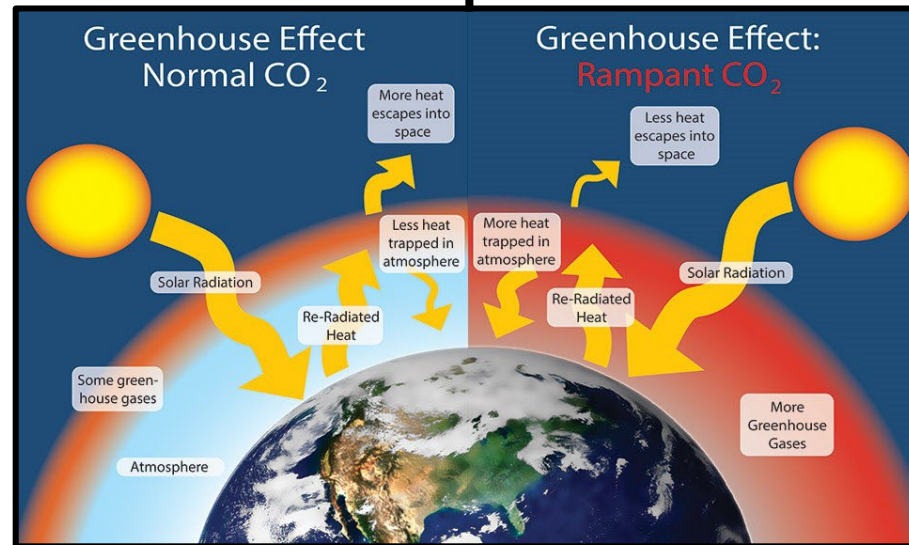
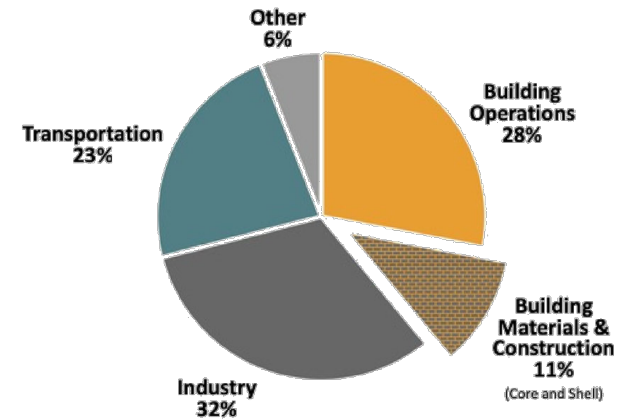




You probably will need to think of solutions related to sustainability!



# Solutions are difficult to 'find' because ...





# Solutions are difficult to 'find' because ...



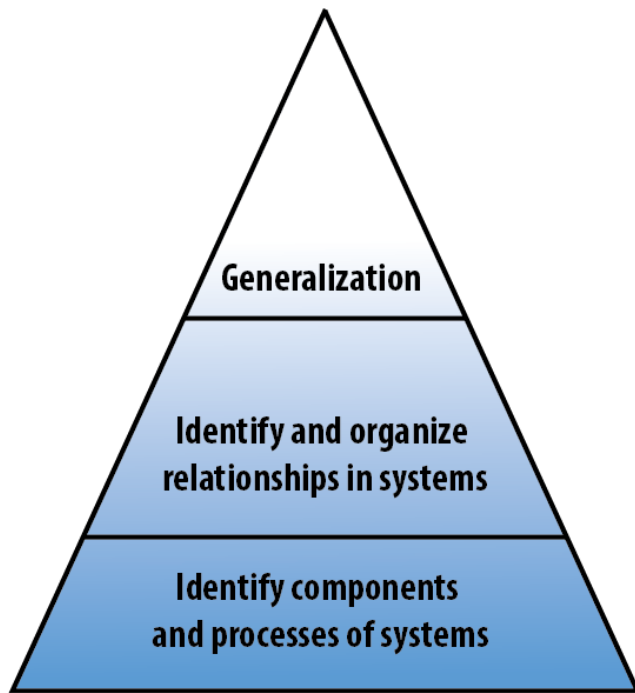
Grand challenges of the 21<sup>st</sup> Century require skills in **investigating and understanding interactions between a system and its environment, including the human components therein.**







# Characteristics of Systems Thinking



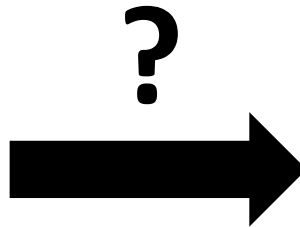
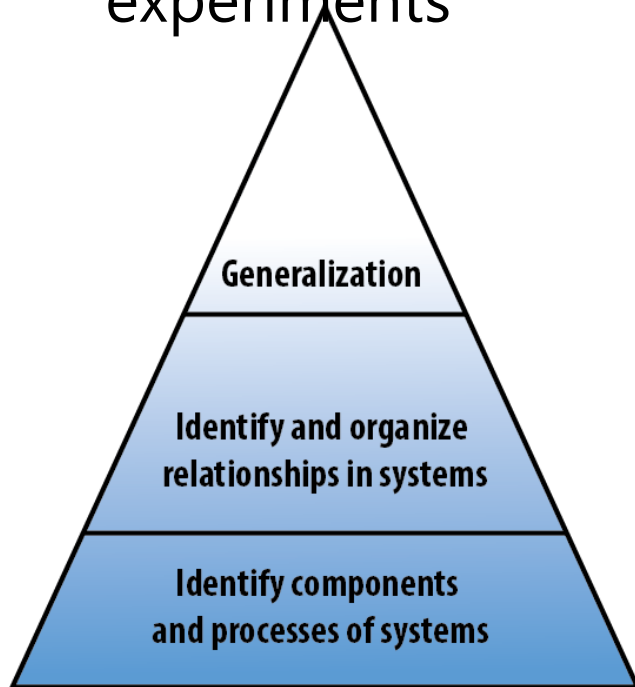
- **Recognizing that a sum is greater than its parts**  
All pieces are interconnected and contribute to the outcomes of the system.
- **Considering closed loops**  
There are many ways in which two system-relevant variables affect each other, as opposed to how one variable affects the other (as in linear chains).
- **Prioritizing candidate solutions**  
Tries to expand the range of options available for solving a problem.

