Designing Your MHS Learning System

LEON MCGINNIS
PROFESSOR EMERITUS
STEWART SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING
GEORGIA TECH

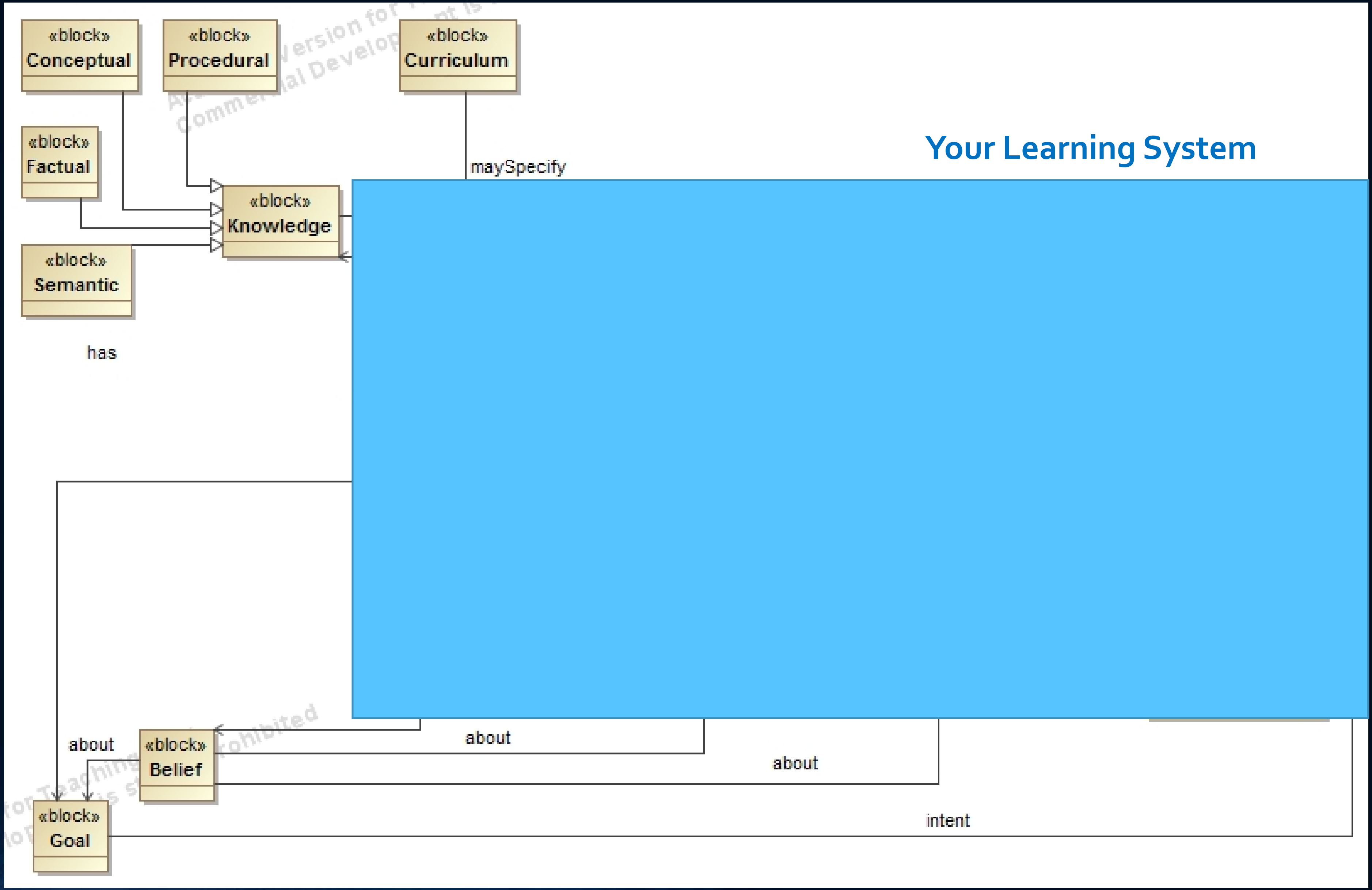
If we think about a course as a "learning system", then perhaps we can apply some systems engineering principles to help us design the course. To do so, we'll need to answer some questions:

- What is the *context* for this system?
- How does this system create *value*?
- What *functions* must this system provide/perform?
- How can we best organize these functions into an *architecture*?
- What *technologies* should we choose to enable these functions?
- How shall we *select and size* the technologies?
- What shall be the final *embodiment* of the system?

How will we judge whether or not this system is a good system?

