

# REASONING AND COMMUNICATION IN SCIENCE AND ENGINEERING

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New Pedagogical Frameworks and  
Tools

Andreas Karatsolis, Associate Director  
Writing, Rhetoric, and Professional Communication  
Massachusetts Institute of Technology



Writing,  
Rhetoric,  
And  
Professional  
Communication



Is the integration of STEM and Liberal Arts possible, and how?

# Yes, in three possible interconnected ways

Curriculum integration

Disciplinary Reasoning: Research  
and pedagogical application

Sustainability and Ethics questions

# CURRICULUM INTEGRATION

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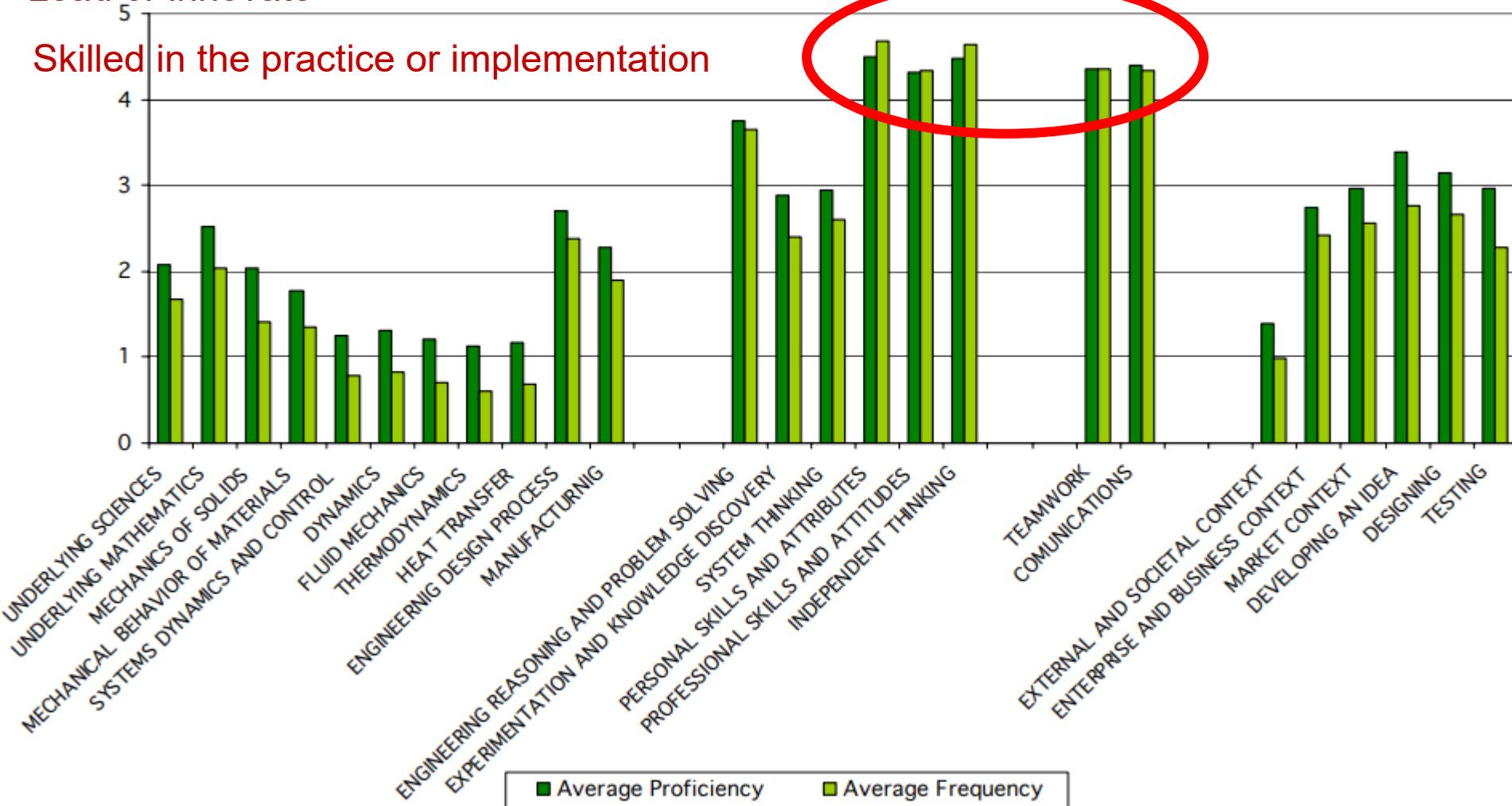
MIT's Undergraduate Communication Requirement

# MIT Alumni Survey (2000)

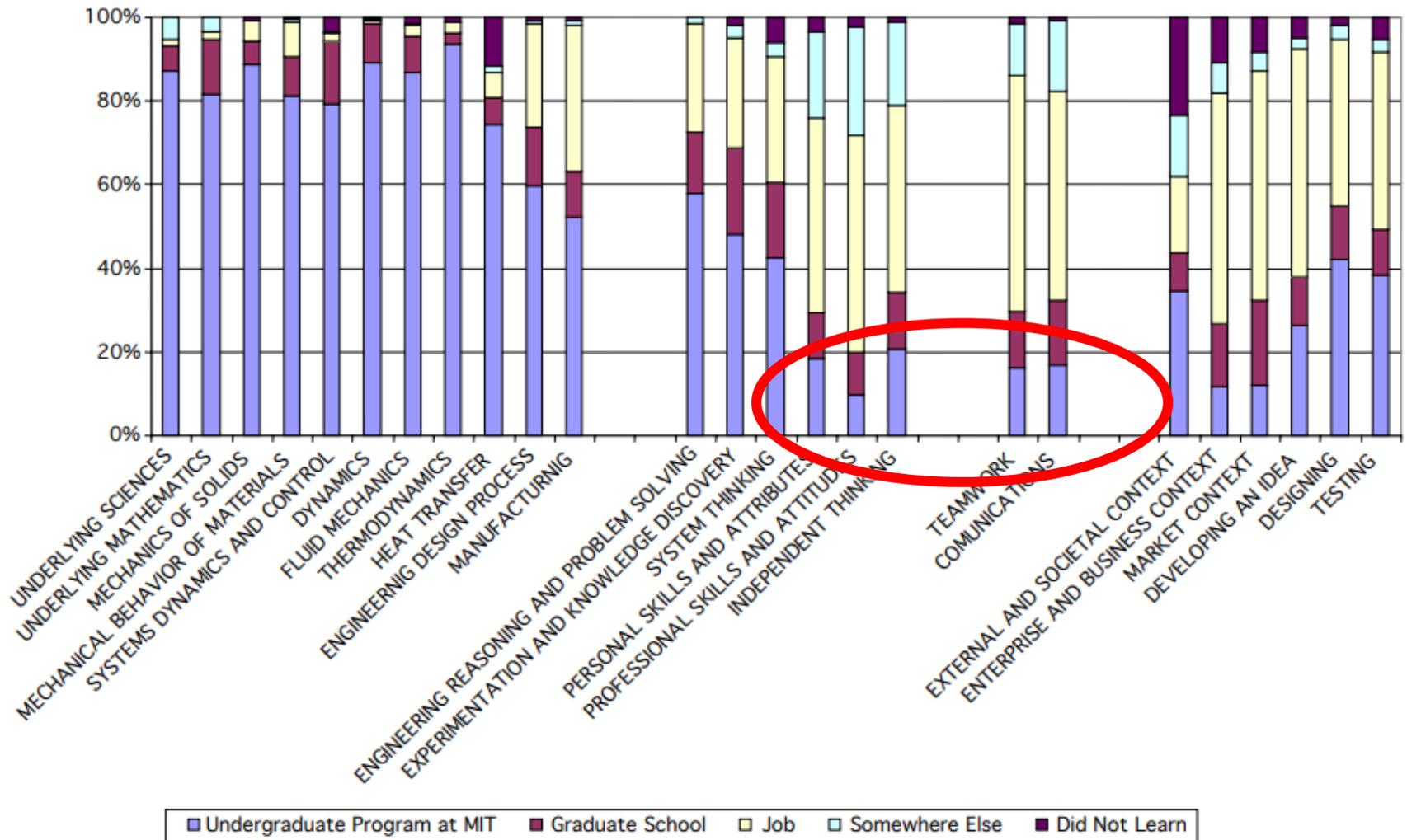
Mean Expected Proficiency and Frequency of Use