**Systems thinkers are curious, have open minds, and seek out root causes**

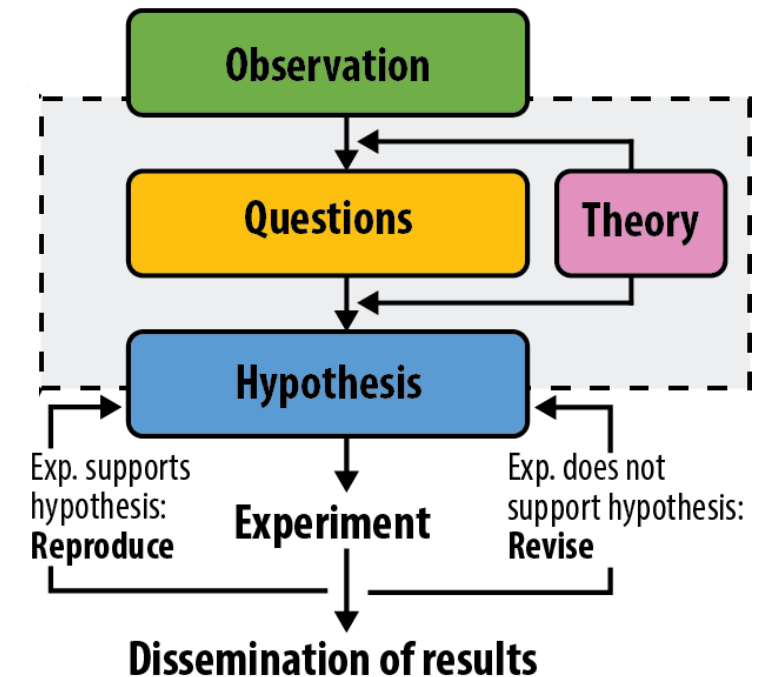


# But how do we go from Systems Thinking (ST) to the classical hypothesis-deductive model?

Think in systems experiments

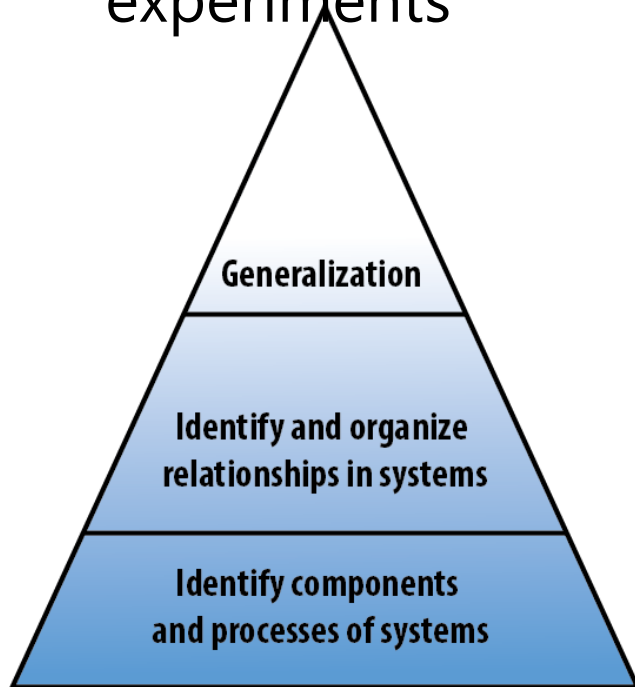


Design chemistry

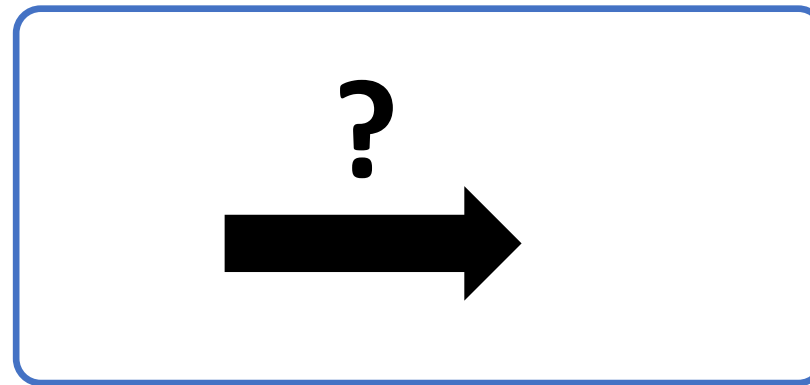


# Summary Part I: We need methods for Systems Thinking in Sustainable Chemistry

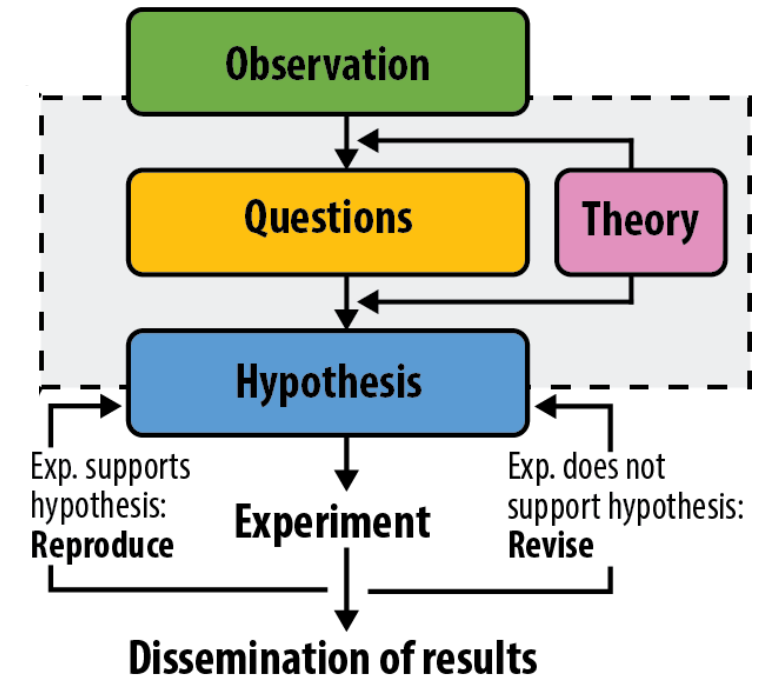
Think in systems  
experiments



Conceptual model



Design chemistry



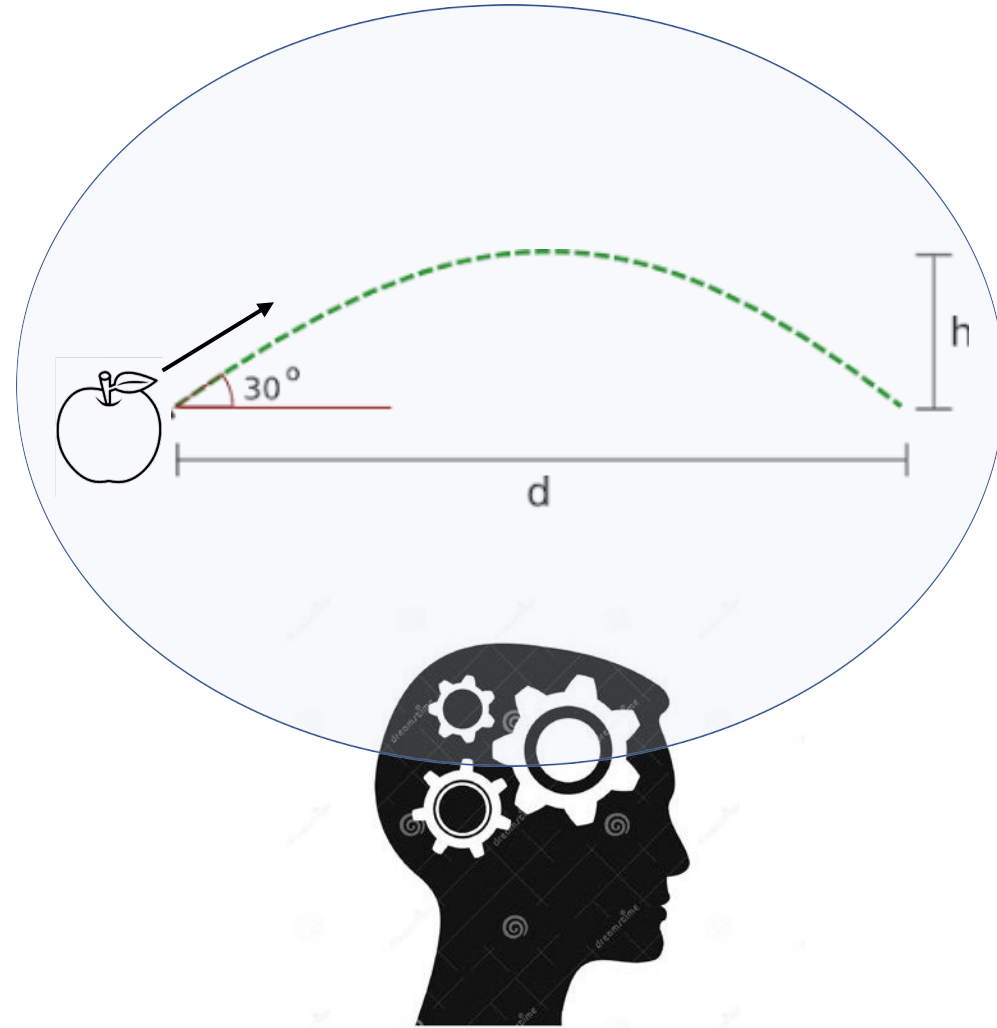
# Part II. Theory: What is a CM?