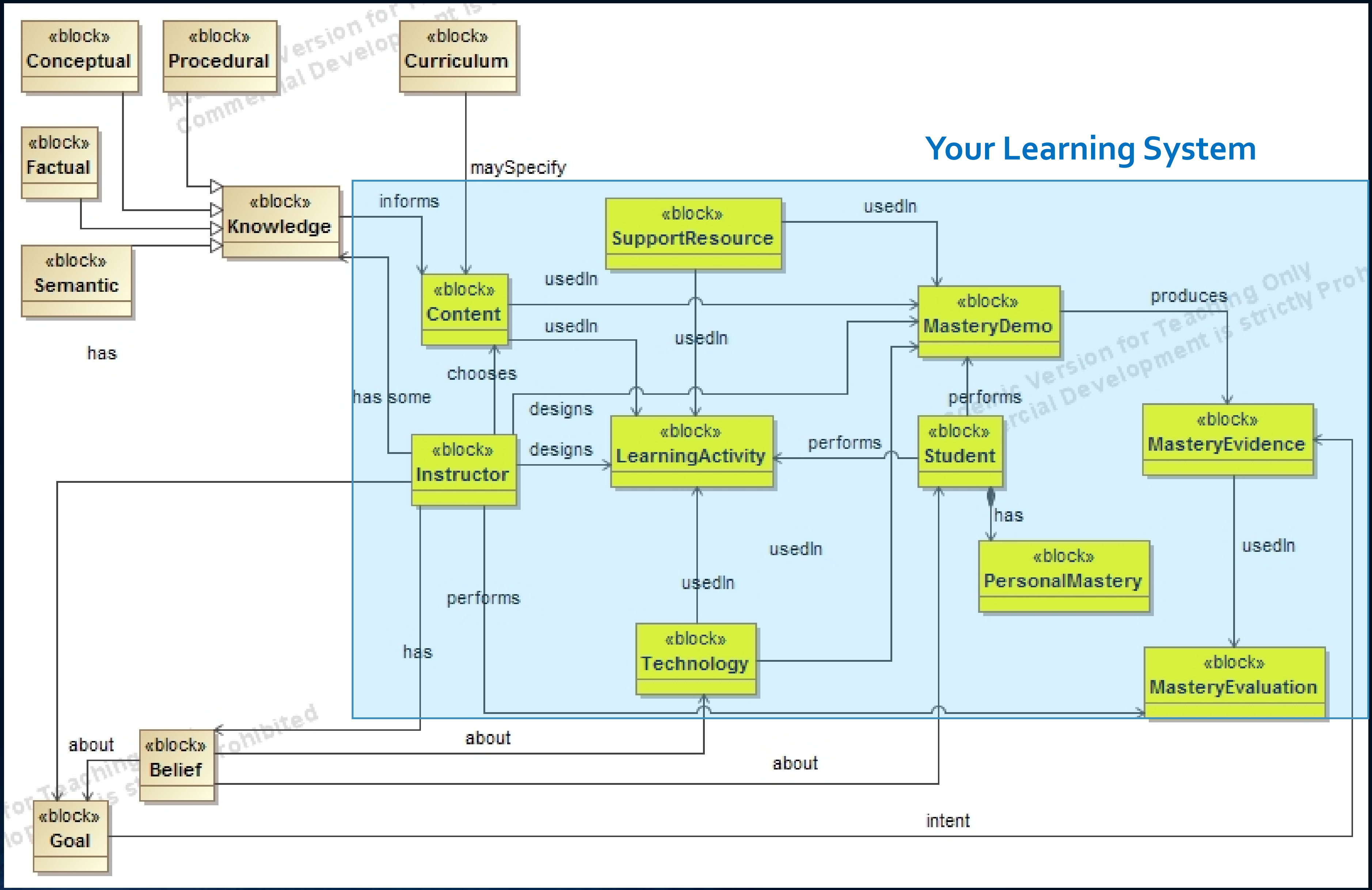
Context

We can get an idea about system content by looking at legacy systems.



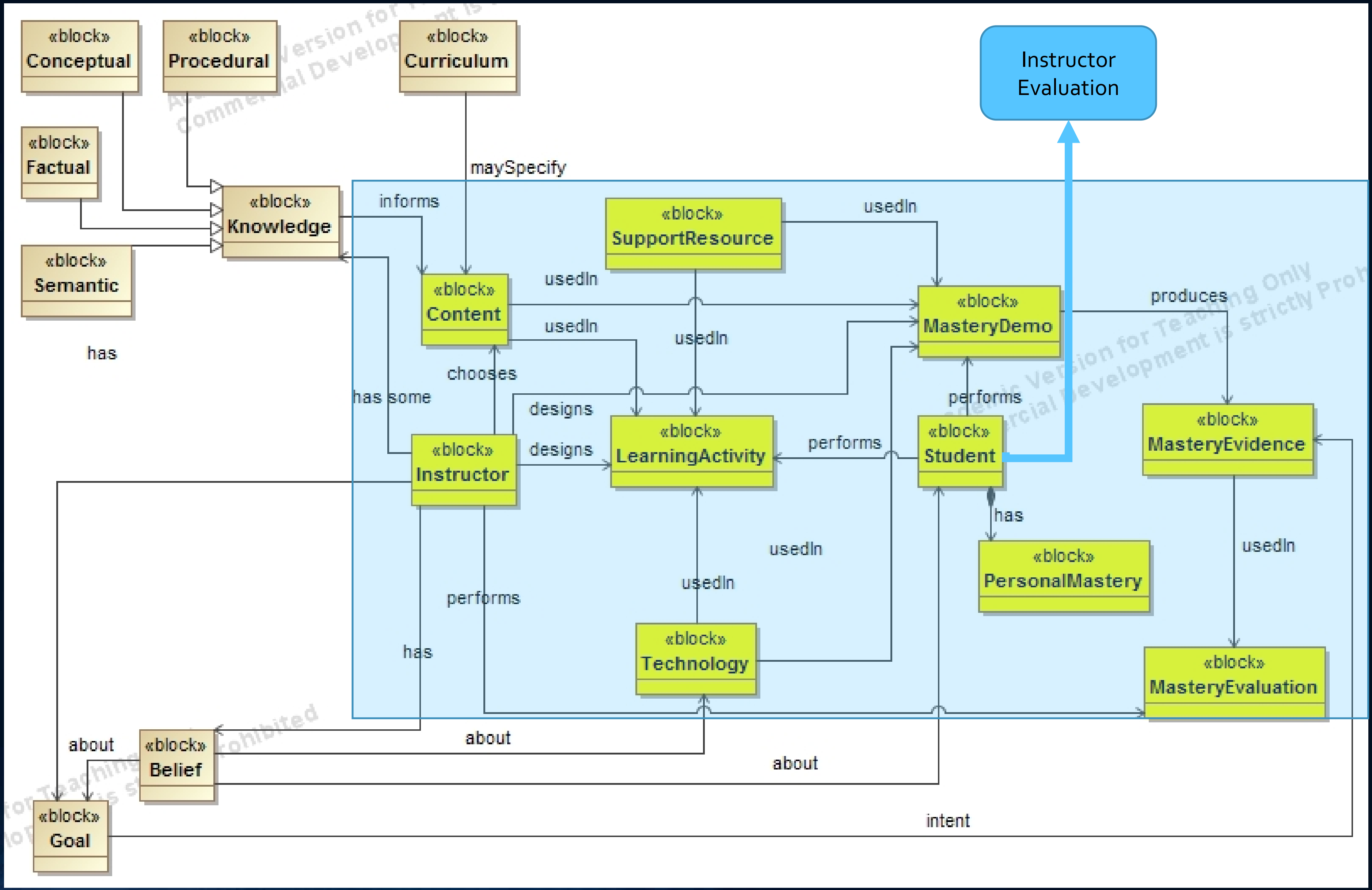
Context

The parts of the learning system are well-known to us.