Lead or innovate

Skilled in the practice or implementation



# The undergraduate curriculum did not prepare them for these critical skills



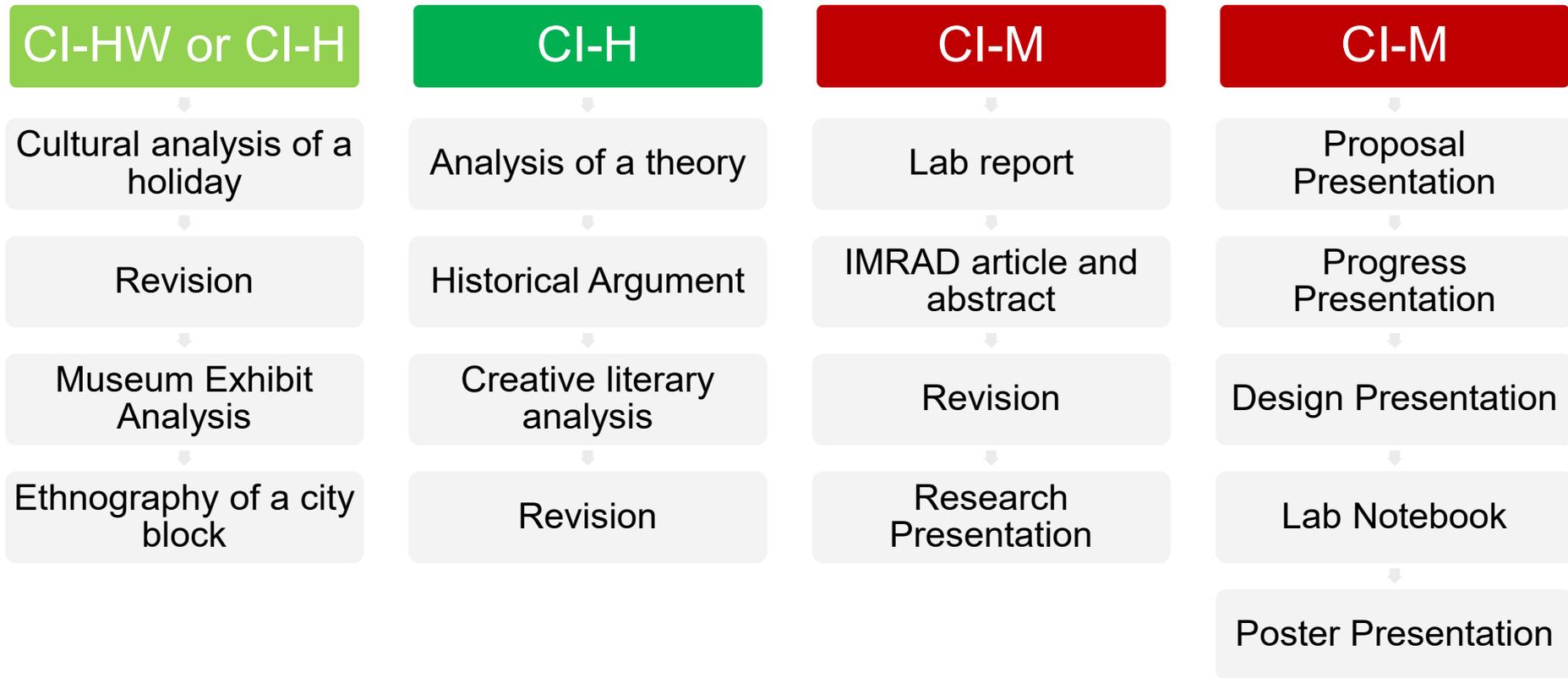
# Faculty-led communication requirement

Since 2001, all MIT undergraduates are required to take  
2 communication-intensive (CI) subjects in HASS  
2 CI subjects in their major

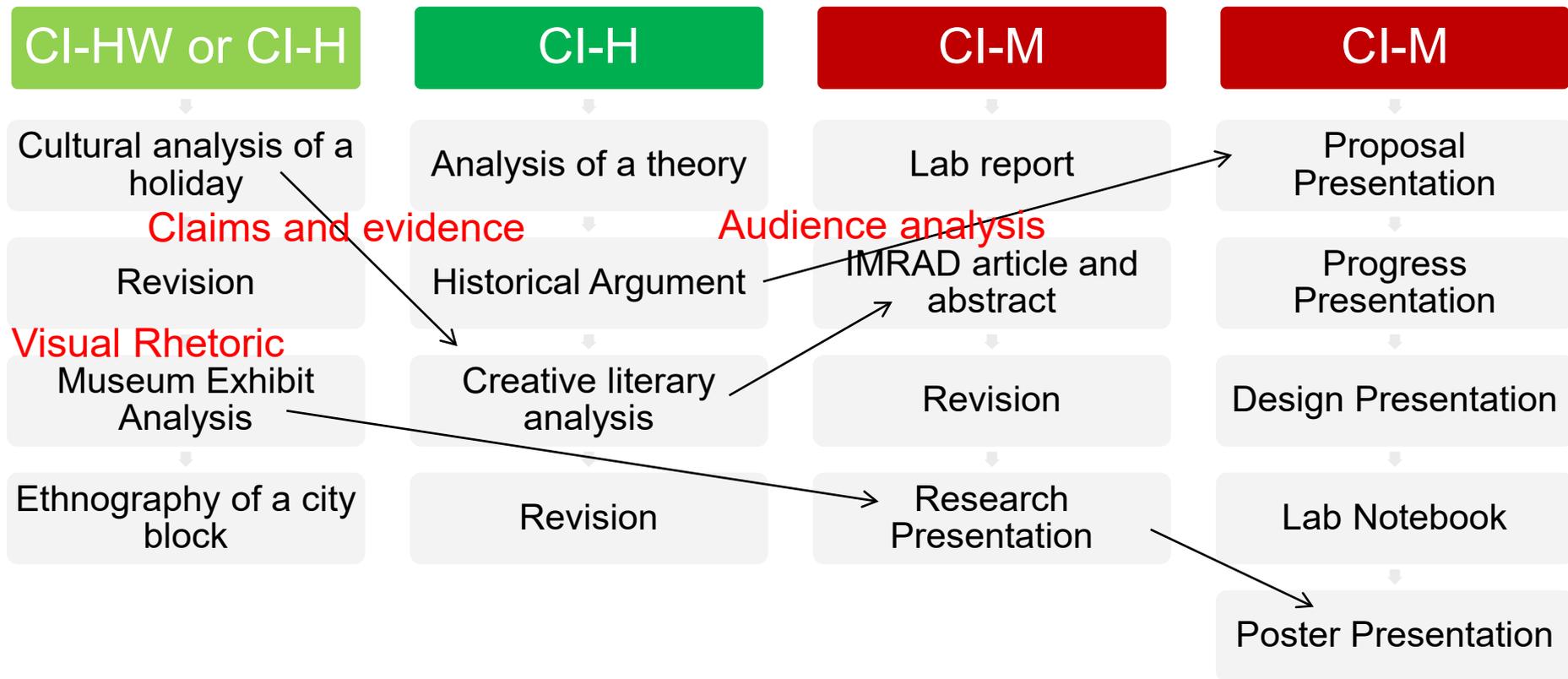
All CI subjects must include:

- Multiple assignments totaling at least 5000 words
- At least one draft and revision sequence
- Instruction in communication and feedback on assignments
- Communication > 25% of grade