# What happened?

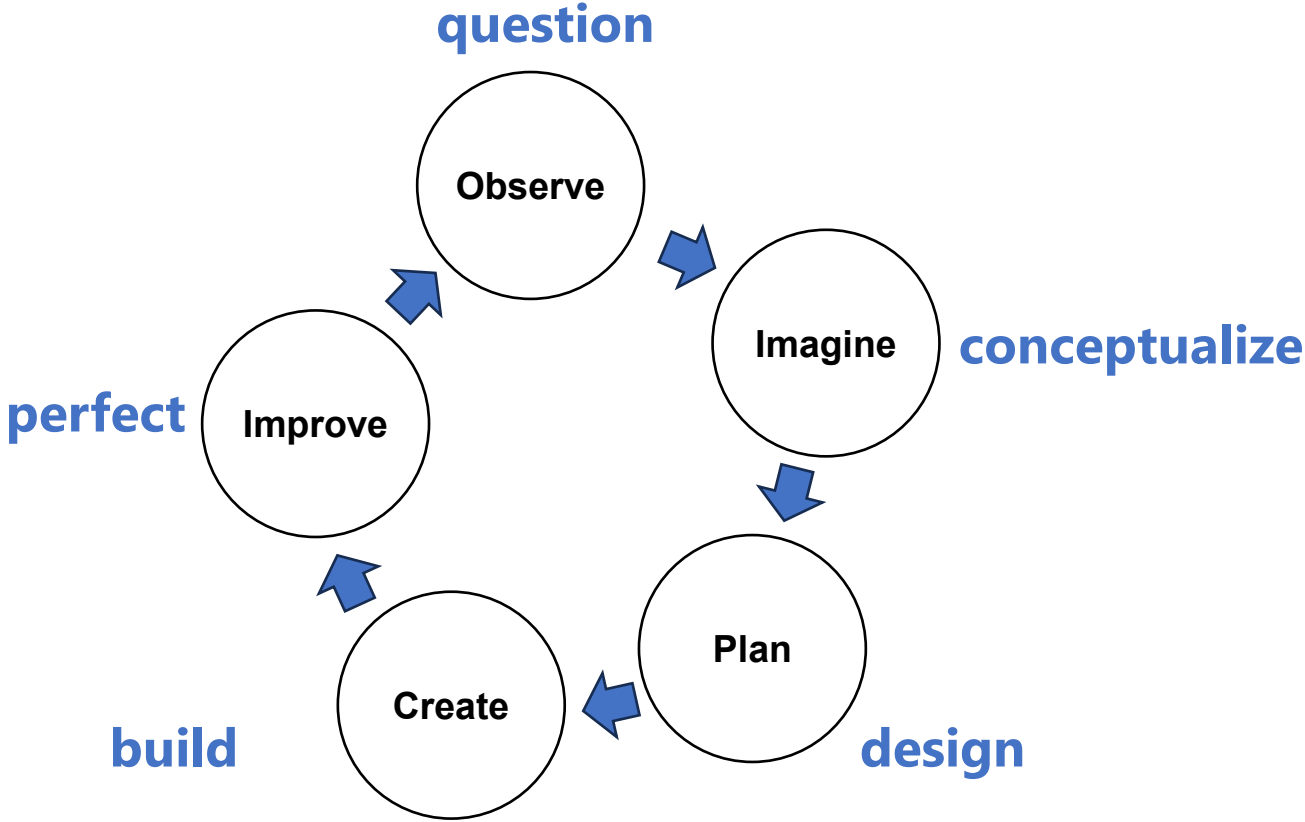


Based on this **conceptual model**, a **mathematical model** can be constructed using Newton's laws.



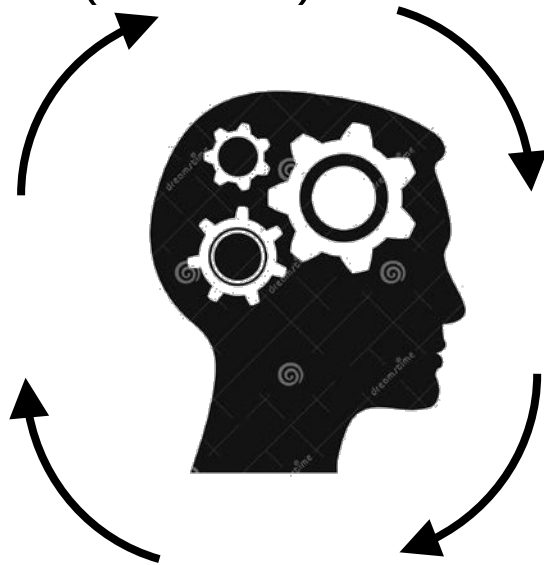


# So, how do you develop a conceptual model?



# So, **how** do you develop a conceptual model?

The **problem** = a 'story' of your understanding of the problem  
(Phase I).



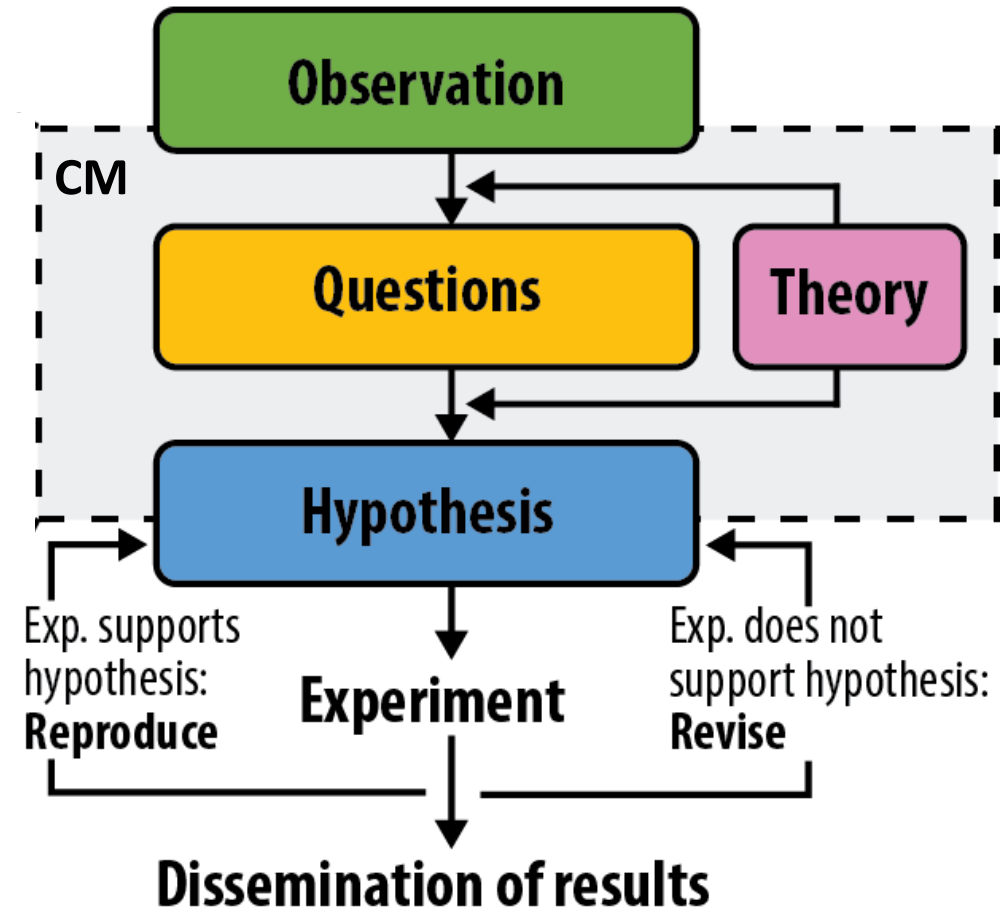
- ↓ **Ask questions** to broaden and deepen your understanding
- ↓ **Search answers** in your textbooks and scientific literature
- ↓ Integrate information into a **coherent** 'story'
- How can you address a **scientific gap**?

The **solution** = your design idea for solving that problem (Phase II).

# Why could CM help?

- You should come up a **hypothesis**,
- Which forces you to enter an empirical cycle (i.e., a **deductive method**).
- Trouble is getting lost:

**On what grounds can we build a hypothesis?**





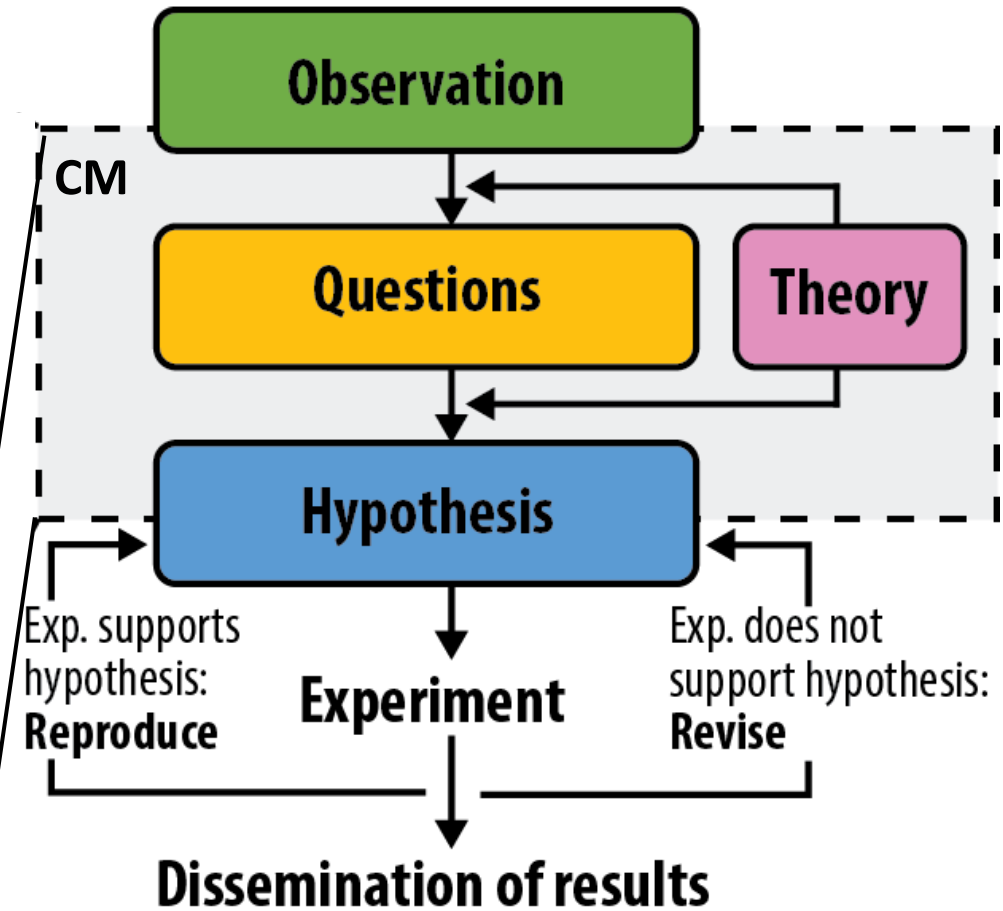
# CM is a tool for developing hypothesis

- You should come up a **hypothesis**,
- Which forces you to enter an empirical cycle (i.e., a **hypothetical-deductive method**).
- Trouble is getting lost:

On what grounds can we build a **hypothesis**?