Context

You will be evaluated based on the experience students have with your learning system!



Fundamental Design Questions: How does this course create value?

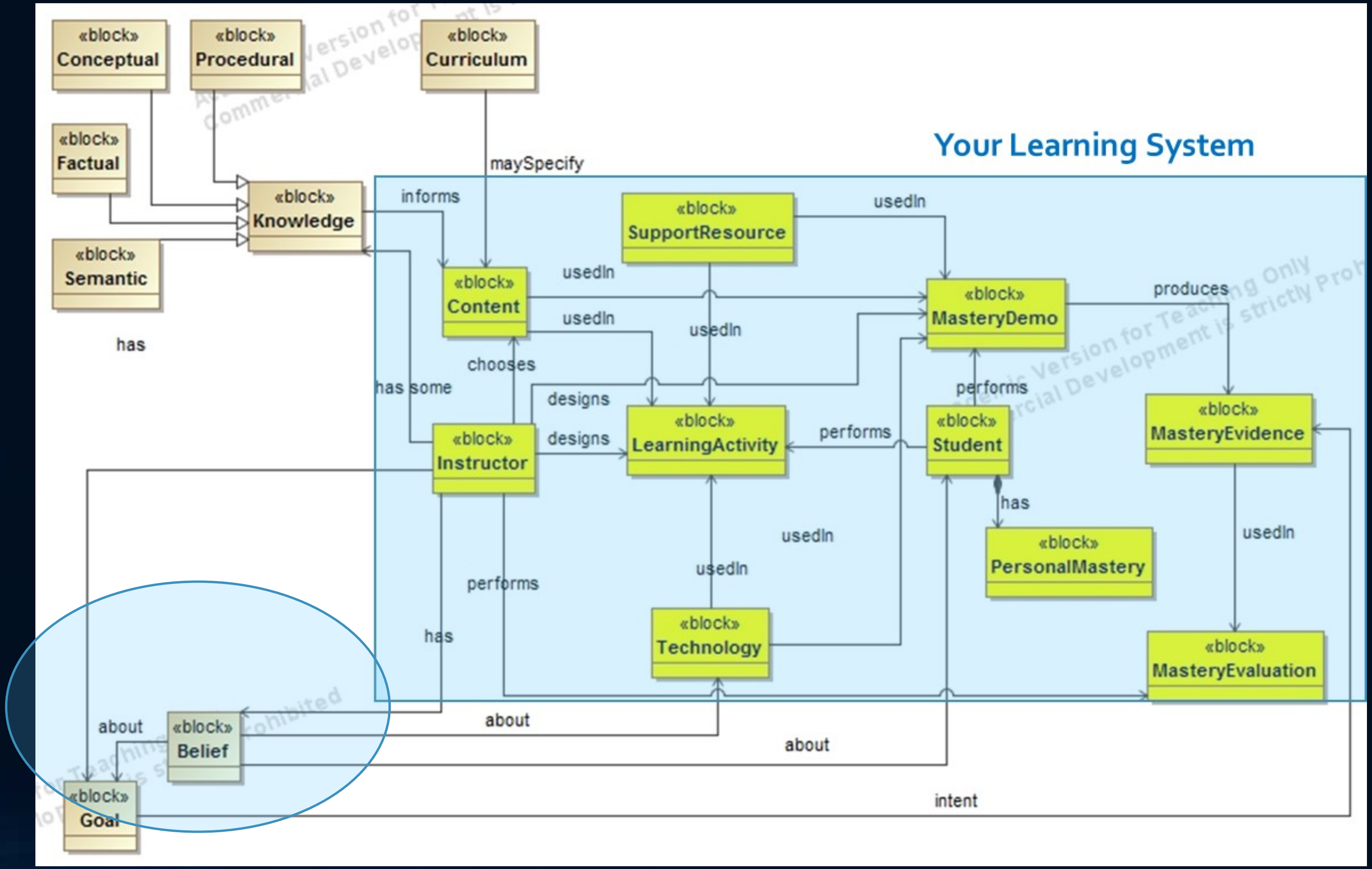
- For the enrolled students?
- For the instructor?
- For the Institution?
- For society?

Value Creation Principle: What is valuable to students is what they can DO with the knowledge they have acquired in the course, i.e., how THEY can create value by applying this knowledge.

What MHS knowledge is *valuable*?

Functional Design: What knowledge and learning functions best support value creation?

- Enable Student Learning
  - Semantic
  - Factual
  - Conceptual
  - Procedural
    - Analysis
    - Synthesis
    - Design
- Assess Student Knowledge Mastery
- Other?



Functional Requirements Analysis: Learning

- Semantics: **Unit load, tote, pallet, conveyor, pallet rack, shelf, lift truck, …**
- Facts: **Average walking speed of a manual picker is 264 ft/min, …**
- Concepts **square-in-time, Product/process/resource/facility; plant/control; …**
- Procedures:
  - Operational **Closest open location putaway, Sort while batch pick …**
  - Analytical **Expected cycle time for AS/RS, …**
  - Design **?**

Potential content vastly exceeds course capacity!