# A cross-section of assignments within the Communication Requirement



# Scaffolded Communication Instruction by WRAP faculty



# Students struggle to integrate multiple knowledge domains

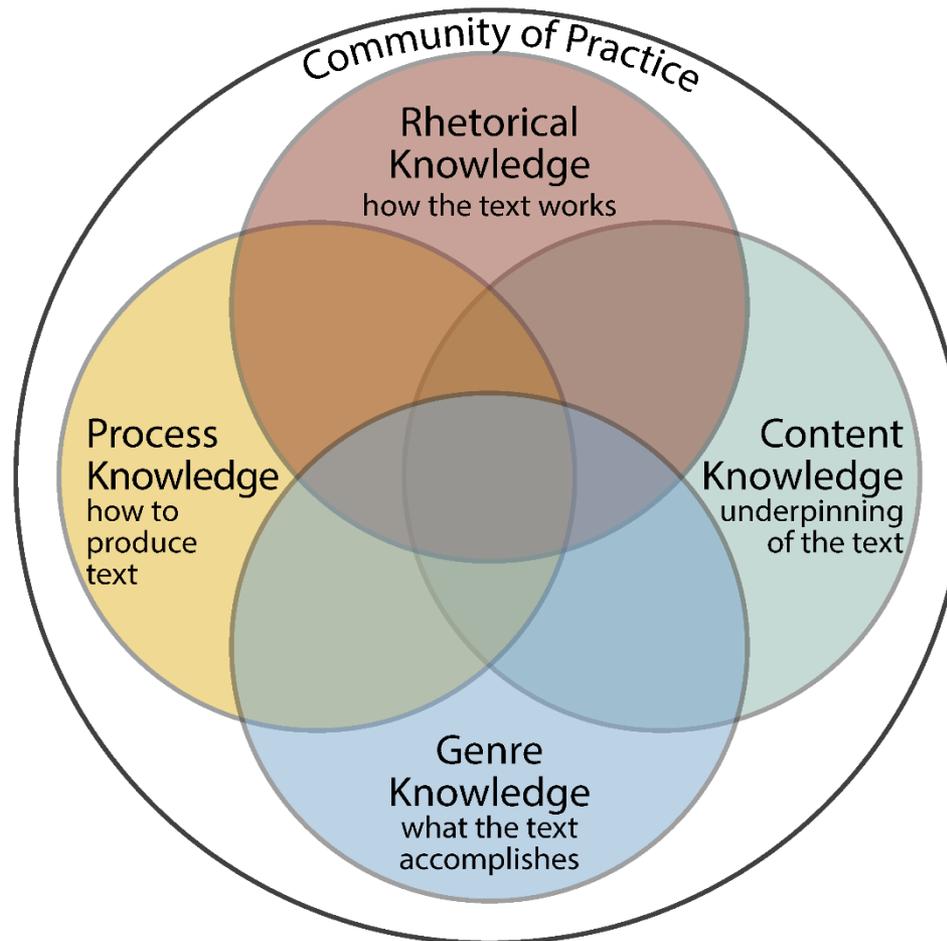


image based on ABeaufort,  
*College Writing and Beyond:  
A New Framework for University  
Writing Instruction*, Utah State UP, 2007 &  
EWenger, *Communities of Practice*,  
Cambridge University Press, 1998

# The challenge: connect content knowledge to other domains (the way experts do)

## Rhetorical knowledge

- Audience
- Purpose
- Context

## Genre knowledge

- Social action
- Ways of thinking in recurring situations

Process (from source use to argumentation to revision)

# DISCIPLINARY REASONING DIAGRAMS

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Can we develop a tool to capture the underlying, tacit disciplinary knowledge that students often lack?

# Our methodology

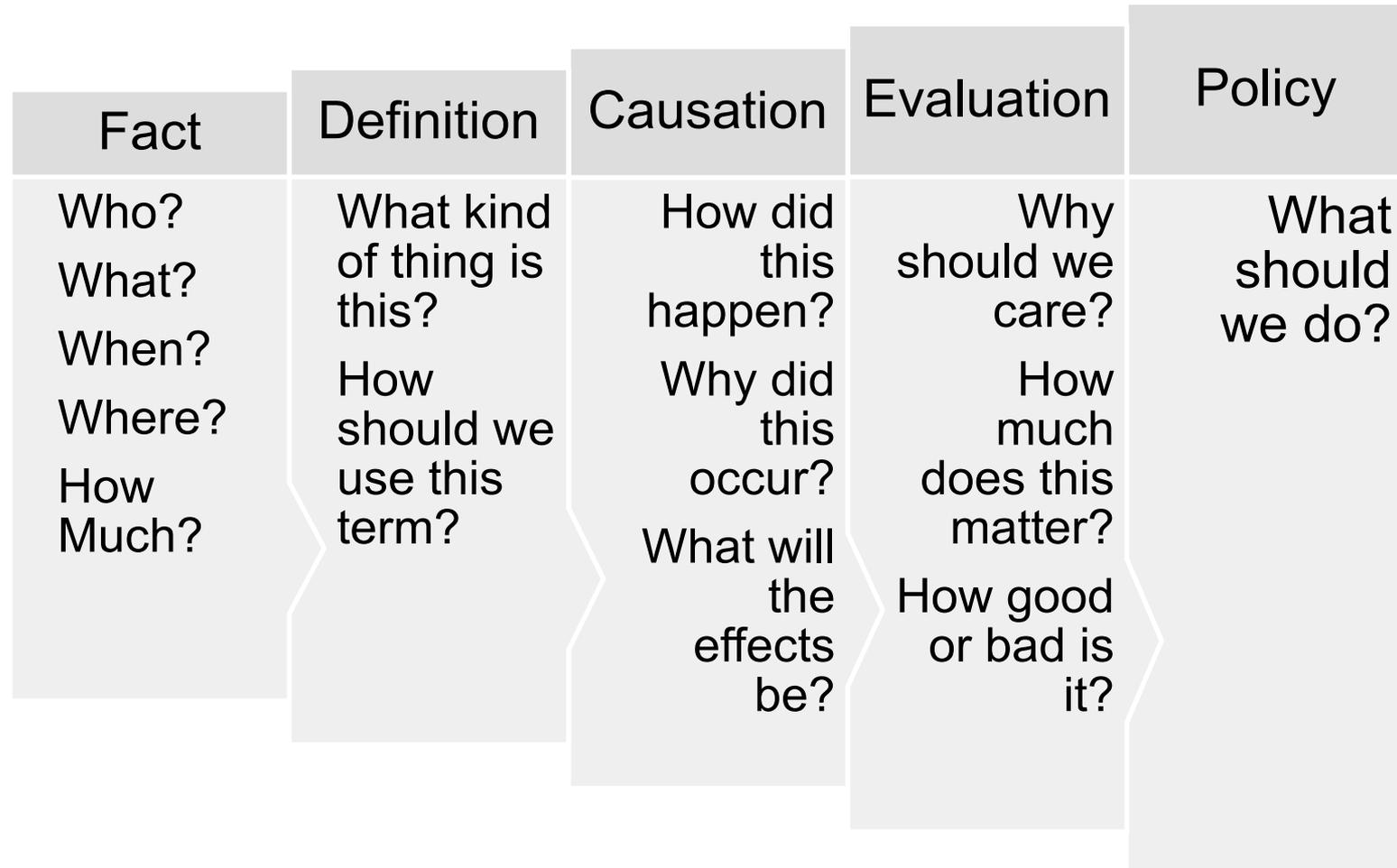
Coding of articles written by faculty in the field to identify rhetorical relationships and frameworks between concepts