## A Conceptual Model:

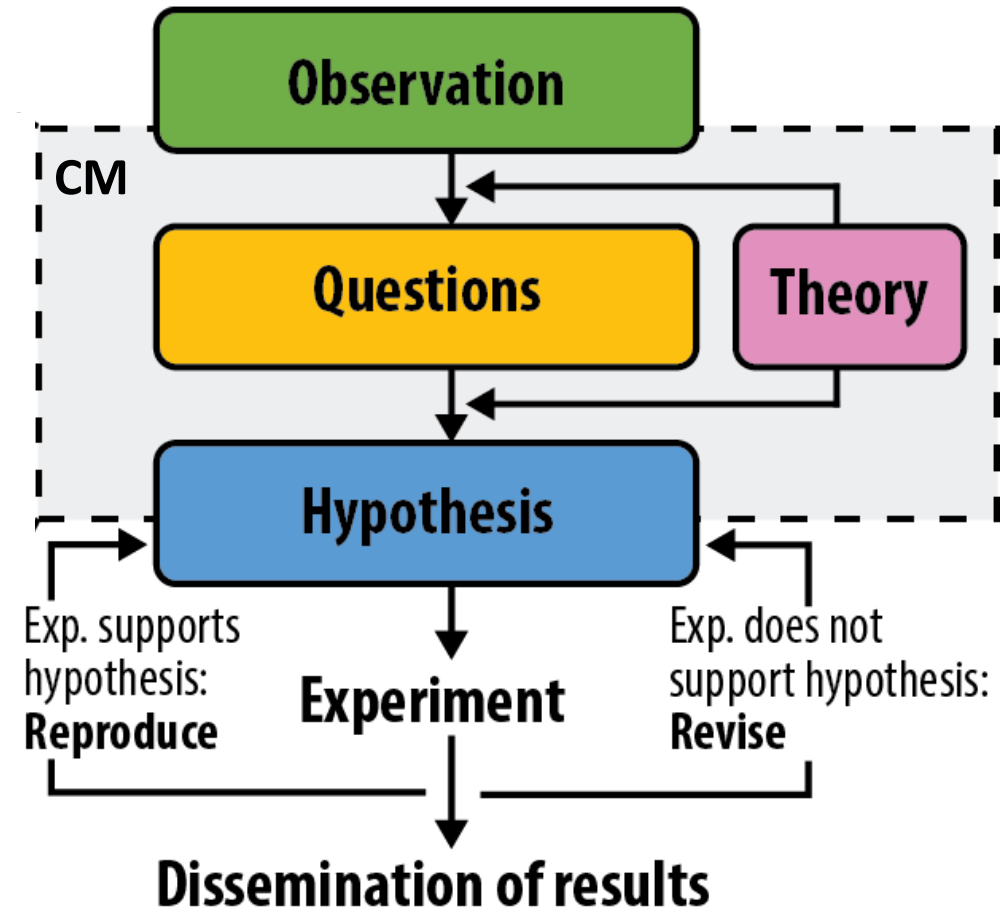
1. A **tool** for getting to a **hypothesis**
2. Entails **simplifications**; is **never complete**



# Requirements: CM must conform method of deduction

## Logical reasoning comprises:

1. **A demonstration that you asked questions** to broaden and deepen your understanding
2. **A demonstration that you searched answers** in your textbooks and scientific literature
3. **An integration** of information into a **coherent 'story'**. (*i.e., information becomes knowledge*)
4. **A scientific gap**. (*otherwise, your experiment was not needed to create knowledge*)



## Summary Part II:

CM **is** a method that promotes **concept-related thinking**

CM **focuses** on the **reasoning ability** of scientists

CM **can** enable the development of **systems thinking abilities**



From Part II to Part III:

CM **is** a method that promote **concept-related thinking**

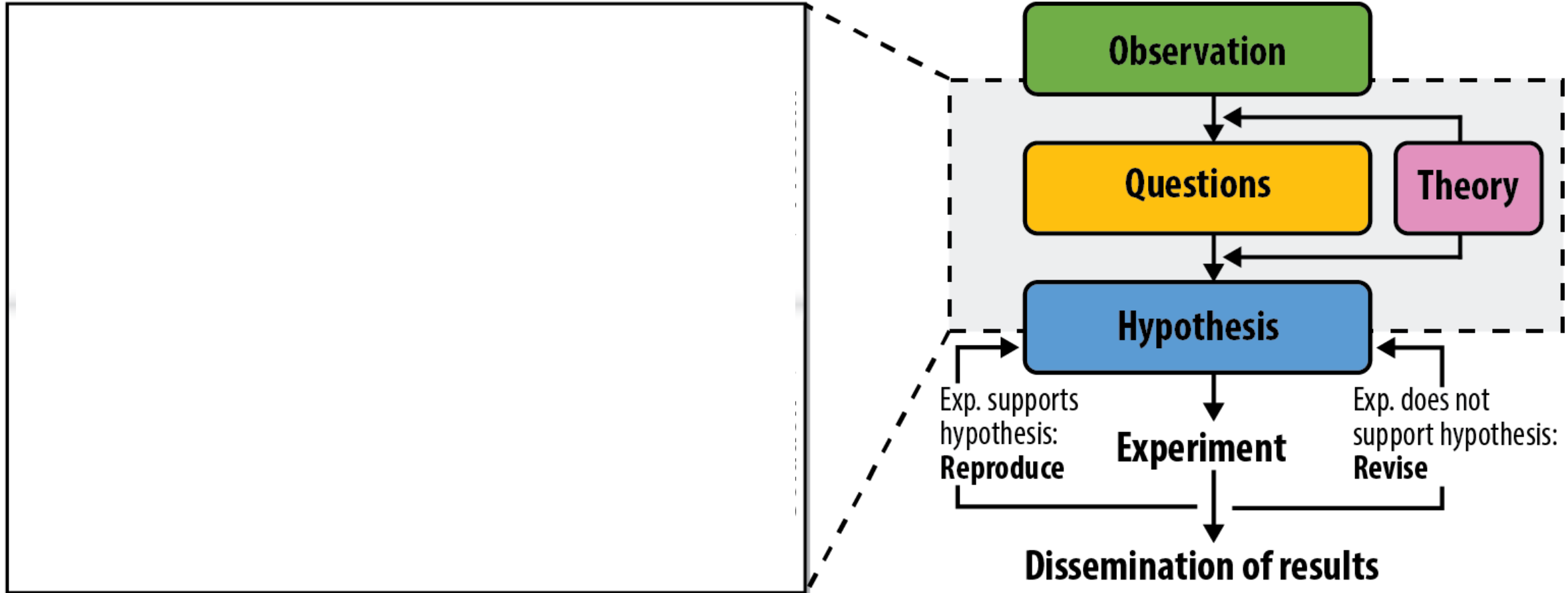
CM **focuses** on the **reasoning ability** of scientists

CM **can** enable the development of **systems thinking abilities**

**Part III.** CM in **this project** should allow you to familiarize with the academic way of thinking and **apply critical thinking skills as a team**

