

A Unified Approach to Engineering Science Education

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Notes

Group Activity 1 --- Answer the following questions

- (a) Is there an engineering science and mathematics core curriculum that should be common for all engineering students?
- (b) Assuming that such a core is desirable, what courses or topics would you place in the core?

Research on Teaching & Learning

– *How People Learn: Brain, Mind, Experience, and School. (HPL)*

J. D. Bransford et al. editors, National Academy Press, Washington DC, 2001, expanded edition. Available online at <http://www.nap.edu>.

– *Teaching Introductory Physics. (TIP)*

A. B. Arons, John Wiley & Sons, New York, 1997.

– *Cooperative Group Problem Solving in Physics. (CGPiP)*

P. Heller and K. Heller, University of Minnesota, 1999. Available for download at <http://www.physics.umn.edu/groups/phised>.

How People Learn - Bransford**

- Nature of expertise
 - experts' knowledge is hierarchically organized around major principles and concepts.
 - experts “construct” solutions from major principles.
 - experts monitor their activities to assess their success.
- Current view of learning
 - individuals construct the knowledge they possess.
 - prior knowledge affects students' ability to learn new knowledge.
- Learning and transfer
 - all learning involves transfer from previous learning.
 - amount and context of learning affects transfer.
 - abstract representations of knowledge combined with understanding can promote transfer.

**Summarized in J. P. Mestre, “Implications of research on learning for the education of prospective science and physics teachers,” *Physics Education*, Vol. 36, No. 1 (Jan 2001), pp. 44-51.

Implications of HPL

- Help students organize their knowledge around important ideas and concepts
- Provide opportunities for students to “learn how to see” a problem like an expert.
- Stress “Why and When?” as well as “What” and “How?”
- Help students integrate their new knowledge with existing knowledge. (constructivism)
- Provide multiple contexts for learning and explicitly address transfer of knowledge.
- Help students learn to monitor their learning and problem solving (metacognition).

Lessons from TIP - Arons

- Teaching for *understanding* not just memorization.
 - **Importance of language and operational definitions.**
 - **Spiraling back** - allow students to review or re-encounter important ideas and lines of reasoning in increasingly rich or sophisticated context.
 - Understand and address **common misconceptions**
 - Help students **see their reasoning**, both flawed and correct, and incorporate new knowledge into this structure.
 - **Test and reward understanding** not just memorization.
- Promote Critical Thinking.

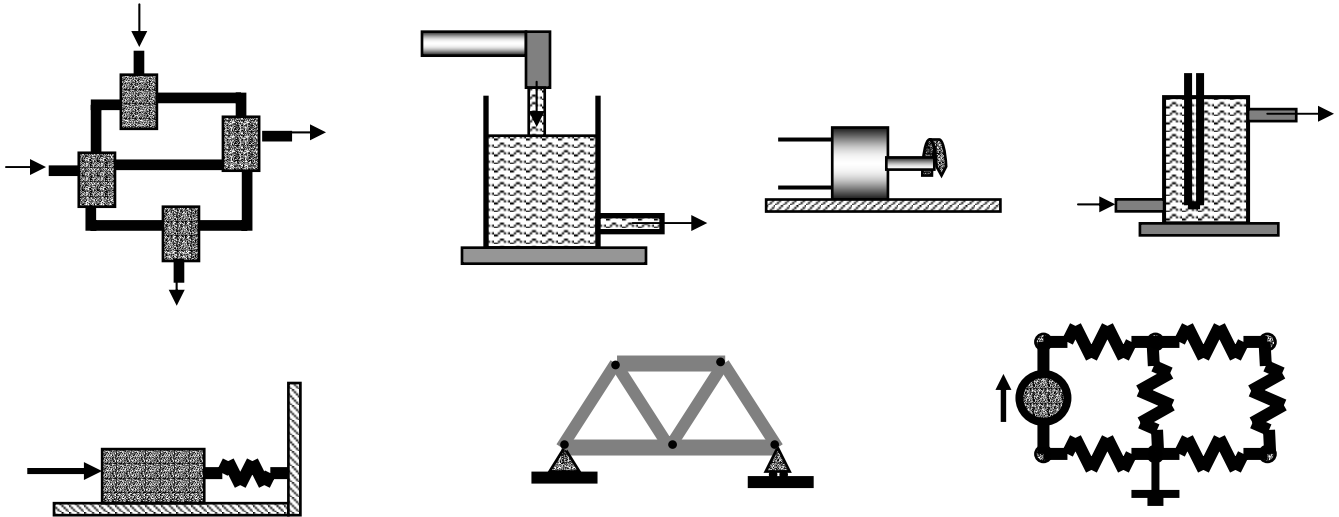
Arons provides an excellent list of critical thinking processes.