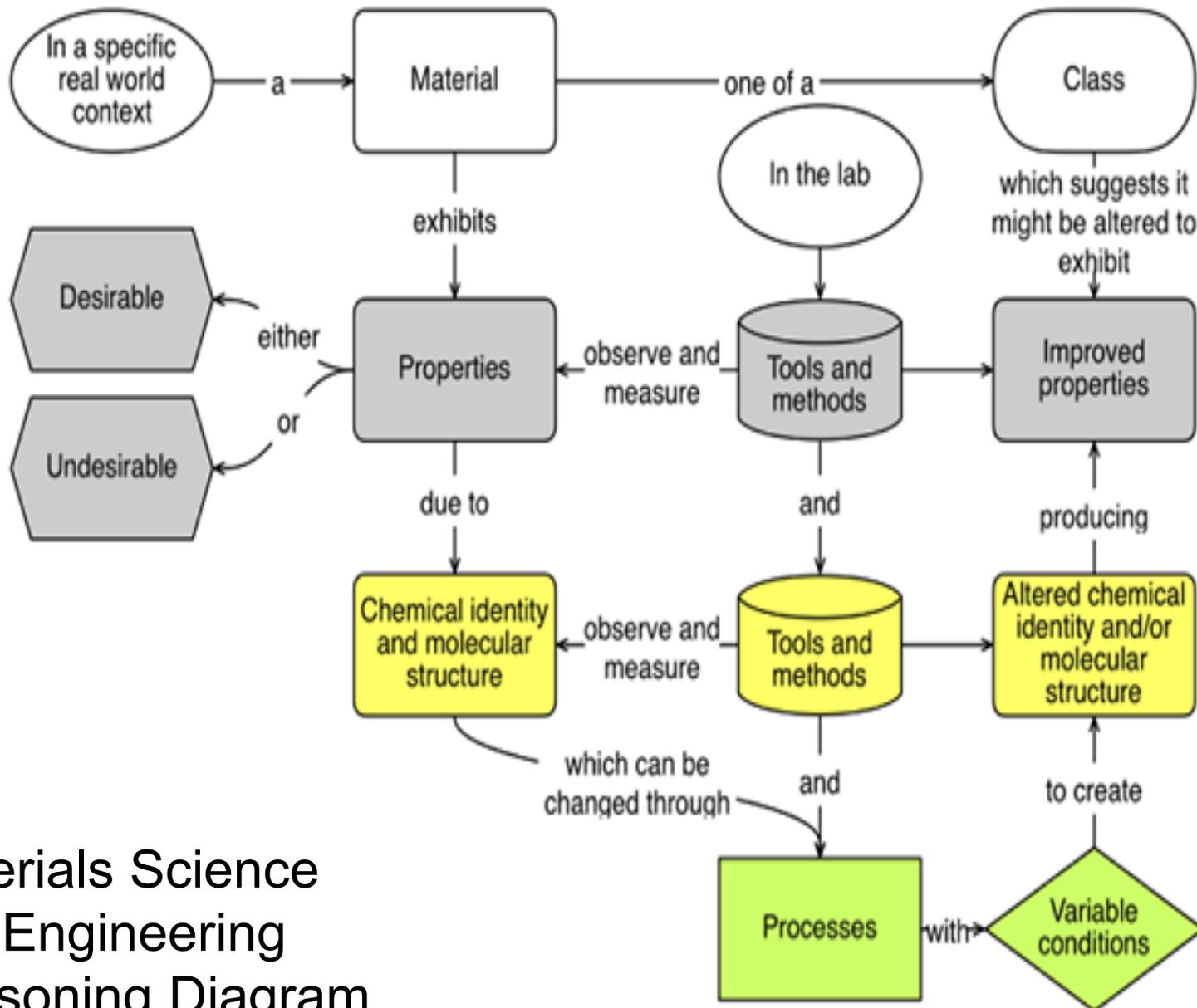
Structured interviews with these faculty in the field to identify core disciplinary concepts and their relationship

Iterative design of reasoning diagram showing these relationships, with feedback from faculty



# Stasis theory identifies points of disagreement or uncertainty (open questions)





## Materials Science and Engineering Reasoning Diagram

# Introductory-level Materials Laboratory

Experimental exploration of the **connections** between structure, properties, processing, and performance of materials. **Hands-on** experience with materials characterization techniques and instrumentation. Covers methodology of **technical communication** (written and oral) with a view to integrate experimental design, execution, and analysis.

General Audience

Technical Audience

## Introduction



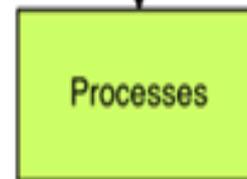
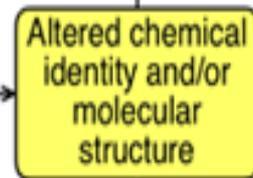
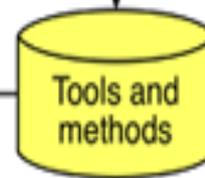
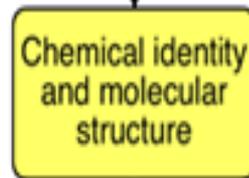
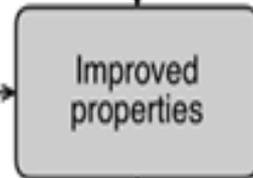
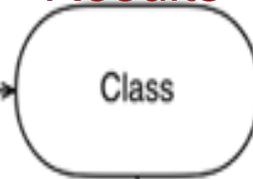
## Background