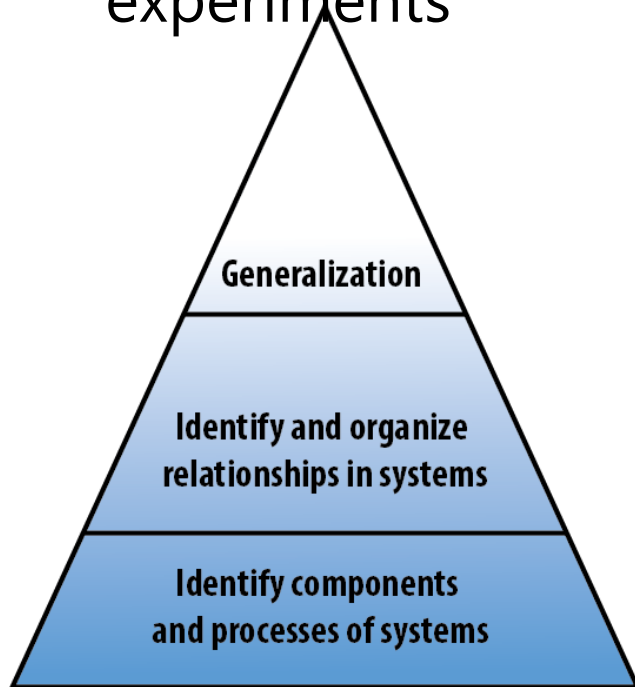


# Assignment: Let us brainstorm

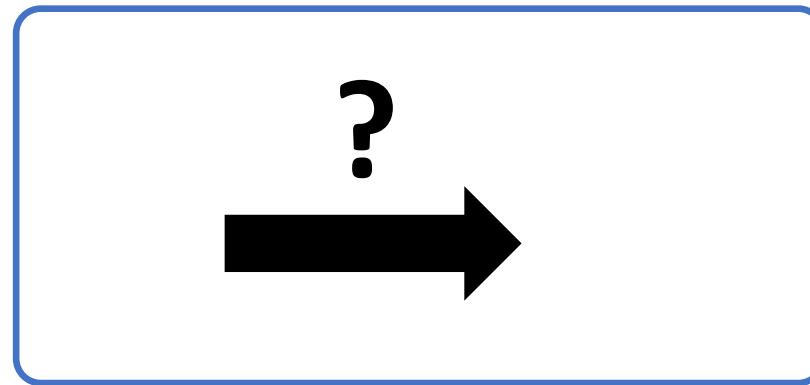


# Recap Part I: We need methods for **Systems Thinking** in Sustainable Chemistry

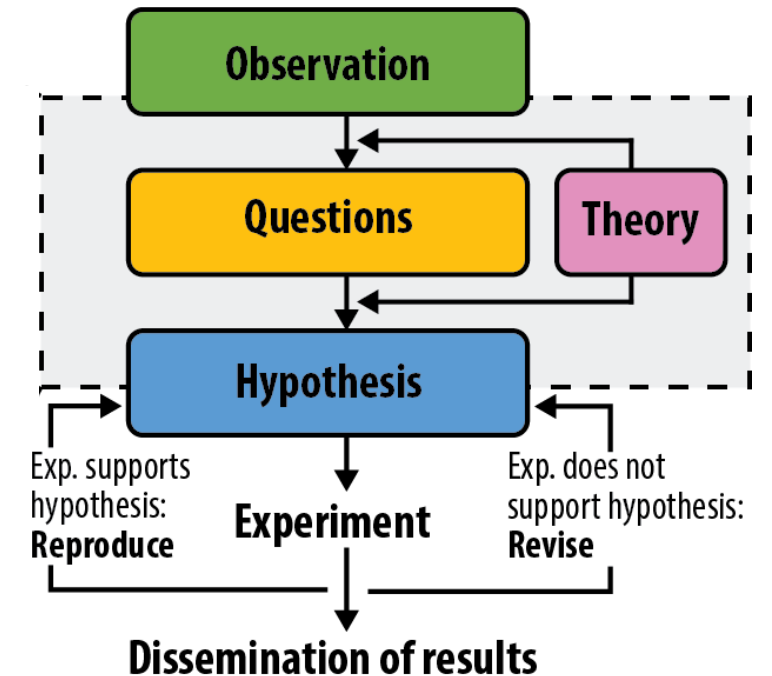
Think in systems  
experiments



Conceptual model

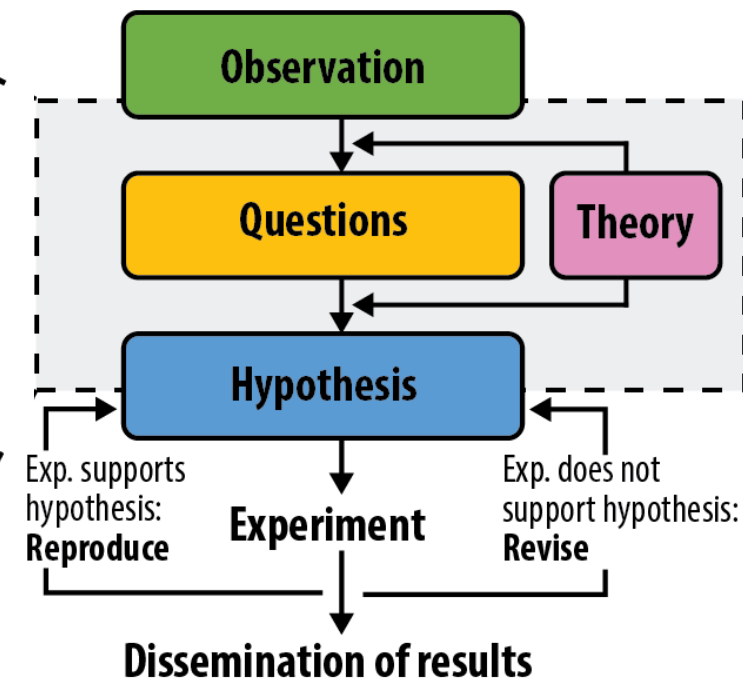
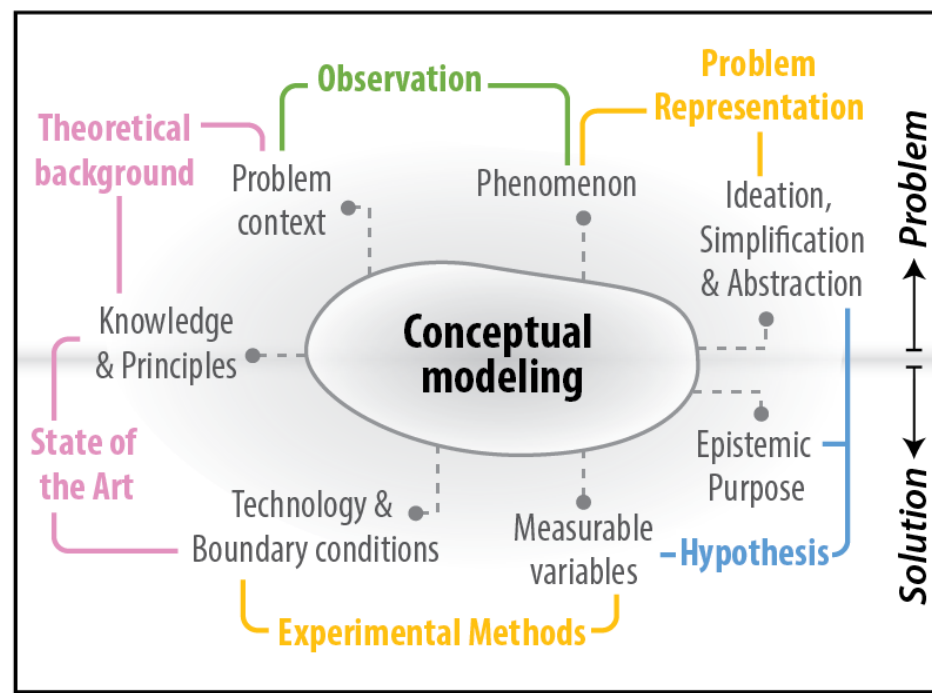
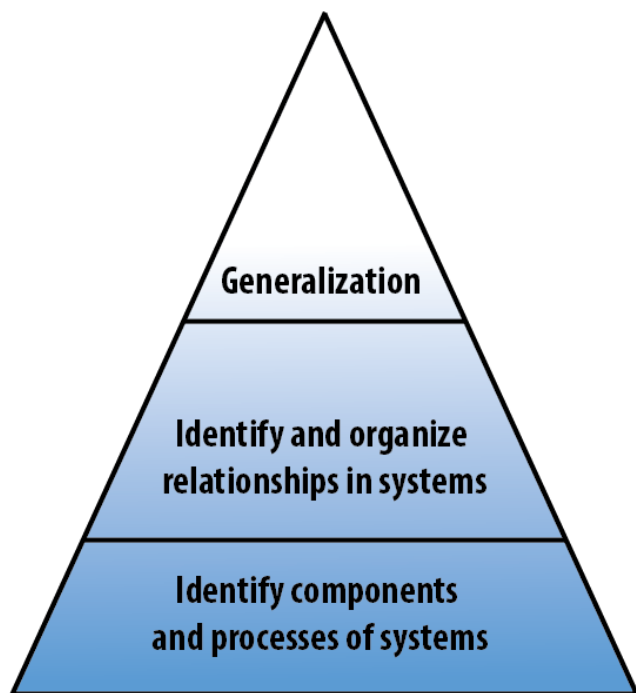