Functional Requirements Analysis: Mastery Demonstration

- Semantics:
- Facts:
- Concepts
- Procedures:
  - Operational
  - Analytical
  - Design

Identify, recite, compose, define, explain, use, appropriately and in context

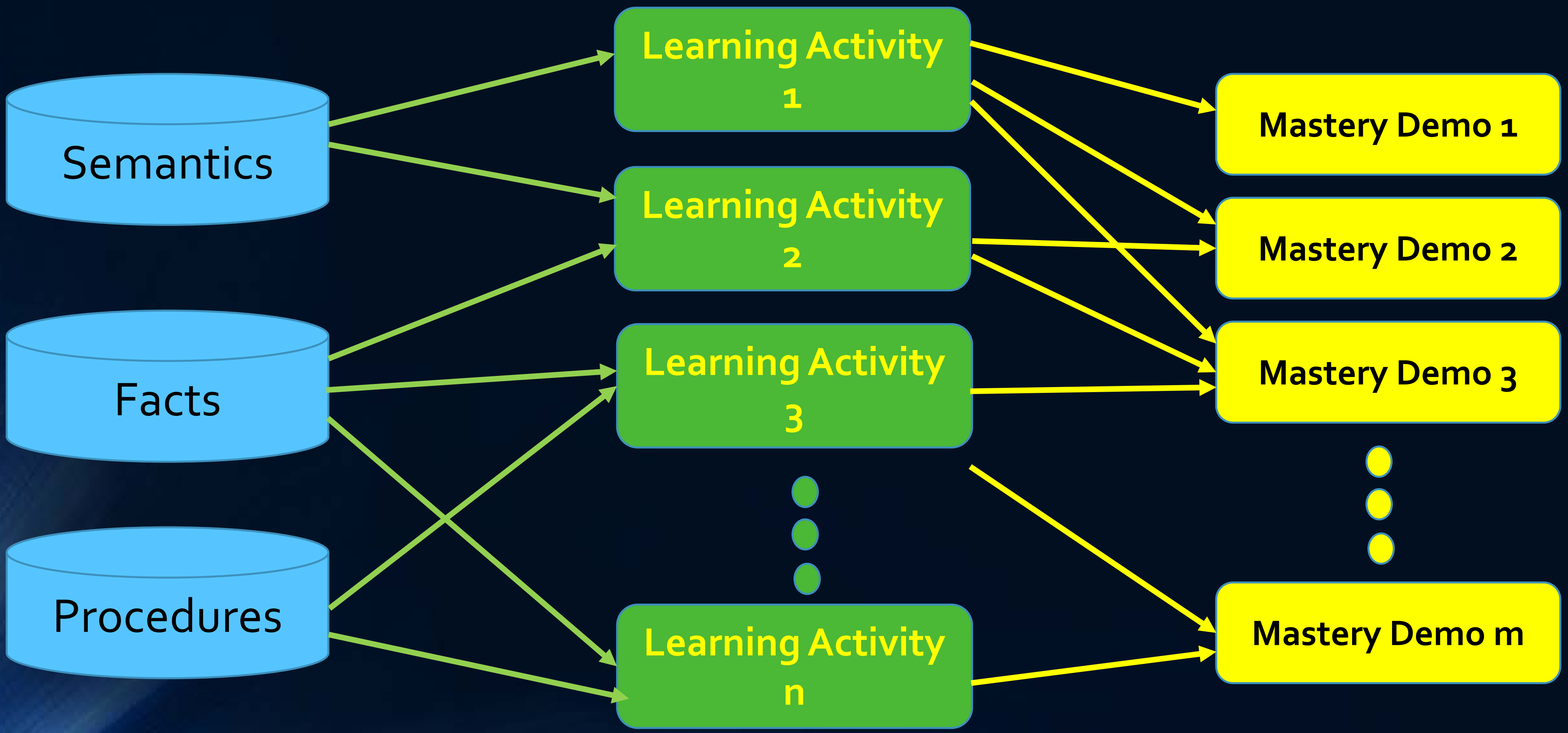
Define, derive, perform appropriately and in context

Nature of mastery demonstration should be consistent with your beliefs and goals, and should "make sense" to all stakeholders

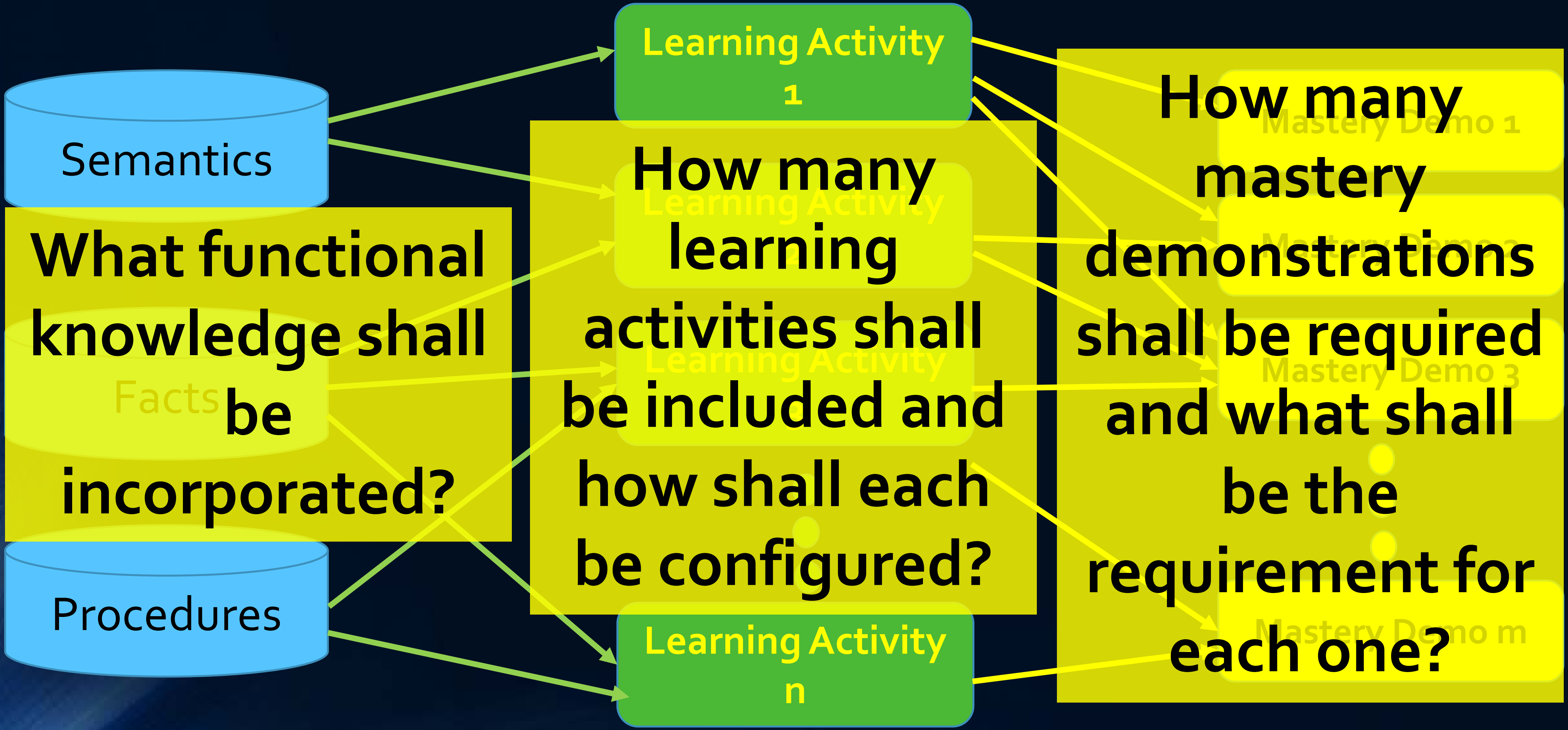
Principle: Functional design follows from beliefs and goals, in context