## Methods



## Results



a

one of a

exhibits

which suggests it might be altered to exhibit

either

observe and measure

or

due to

and

producing

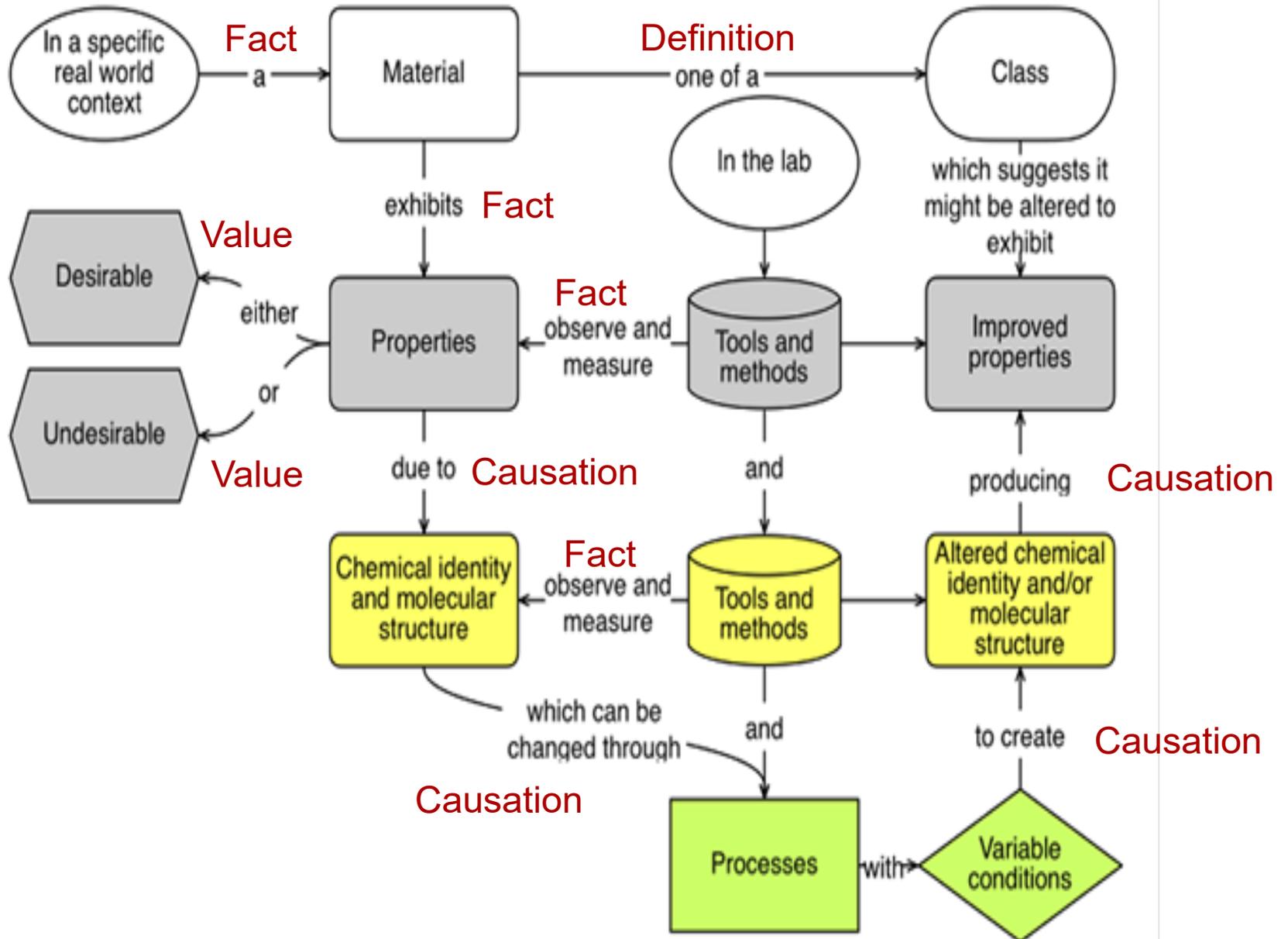
observe and measure

and

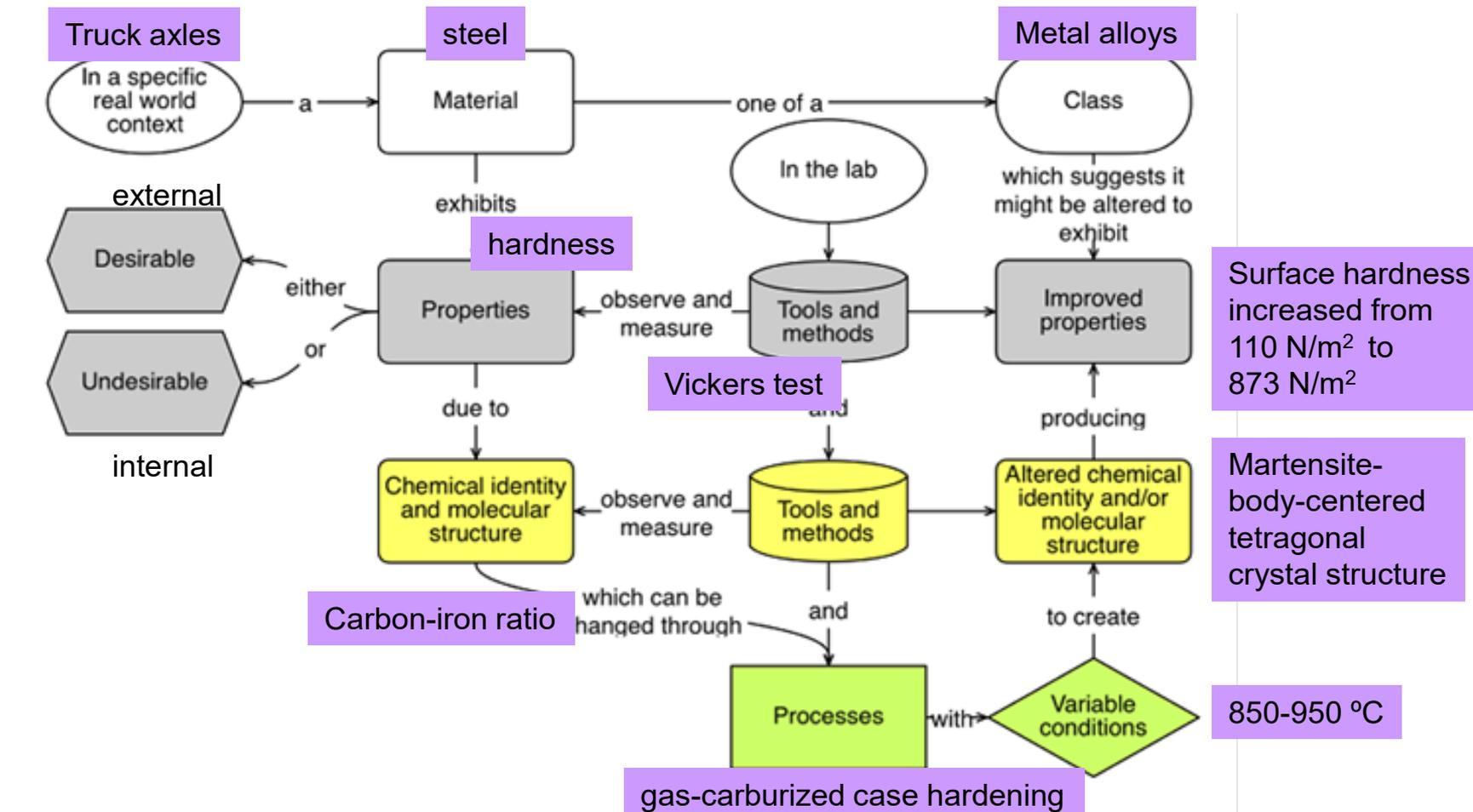
to create

which can be changed through

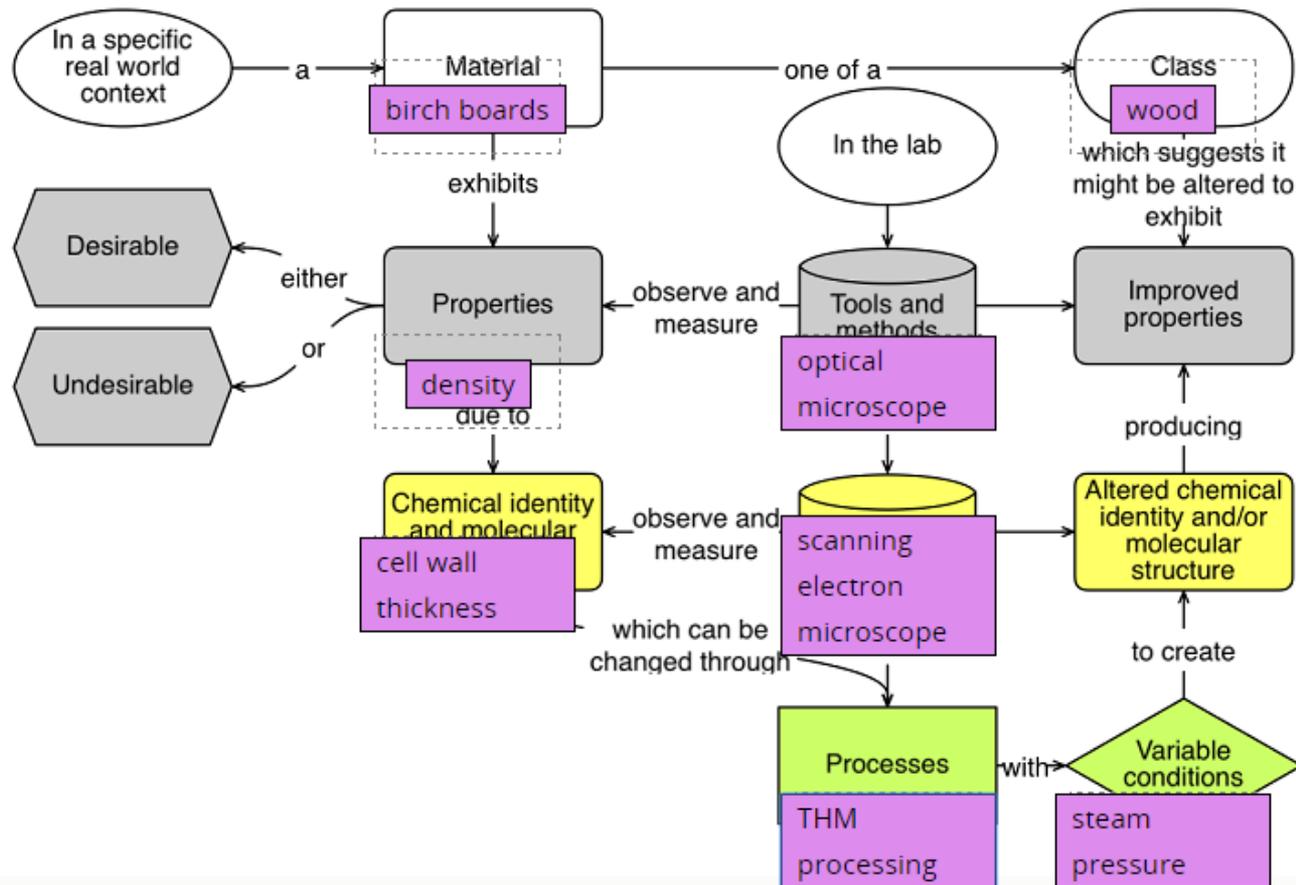
with



# Students prepared for labs by following the logic of the reasoning diagram



# Students were able to read and critically analyze literature in the field





OK, but does it actually help students integrate the technical content with the other domains (including the rhetorical)?