Design chemistry





# Combining all parts

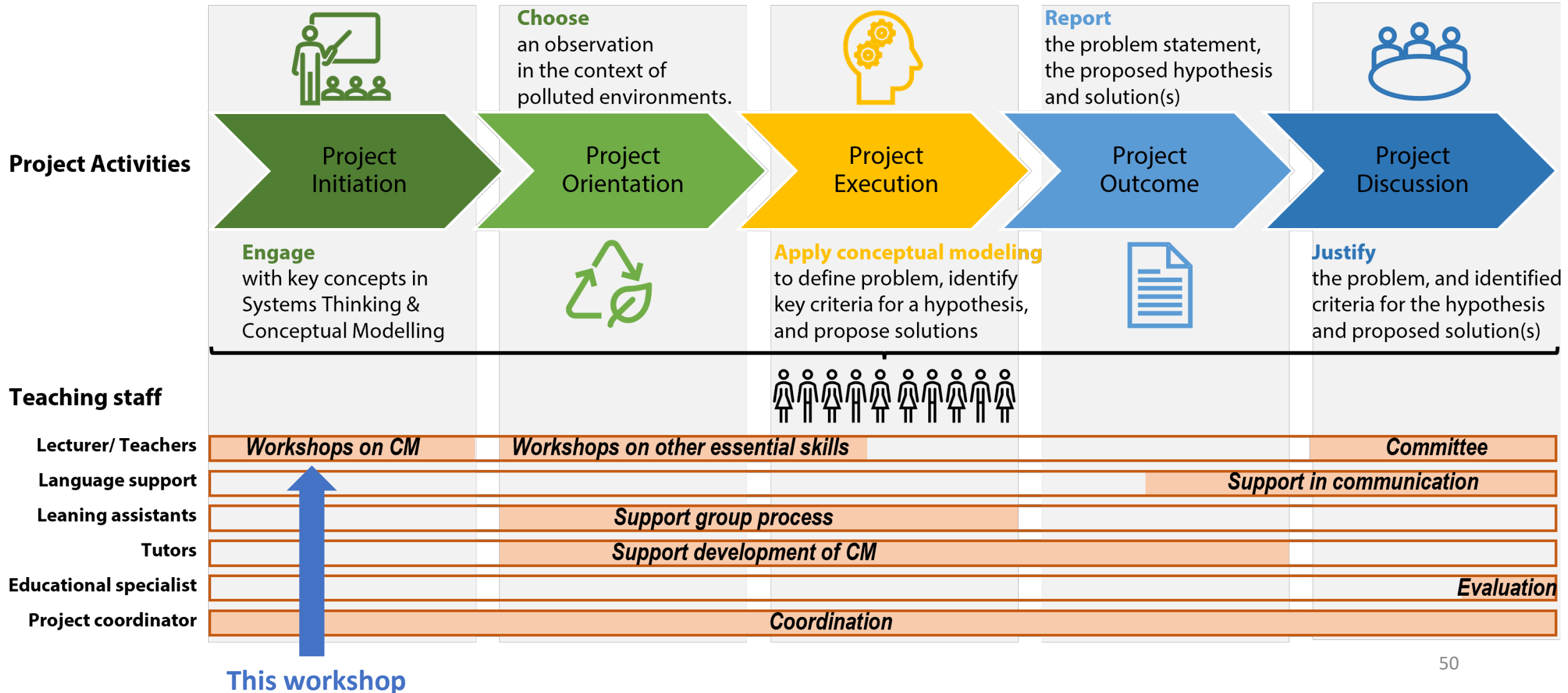


## Conceptual Modeling Enables Systems Thinking in Sustainable Chemistry and Chemical Engineering

Leonie E. Krab-Hüsken, Linlin Pei, Pepijn G. de Vries, Saskia Lindhoud, Jos M. J. Paulusse, Pascal Jonkheijm, and Albert S. Y. Wong\*

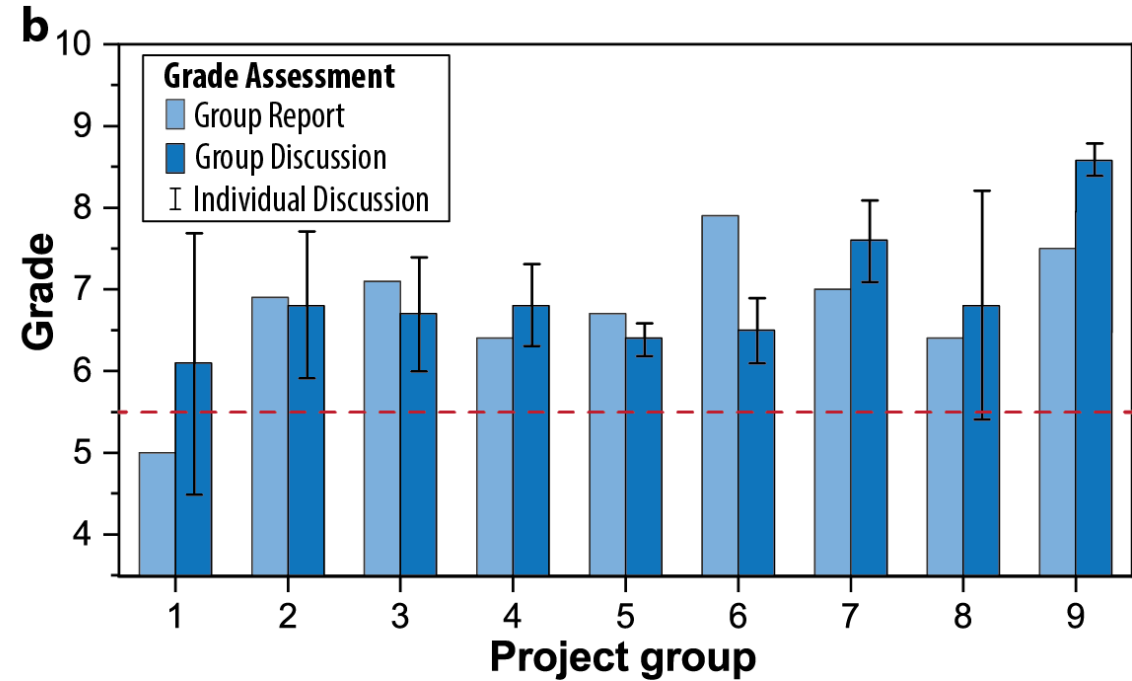
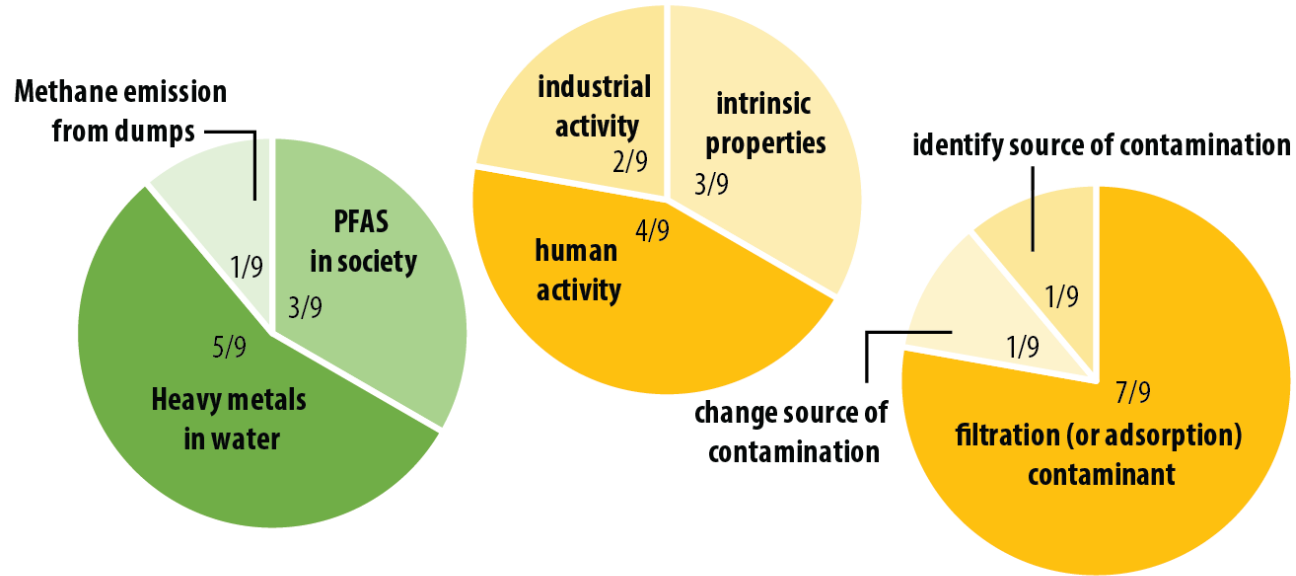
We published this in November 2023: <https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00337>