- Clearly define your goals, considering the value creation principle, and make sure the functional requirements for learning and mastery demonstrations and your goals are aligned

Architecture Design—How Functions Are Organized



Fundamental Architecture Design Questions



Architectural Issues

- Baselining the students
- Time available and allowable workload
- Instructor's knowledge
- Instructor's availability
- Other available resources

Fundamental conflicts:

- **Broad coverage vs Deep knowledge**
- **Hard work vs Happy Students**
- **Teaching vs research**

How you resolve these issues depends upon your beliefs and goals!

Once you've decided the "what", you will have to design the "how"…

Architecture Implementation: Legacy Technology Options

- Learning Activities
  - "Sage on the stage"
  - Teaching assistant
  - Reading the textbook
  - Homework problems
  - Recitation
  - Site visits
  - Case studies and projects

- Mastery Demonstrations
  - Written examinations
    - Closed book
    - Open book
  - Homework solutions
  - Oral presentations
  - Written reports

Individual and/or Team (applies to homework solutions, oral presentations and written reports)

Architecture Implementation: Legacy Supporting Technologies

- Classrooms
- Textbooks
- Web sites
- Software tools
- Written documents

Architecture Implementation: New Technology Options

- Learning Activities
  - "Flipped" classroom
  - Serious games
  - MOOCs
  - Interactive e-books
  - Interactive and integrated analysis platforms (e.g., Matlab and similar)
  - "Just in time" learning
  - …?
- Mastery Demonstration
  - "Clickers"
  - Web-based testing
  - Video presentations
  - Webex oral exams
  - …?

(Learning) System Evaluation

- Does the design maximize value within the given resources budget?
  - Do you have the “right” knowledge content?
  - Do you have the “right” mastery demonstration activities?
  - Do you have the “right” learning activities?

“Right” => add the most value for the available resource investment

An Example

Undergrad Course on “Material Flow Systems” (joint work with Dima Nazzal)

- Re-purposing a “manufacturing and warehousing systems” course
- Text has flipped between *Factory Physics* (Hopp & Spearman) and *Production and Operations Analysis* (Nahmias) and consequently, focus has flipped between flow analysis and inventory analysis
- Taught as a “methods and algorithms” course
- Dissatisfaction with students’ ability to understand and analyze material flow systems in capstone design course
- Dissatisfaction with integration of topics
- Dissatisfaction with lack of computational tools to support student learning

Context: Intended Content (Curriculum Document)

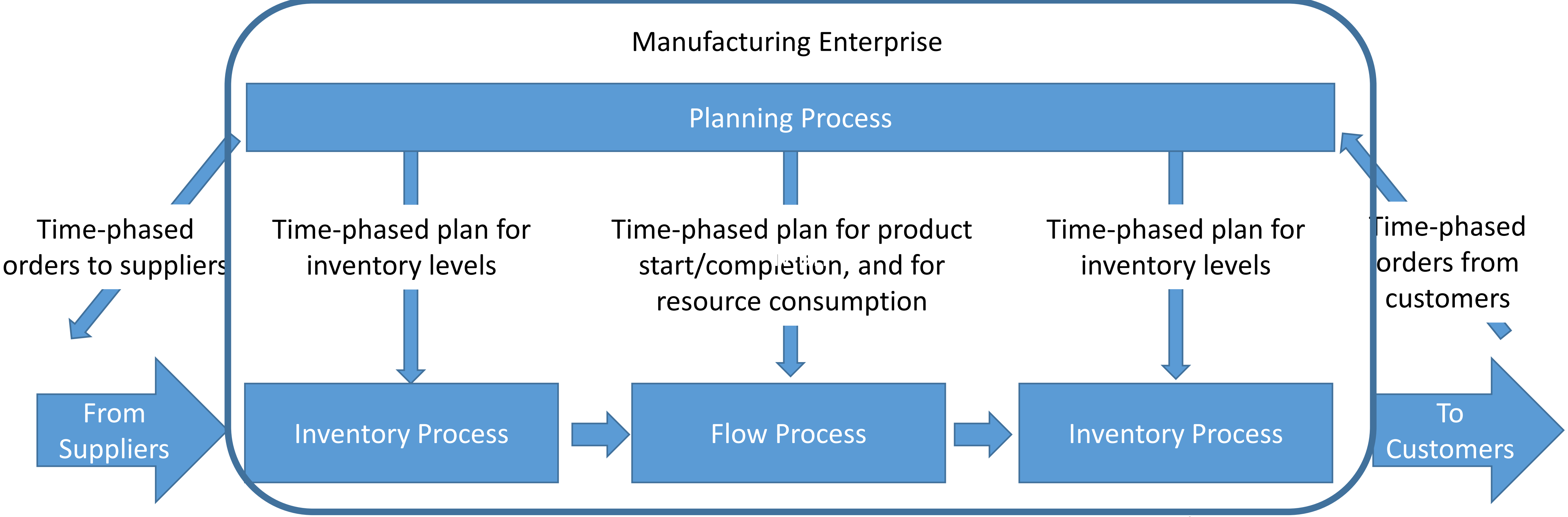
- Push systems and queuing approximations
- Pull systems and MVA
- Scheduling
- Inventory (EOQ, newsvendor, base stock, (Q,r)
- Production planning and MRP
- ~~Warehousing~~