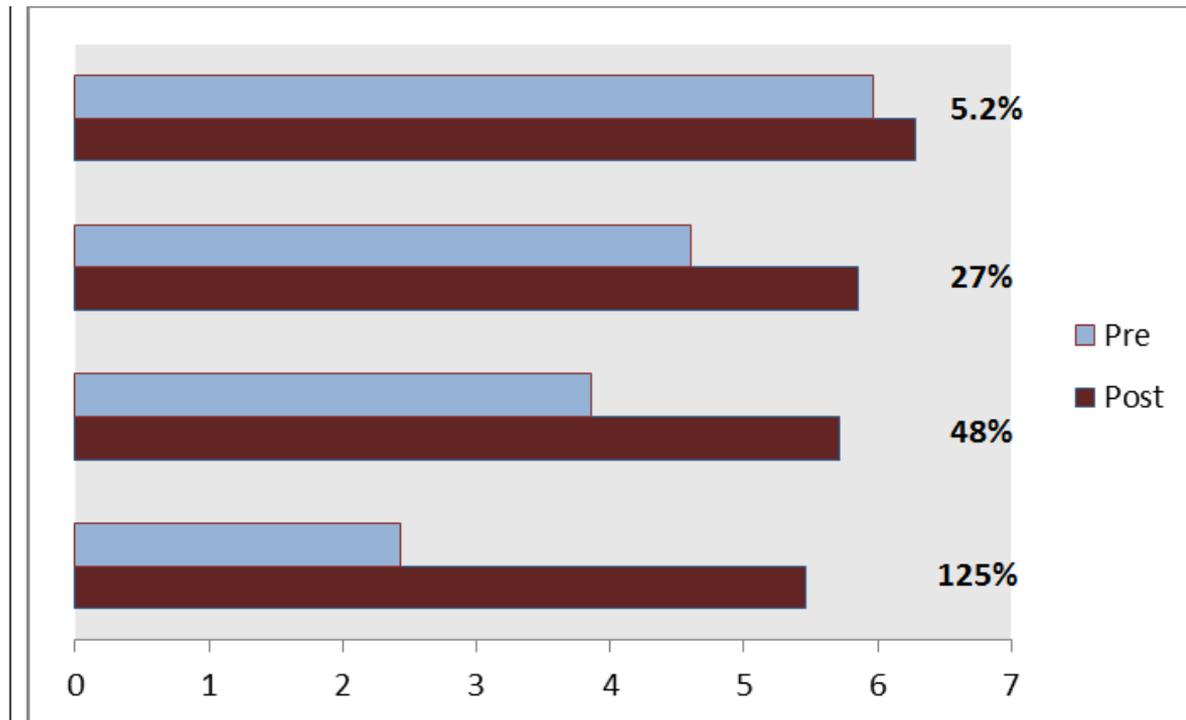
# Pre-post results: Disciplinary communication

I recognize that conventions (such as formal and informal rules of content, organization, style, evidence, citation, mechanics, usage) are dependent on discipline and context

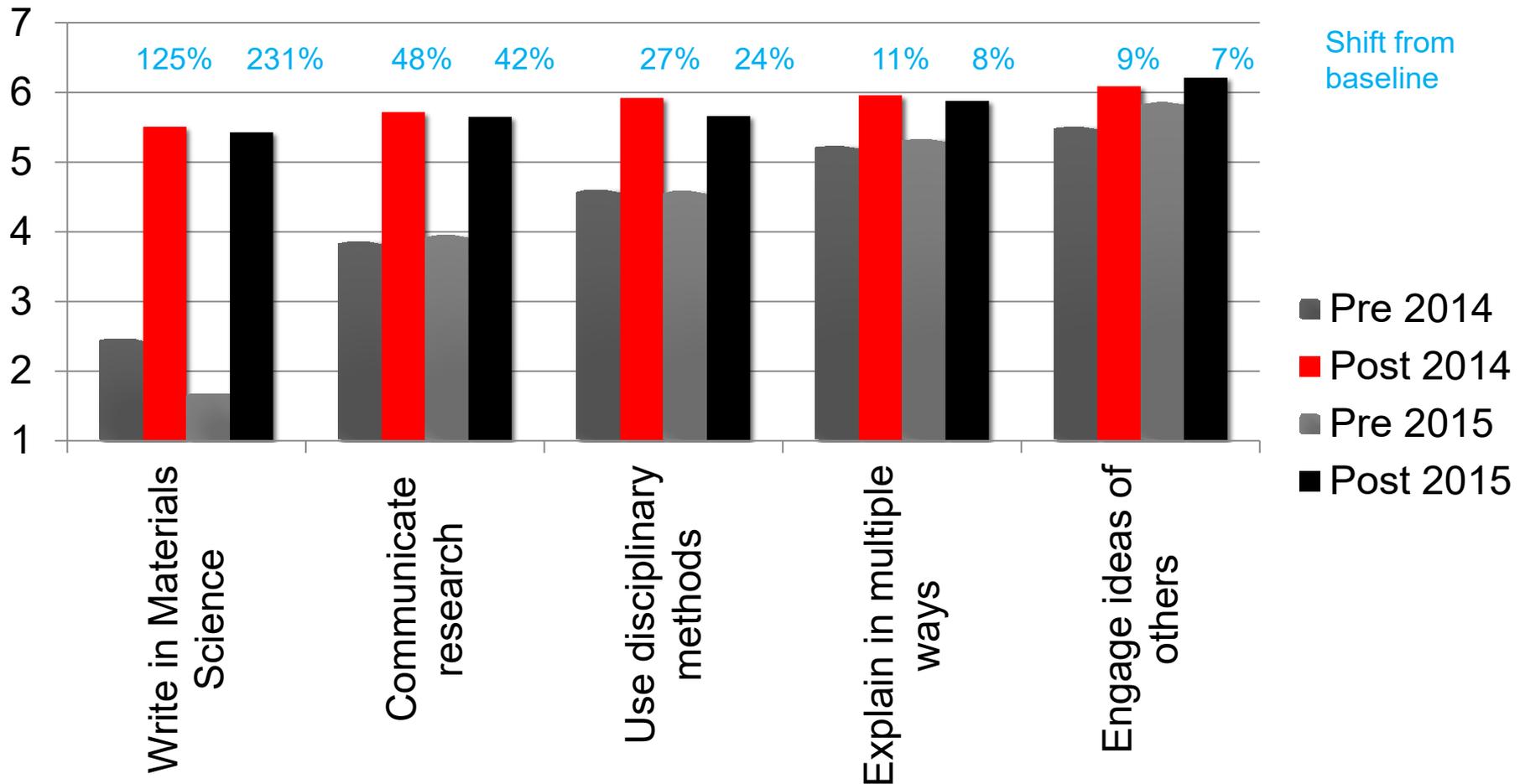
I conduct research using methods for investigating questions appropriate to my discipline

I can communicate research findings to multiple audiences using discipline-appropriate conventions

I have sufficient experience and knowledge about writing in Materials Science



# Consistent self-reported Improvement in Writing Knowledge



# Students report in focus groups that the reasoning diagram is very useful

“It’s really clear. You can devote a paragraph to each little bubble, or even just a sentence or phrase, depending on the scale you want. But it **sorts things into bins**, which is really nice if you have a lot of mush that isn’t in bins in your head.”

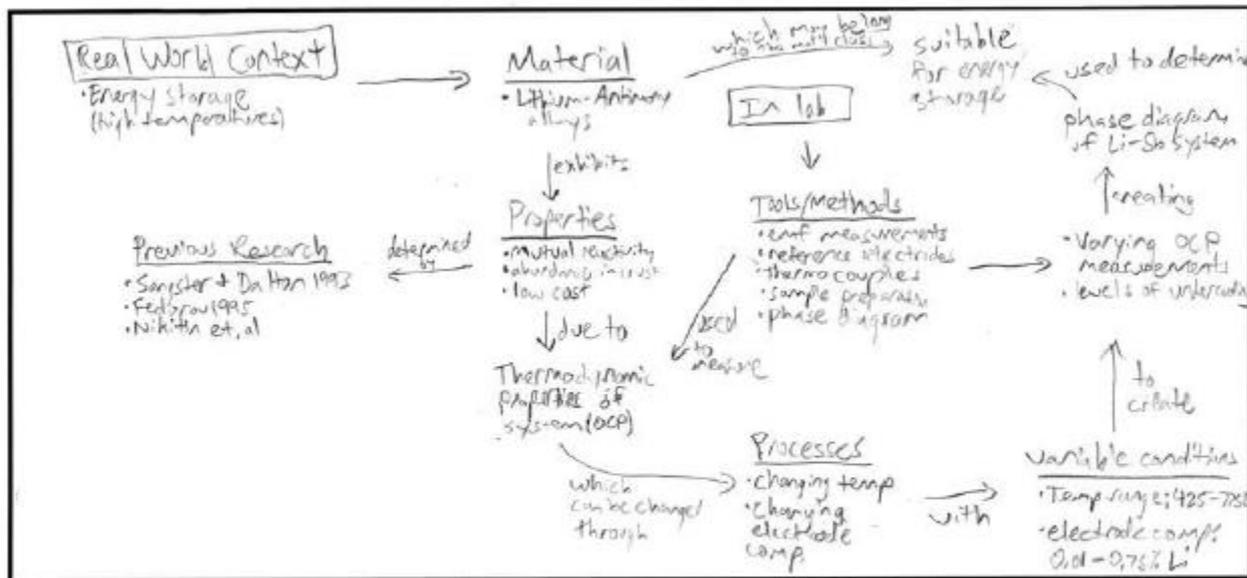
“I used [the reasoning diagram] for the group presentation—that was helpful. I think it helped us outline the presentation, making sure we were including everything—that was good. But now, it’s kind of like a **guideline that’s inserted at the back of my mind.**”

“[The reasoning diagram] was useful in my assignments to make sure **the path I’m taking makes sense.**”

“I would glance at it. Like, “I don’t know what to **write about next.** I’m going to look at the diagram.”