# General activities and objectives in the project



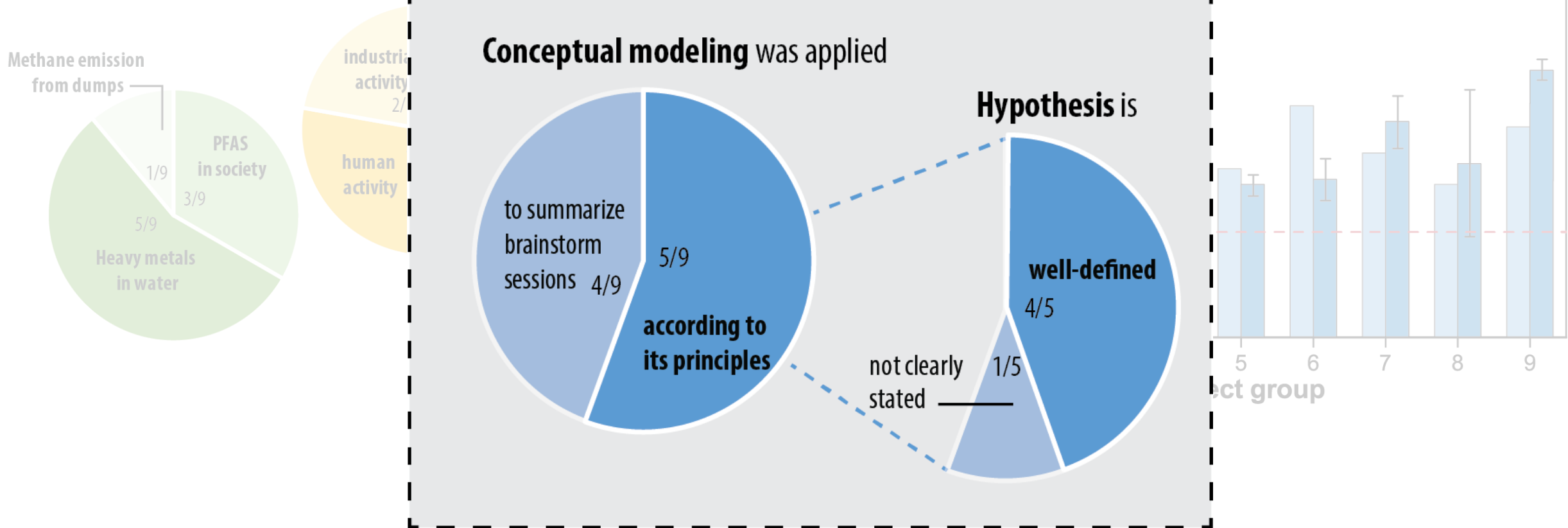
# Examples from previous year

**a** Project topic centers around Identified problem arises from Proposed solution aims at



# Examples from previous year

**a** Project topic centers around **Identified problem** arises from **Proposed solution** aims at **b**





# Lessons learned: A collective student's perspective

**Procedure** to organize their final CM.

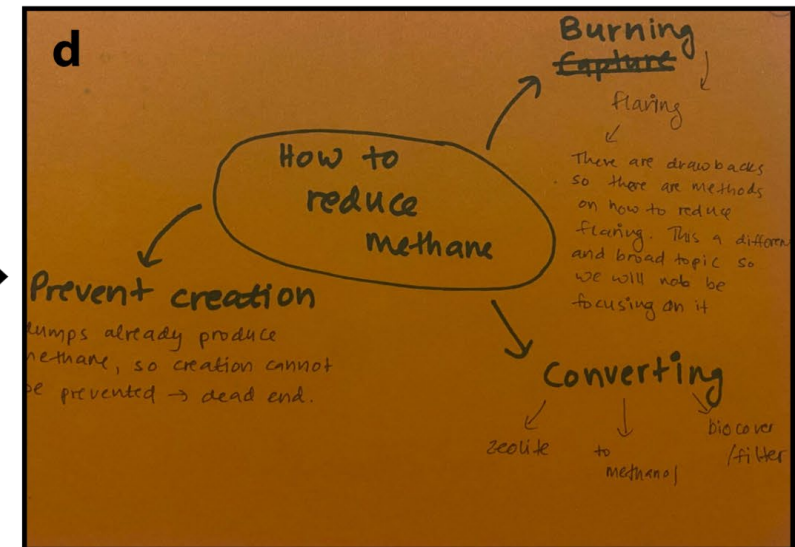
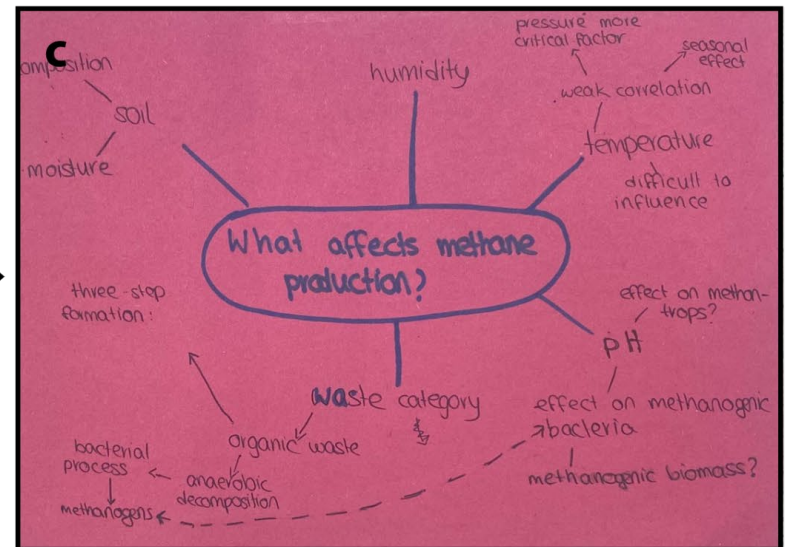
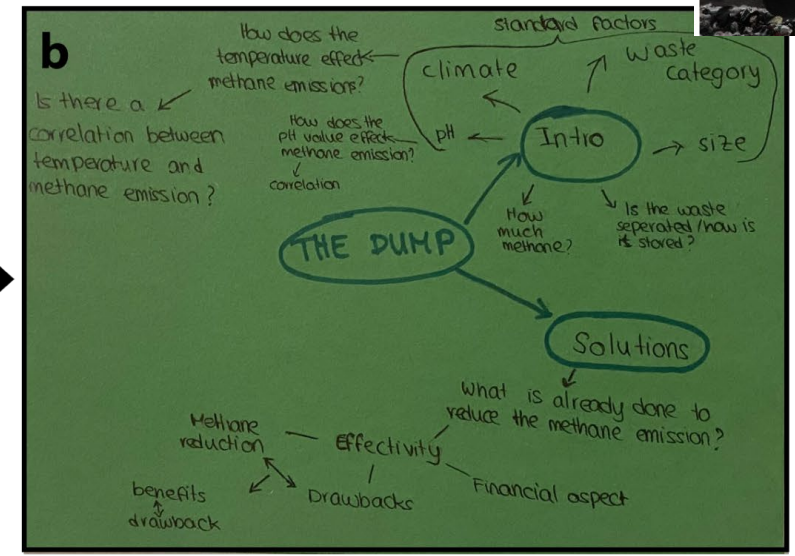
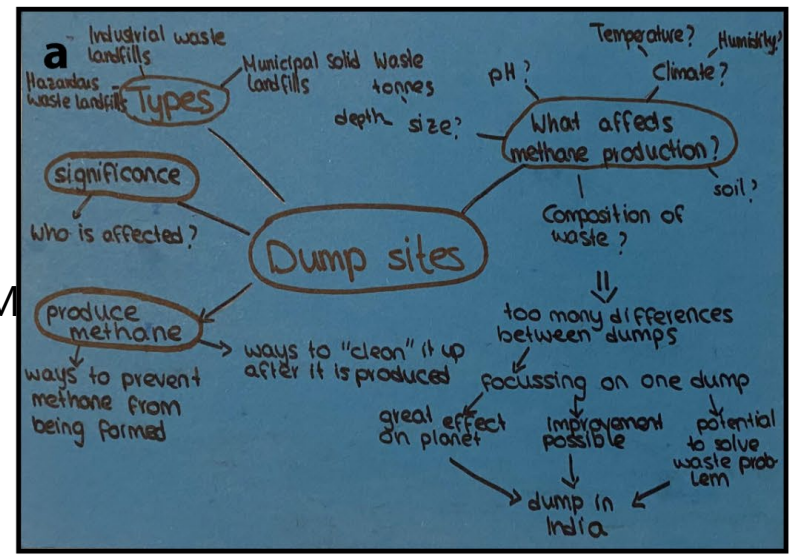
- 1. Find background information** to understand the relevance of the topic
- 2. Specify search** to find correlations between the phenomenon and different variables. Furthermore, look into existing methods that one could use.
- 3. Narrow down the approach**, based on correlations found in step 2.
- 4. Discussed and compared various methods**, as a group. The discussion includes materials and operating costs, which are an essential factor in large scale application.