Our Goals and Beliefs

- Beliefs
  - This is a “discipline” engineering course
  - Needs a unifying framework
  - Students need to know how to use appropriate models appropriately
  - Learning by doing is essential
  - Students need to have intuition about the limits
- Mastery Goals
  - Describe, analyze, benchmark, & design simple flow systems
  - Translate flow metric preferences into appropriate dispatch rules
  - Balance costs and service in inventory systems
  - Formulate & solve “typical” multiperiod prod-inv plan probs
  - Integrate planning/inventory/flow models for operations planning & system design

Curriculum Requirements

- Basic factory dynamics (6 weeks)
  - TH, r_b, W_c, ρ, BC/WC/PWC, variability propagation, VUT
  - CONWIP, MVA
- Scheduling (1.5 weeks)
  - Dispatching rules
- Inventory (3 weeks)
  - EOQ and variants
  - Newsvendor and Base Stock
  - (Q,r)
- Aggregate planning (1.5 weeks)
  - Inventories, headcount, overtime
- Integration (1 week)



The arrival of material from suppliers cannot be predicted with certainty, regarding the timing, the amount, or the quality

Inventory is necessary as a buffer between the uncertainties of the supply process and the uncertainties of the flow process

The flow process is where value is created for customers by converting material from suppliers into the products the customers want. The behavior of the flow process cannot be predicted with certainty regarding manufacturing cycle time, yield, resource utilization, cost, etc.

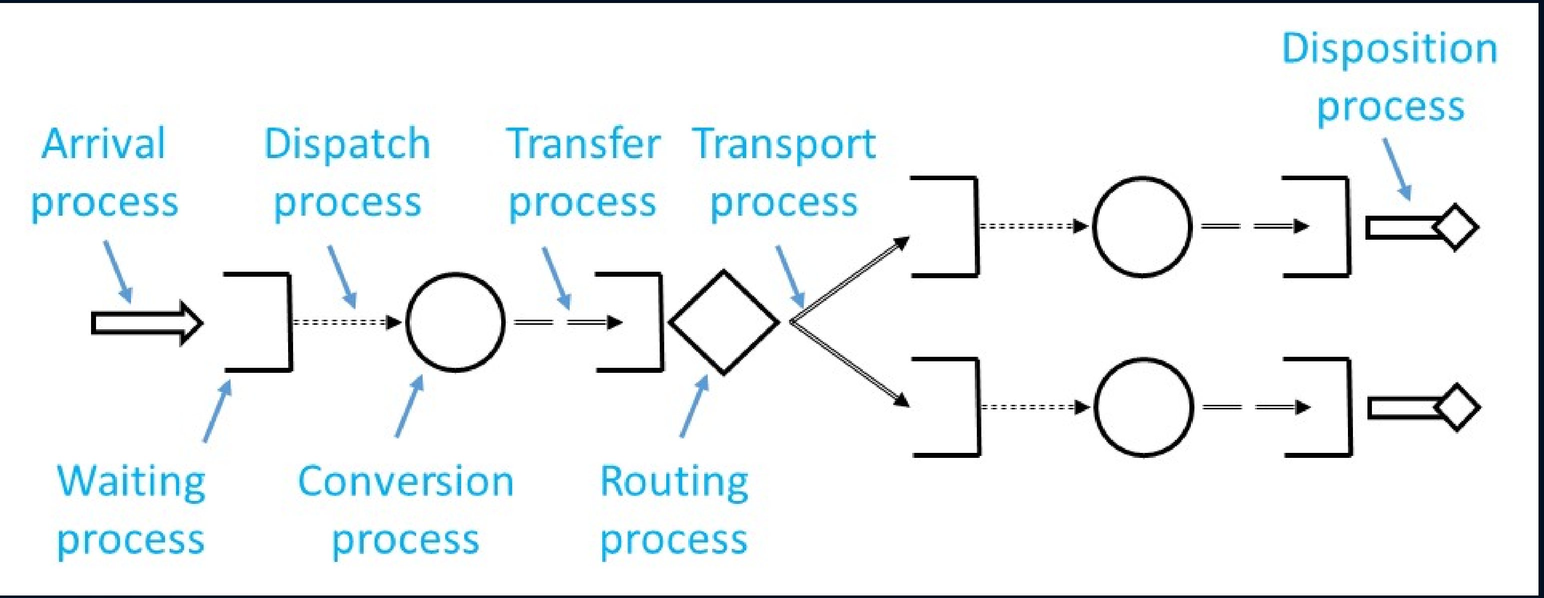
Inventory is necessary as a buffer between the uncertainties of the flow process and the uncertainties of the demand process

The need to ship to customers cannot be predicted with certainty, regarding the timing, the amount, or the quality

Other “Conceptual Frameworks”

- Product/process/resource/facility
- Describe/predict/control/design

“Describe”: Process Mapping Concept



Other processes: metrology, storage, …

Predict: The VUT Equation

$$\mathrm{CT}_q \approx V \times U \times t$$

$$\approx \left(\frac{c_a^2 + c_e^2}{2}\right)\left(\frac{u^{\sqrt{2(m+1)}-1}}{m(1-u)}\right)t_e$$