# Students read and critically analyze literature in the field more efficiently

## Part A: Reasoning Diagram for Kane et al (2015)



Question to exam  
Positive correlation  
(P-Value <0.01)

Question to course  
Positive correlation  
(P-Value 0.0372)

Describe in 75 words or less the core line of argument (can use the diagram above):

To determine the suitability of the Li-Sb system for applications in energy storage, this study aims to determine the thermodynamic properties of the system (specifically cell potential) when varying lithium composition and temperatures. This data is used to produce a phase diagram, which can determine the optimal energy storage material.

# Students can write in multiple genres on the same data/technical question

## Executive Summary

**To advise the company on a plan of action** regarding the recently discovered borax deposit in southern California, my team and I have been working with sodium borate glasses and alpha-brass to discern these materials' properties. . . .The results we found are significant for **helping the company maximize the durability of a new light bulb made of sodium borate glass and alpha-brass.**

## Technical Memo

Materials attribute many of their specific properties to their chemical makeup. Yet even if certain materials have the same chemical components, they may not have the same properties. **The purpose of this experiment was to determine the effects that defects and network modifiers had** on the mechanical properties of alpha-brass and sodium borate glass. **The alpha-brass was chosen to be representative of a crystalline material, and the sodium borate glass was representative of an amorphous material.** **Definition**

Cause/  
effect

Policy

Value

# In peer review, students ask peers to connect concepts with reasoning (tool to structure, structure to property, etc.)

Abstract:  
Argues for significance

Mentions oxygen vacancies but no significance of them. No recommendations made.

Introduction:  
Claims centrality

Gives good background, does not get more specific about this module though. Tells that XRD is a powerful tool, but not why the results it gives are significant.

Introduction:  
States value and purpose

States the value of XRD, but not in context. Doesn't say why these structure parameters are important. Also why use "d-values" instead of interplanar spacing (or some derivative of that)?

# And make requests for links between concepts which integrate subject, genre, and rhetorical knowledge domains

Abstract:  
Shows a concern, debate,  
or gap in knowledge

I think for the abstract you need to connect the material you introduce, chemicals that can serve as heat energy storage materials, with why we're doing the experiment. Maybe include something about why developing heat energy storage materials is important, and then focus on why we chose this particular energy storage material, and then use that to segway into the methodology of the experiment.

Conclusion:  
Summarizes and highlights

Succinct summary that 1) reminds the reader why we're researching these chemicals, and 2) which composition of lauric-stearic acid would be the best as a heat storage material.

Conclusions:  
Suggests future research

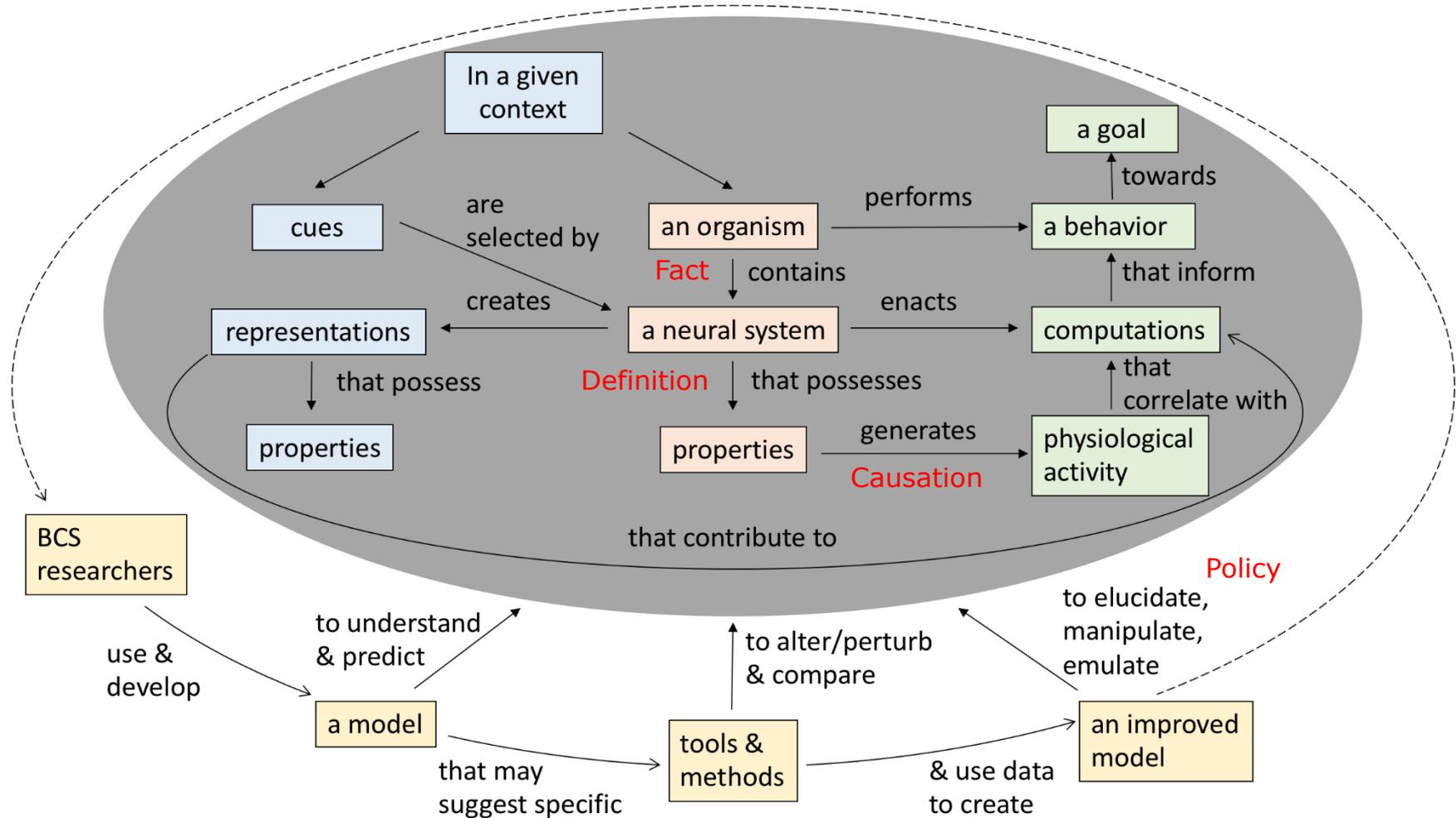
I like your inclusion of intermediate phases and tying it in to future research. Maybe add something about real-life applications, such as in buildings or in clothing.

COULD WE REPRODUCE  
THIS IN OTHER FIELDS?