Methane emission from dumps

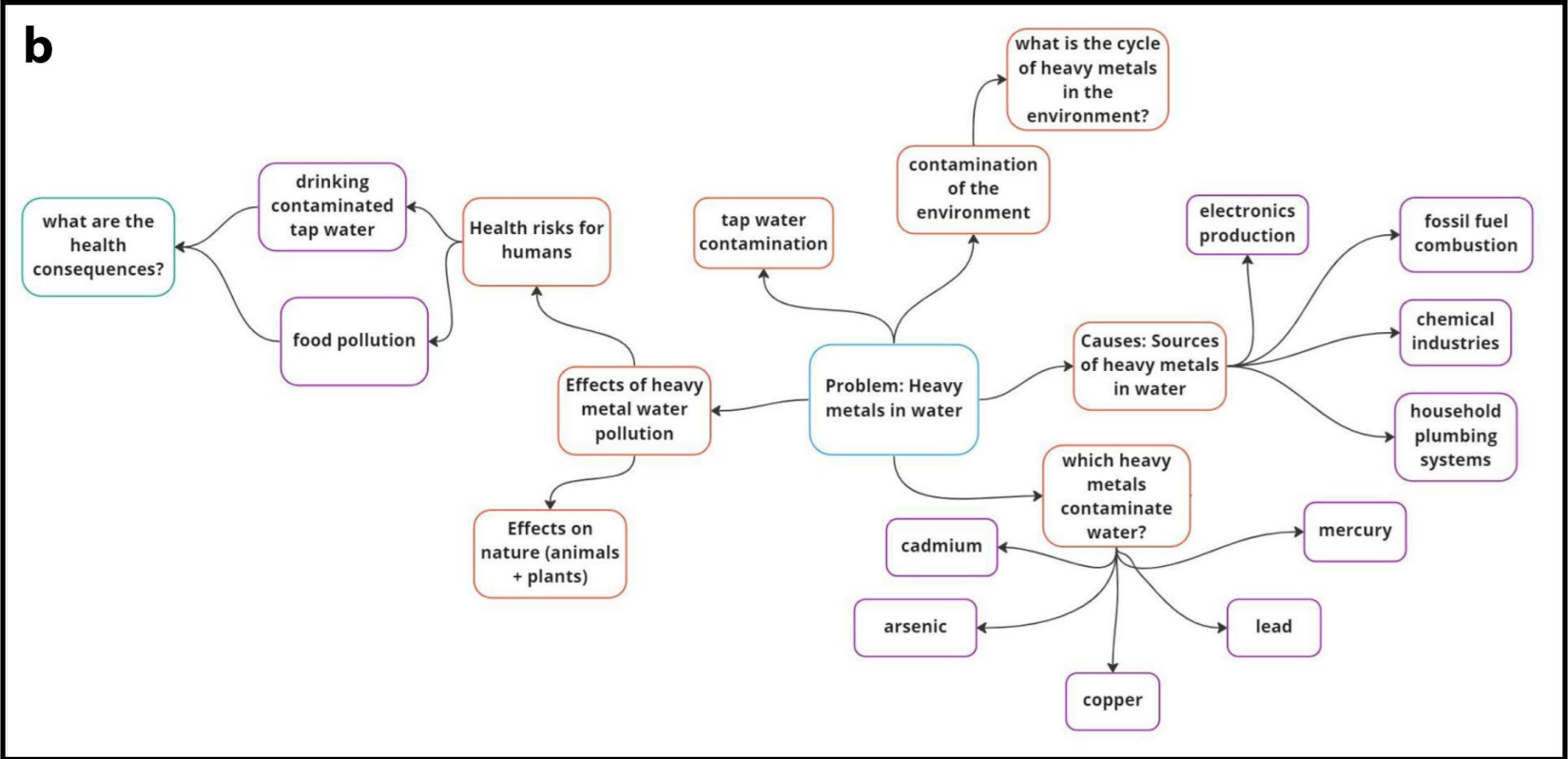
# Example of **successful** applications of CM

Procedure to organize CM





# Example of **unsuccessful** applications of CM



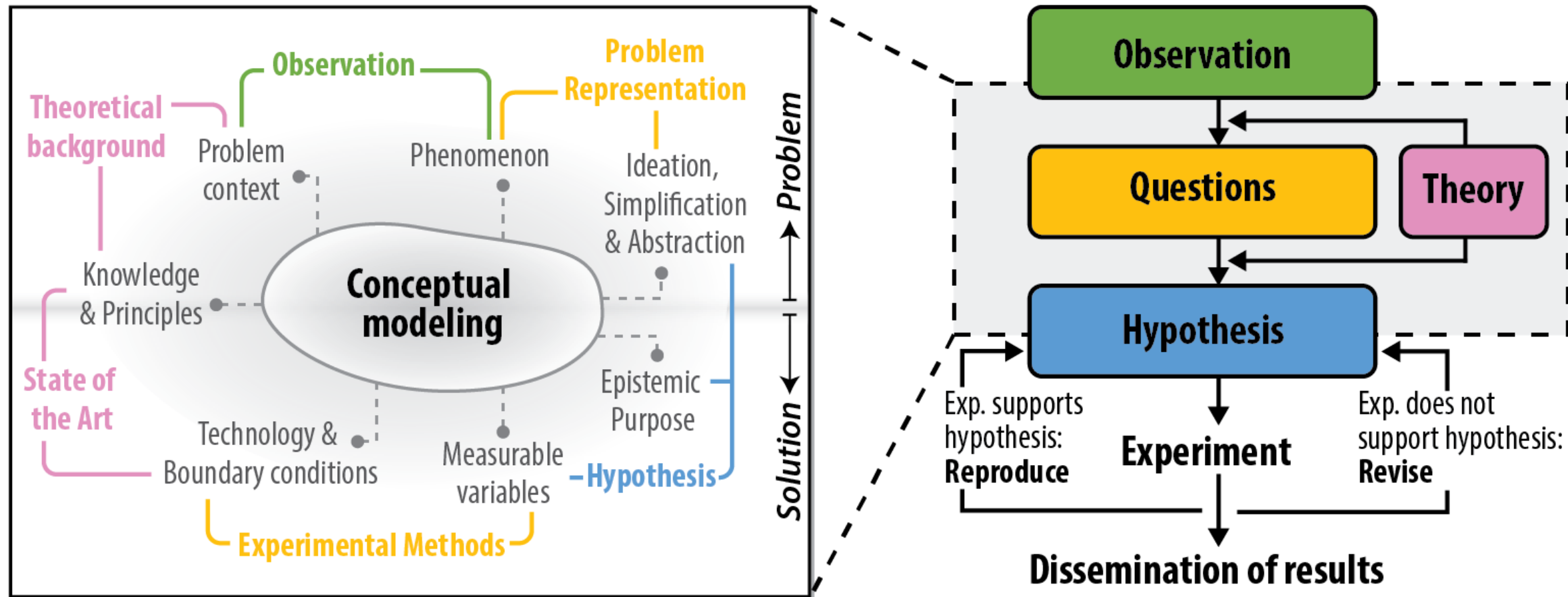
A CM depicted as a mind map for **unstructured connections**

# Roles of tutors and learning assistants in guiding

Teaching staff	Role in project	Possible actions wherein help could be provided
<p><b>Tutor</b> (experienced researcher with a PhD degree in chemistry and a permanent position at our university)</p>	<p><b>Guidance of the development of CM</b></p>	<p>Create an accurate representation of a relevant societal problem.</p> <p>Assess if scientific literature is relevant.</p> <p>Identify criteria for narrowing down the problem.</p> <p>Asking the right questions to formulate a research question.</p> <p>Getting to a meaningful hypothesis.</p> <p>Designing a plausible solution.</p>
<p><b>Learning assistant</b> (senior student with extensive didactical training and experience in CSE projects)</p>	<p><b>Guidance of the group process</b></p>	<p>Organize agenda, communication, and division of team roles.</p> <p>Monitor and stimulate group dynamics.</p> <p>Establish and maintain a friendly and open atmosphere.</p> <p>Level with students (being approachable).</p>



**Summary :** CM scaffolds the transition from an observation to developing a hypothesis.



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**“Be curious, have open mind, and seek out root causes”**  
—> CM provides you the framework

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