Control

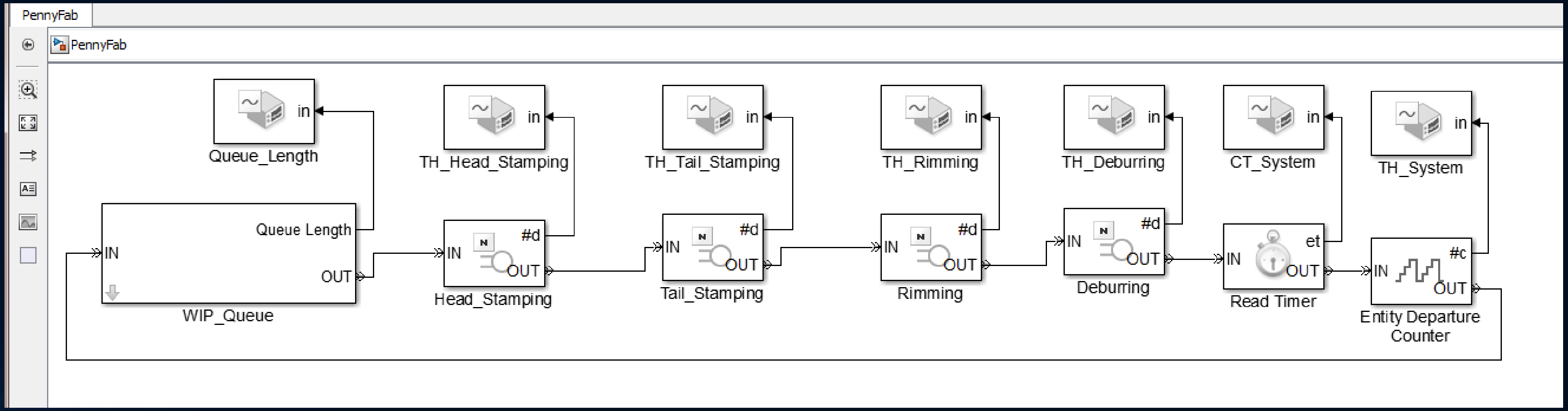
- CONWIP
- Dispatching rules
- Inventory policies

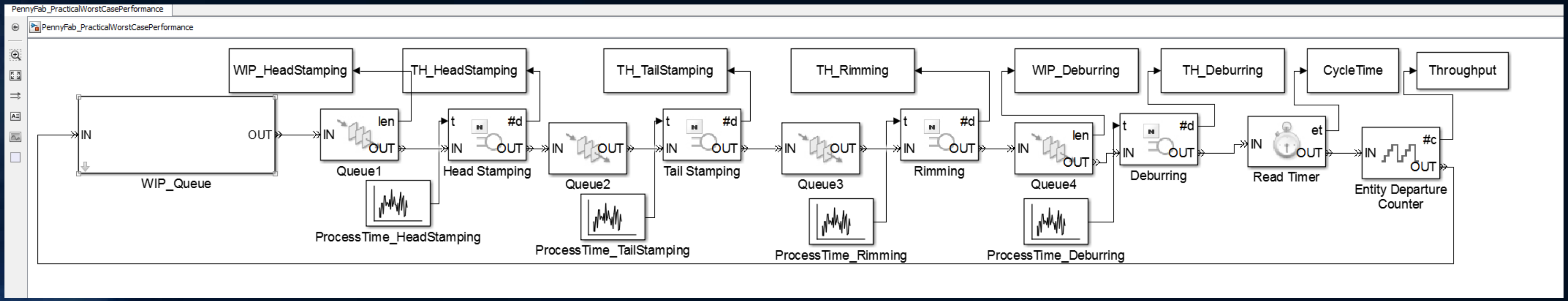
Design

- Analyze trade-offs
  - Speed vs reliability
  - Batching vs speed
  - Utilization vs service level
  - Inventory cost vs service level

Students will be provided with Matlab modules that will support trade-off analyses

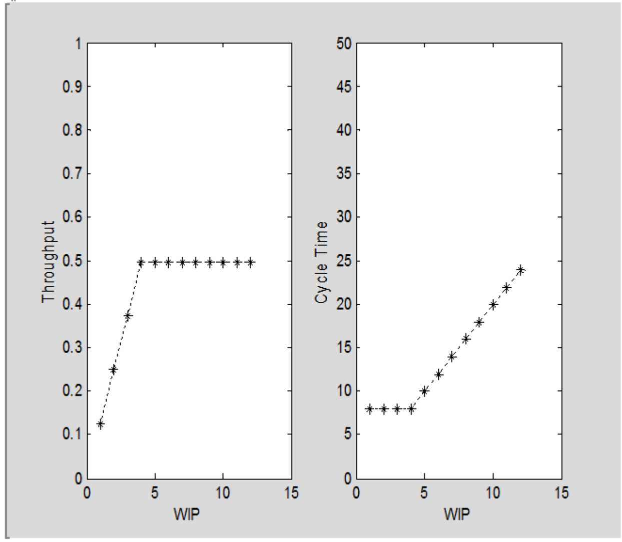
Penny Fab 1


PennyFab
PennyFab
Queue_Length
TH_Head_Stamping
TH_Tail_Stamping
TH_Rimming
TH_Deburring
CT_System
TH_System
Queue Length
WIP_Queue
Head_Stamping
Tail_Stamping
Rimming
Deburring
Read Timer
Entity Departure Counter


WIP_HeadStamping
TH_HeadStamping
TH_TailStamping
TH_Rimming
WIP_Deburring
TH_Deburring
CycleTime
Throughput
WIP_Queue
Queue1
Head Stamping
Queue2
Tail Stamping
Queue3
Rimming
Queue4
Deburring
Read Timer
Entity Departure Counter
ProcessTime_HeadStamping
ProcessTime_TailStamping
ProcessTime_Rimming
ProcessTime_Deburring

Matlab "Notebook"

```
simOut = sim('PennyFab_outputData', 'StopTime', '1000');

getCycletime(simOut)

ans =
    34.3613

getThroughput(simOut)

ans =
    0.3482

for W0 = 1:12
PennyFabScript
```



Snippets from the Word 'Notebook'. The text in green is executable by right-clicking on it (right). The answers that would be returned to the Matlab workspace are instead written directly into the word document (in blue) including figures.