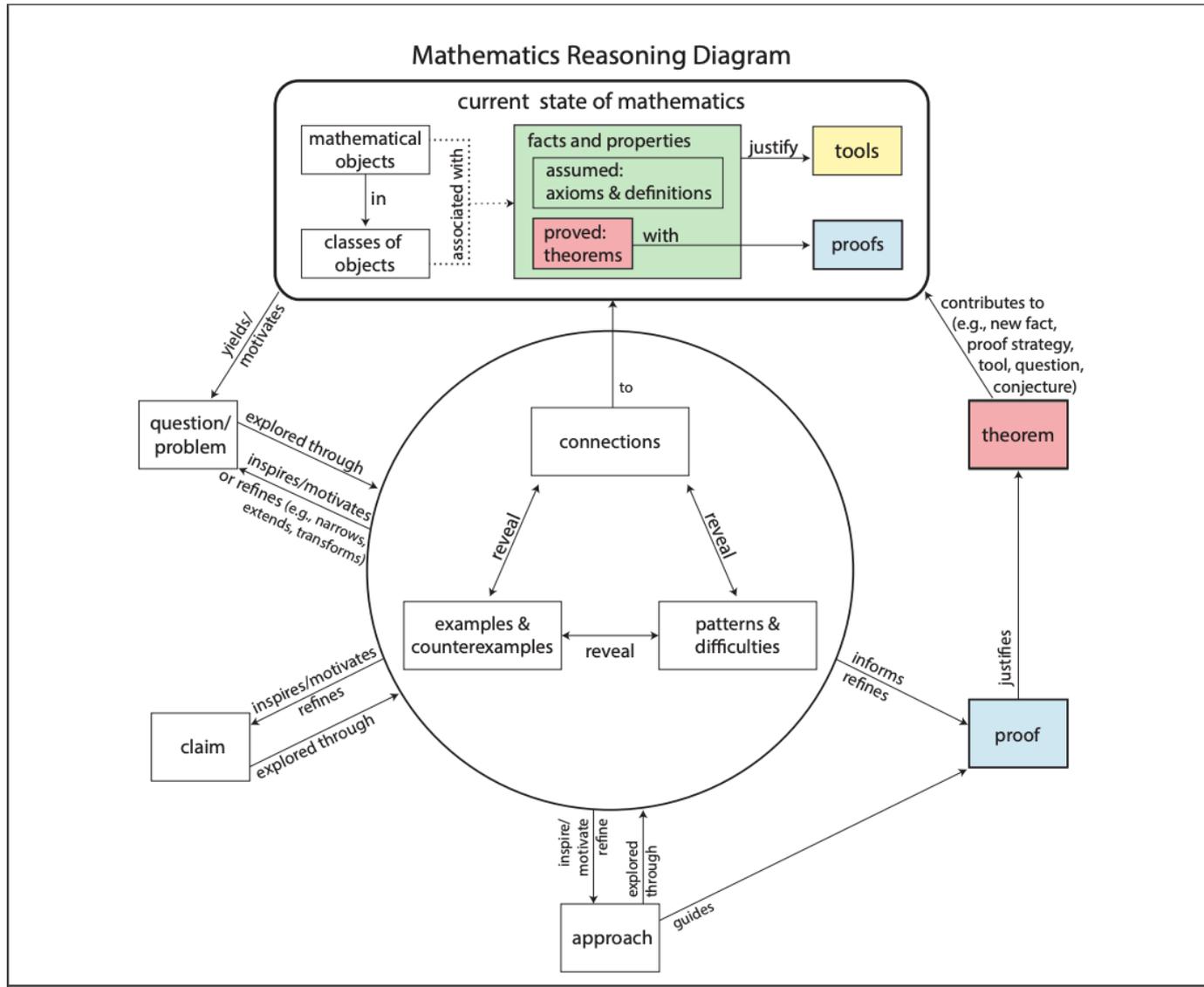
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# Brain and Cognitive Sciences



# Mathematics

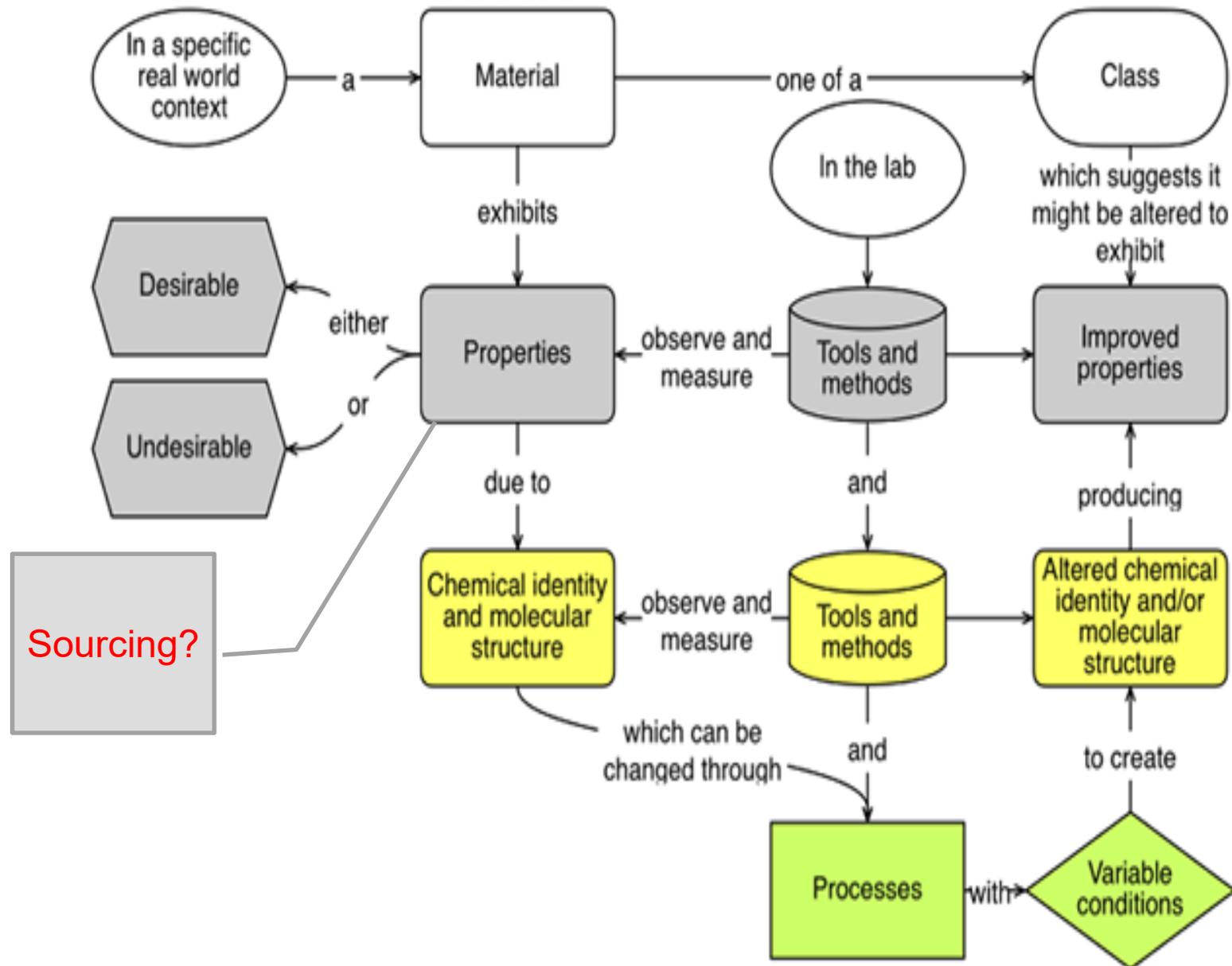


# SUSTAINABILITY AND ETHICS QUESTIONS

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Does the future of Engineering include the Liberal Arts (beyond Communication)?

## Cobalt



# Systems Design Project

## III. Your improved contact tracing system

You will have noticed that each of the above examples broadly provides a partial solution to effective contact tracing, privacy of the individual, support for the public health system, and efficient and scalable utilization of resources. None is ideal. As outlined more below, you will be designing a system to operate in a university of similar size to MIT that improves on that combination of objectives. We realize that we are identifying a set of goals for this system, some of which may be contradictory, so part of your challenge will be to find a defensible compromise among them. First, we can identify in more detail the goals for the users followed by those the central organization and the underlying system to provide the intended functionality.

### A. Goals

The goals for support of the users can be grouped as follows:

- Functionality: accuracy, timeliness
- Ease of use
- Low-impact on phone (storage, computation, communication)
- Privacy

# Robotics Video Analysis Assignment

*Due* **XXX at XXX pm on Canvas as a single Word doc.**

*Assignment* **Write two critical analyses of robotics videos (~300 words each).**

## **Part 1:**

**Learning objective:** thinking about the ethics of design.

Watch the 4 videos in “*The Ethics of Robotics*” list. Then write a critical analysis synthesizing key ideas and evidence from each, noting where and how ideas overlap and diverge. Your goal is to present a brief overview of the **ethical issues highlighted in** each video for a reader who has not seen the videos.

**Organization:** Rather than organize your analysis source by source, aim for a topic-based paragraph organization that shows how the sources intersect and enrich our understanding of ethical issues in robotics. Lead with an introduction that establishes the significance of ethical considerations in design as discussed in the sources, and forecasts the key points of your analysis, and end with a conclusion that captures the main takeaways from the videos’ discussion of ethics in robotics.

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## **Researchers:**

Atissa Banuazizi

Jared Berezin

Amy Carleton

Mary Caulfield

Dave Custer

Malcah Effron

Jane Kokernak

Suzanne Lane

Ari Nieh

Susan Ruff

Juergen Schoenstein

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