Architecture: Learning Activities

- Computational support
  - Matlab modules that implement all the analytic models in *Factory Physics*
  - Corresponding discrete event simulation models, to test the limits
- "Flipped" classroom
  - Introduce topics briefly
  - Video's and Matlab exercises
  - In-class hands-on problem solving
  - Recap and characterize

Tuesday: (#3: 8/27) Enriching the PennyFab1 model to account for random arrivals and random process times, but with identical means

Lecture:	Exercise
Show variations of penny fab that are "open" with random arrivals, random process times	Students do simulations with open/random and compare results to BC, WC, PWC analysis; discuss results; look for generic statements

Homework:
tegrity: variability sources; variability measures (sigma, CoV); effective process times, impact on CT, TH for given WIP

Thursday: (#4: 8/28) TH, CT, rb, WIP for arbitrary PennyFab1 (non-identical process times); PennyFab2, with multiple servers

Lecture: Review PennyFab 1 with non-identical servers	Exercise word problems for PennyFab1, determine correct rb, CT, TH for given WIP
Equations for rb, TH for given WIP; idea of "critical" WIP	

Homework:

We are developing a week-by-week and lecture-by-lecture storyboard.

- Plan for all learning and mastery demonstration activities
- Plan for topic introduction, video module content and timing, and topic followup
- Plan for Matlab exercises

Plan to distribute to students at first lecture

Architecture: Mastery Demonstrations

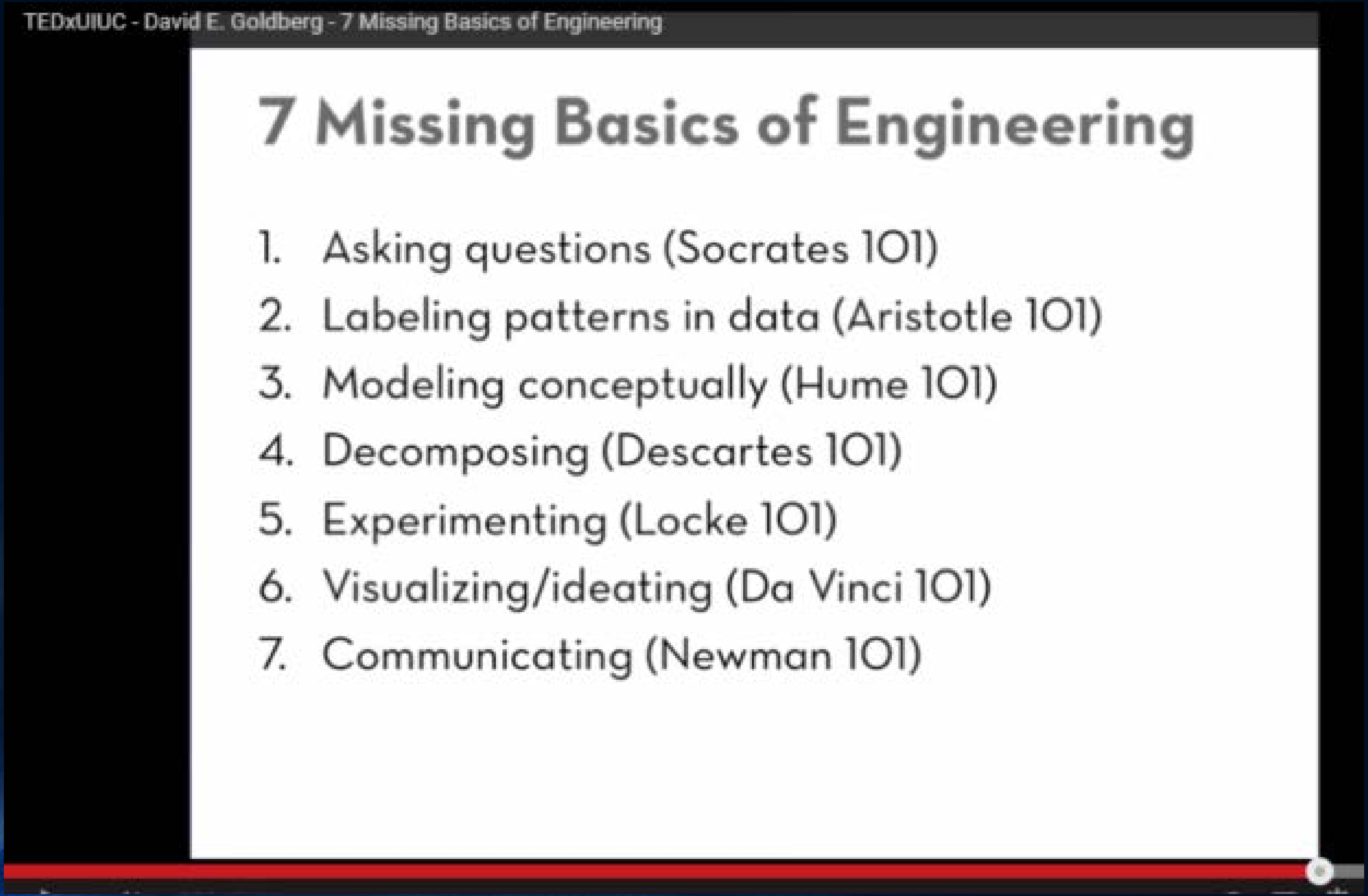
- Matlab "Notebook" submissions for random grading
- In-class participation
- Conventional exams
- Project report/presentation

Evaluation

- Look at student submissions
- Look at student course evaluation surveys
- Conduct our own survey and analysis

- Ask me next January whether or not it was satisfying

Food for Thought



Conclusion

- This week at MHTI
  - Gain a lot of knowledge, especially about what knowledge sources are available to you
  - Gain insight into how others are teaching MH-related courses
- Your challenge
  - Design *your* MH-related course, *your* learning "system"
  - Consider the context
  - Use the value creation principle
  - Define the functional requirements
  - Design *your* learning systems architecture
  - Design *your* embodiment
  - Reap satisfaction!

Your turn