CGPiP - Heller & Heller

- Modeling-coaching-fading paradigm
- Modeling “culture of expert practice”
 - Conceptual framework or “story line” ties things together
 - Problem-solving methodology used explicitly by faculty and students.
 - Explicit decision-making by faculty solving problems.
 - Context-rich word problems that require construction of a solution not just “plug-and-chug” solution.
 - Grade solution strategy not just answer.
- Coaching and Scaffolding
 - Cooperative group problem solving.

Group Activity 2 ---

What if any are the common concepts, themes, or topics that would run through an engineering science core?



Group Activity 3 -- Match each term with its definition.

DEFINITIONS	TERMS
1. A characteristic of a system that can be assigned a numerical value at a specified time without considering the history of the system.	_____ Model
2. A complete description of the system in terms of its properties.	_____ System
3. A purposeful representation.	_____ Property
4. A mathematical relationship between variables that describe a physical phenomenon, that by its very nature is specific and cannot be applied in general, and is only valid under a restricted set of conditions.	_____ Extensive Property
5. A system that exchanges mass with its surroundings.	_____ State of a System
6. A property whose value does not depend on the extent of the system, i.e. it has a value at a point. Examples include pressure, temperature, and velocity	_____ Intensive Property
7. A region of space or quantity of matter set aside for analysis.	_____ Closed System
8. An extensive property that cannot be generated or consumed.	_____ Process
9. A system that does not exchange mass with its surroundings.	_____ Open System
10. The means by which a system changes its state.	_____ Steady-State System
11. A simple balance relationship for an extensive property: the accumulation of an extensive property within a system equals the transport of the extensive property into the system minus the transport of the extensive property out of the system plus the generation (or production) of the extensive property within the system minus the consumption (or destruction) of the extensive property within the system.	_____ Interaction
12. A system that behaves in such a manner that all of its intensive properties and interactions with the surroundings are independent of time.	_____ Conserved Property
13. The transport of an extensive property across a system boundary.	_____ Accounting Principle
14. A property whose value depends on the mass or extent of the system, e.g. mass, volume, and energy.	_____ Constitutive Relation

Rate form of the Accounting Principle for Property B	
<p style="text-align: center;">Generic Extensive Property B</p> $B_{\text{sys}} = \int_{V_{\text{sys}}} b \rho dV$	$\frac{d}{dt} B_{\text{sys}} = \underbrace{\left[\dot{B}_{\text{in}} - \dot{B}_{\text{out}} \right]}_{\substack{\text{net rate transported} \\ \text{across the boundary} \\ \text{into the system}}} + \underbrace{\left[\dot{B}_{\text{generated}} - \dot{B}_{\text{consumed}} \right]}_{\substack{\text{net rate generated} \\ \text{within the system}}} \quad \text{(a)}$
	$= \left[\dot{B}_{\text{net,in}} \Big _{\text{without mass flow}} + \dot{B}_{\text{net,in}} \Big _{\text{with mass flow}} \right] + \left[\dot{B}_{\text{generated}} - \dot{B}_{\text{consumed}} \right] \quad \text{(b)}$
	$= \left[\dot{B}_{\text{net,in}} \Big _{\text{without mass flow}} + \sum_{\text{in}} \dot{m}_i b_i - \sum_{\text{out}} \dot{m}_e b_e \right] + \left[\dot{B}_{\text{generated}} - \dot{B}_{\text{consumed}} \right] \quad \text{(c)}$

Group Activity 4 -----

Match the extensive properties listed below with the appropriate accounting (or conservation) equation.

Mass	Linear Momentum	Energy
Charge	Angular Momentum	Entropy

Extensive Property	Rate-form of the Accounting (or Conservation) Principle
	$\frac{d}{dt} m_{\text{sys}} = \sum_{\text{in}} \dot{m}_i - \sum_{\text{out}} \dot{m}_e$
	$\frac{d}{dt} E_{\text{sys}} = \dot{Q}_{\text{net,in}} + \dot{W}_{\text{net,in}} + \sum_{\text{in}} \dot{m}_i \left(h + \frac{V^2}{2} + gz \right)_i - \sum_{\text{out}} \dot{m}_e \left(h + \frac{V^2}{2} + gz \right)_e$
	$\frac{d}{dt} S_{\text{sys}} = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_{\text{in}} \dot{m}_i s_i - \sum_{\text{out}} \dot{m}_e s_e + \dot{S}_{\text{gen}} \quad \text{with } \dot{S}_{\text{gen}} \geq 0$
	$\frac{d}{dt} \mathbf{L}_{o,\text{sys}} = \sum_{\text{external}} \mathbf{M}_{o,j} + \sum_{\text{in}} \dot{m}_i (\mathbf{r}_o \times \mathbf{V})_i - \sum_{\text{out}} \dot{m}_e (\mathbf{r}_o \times \mathbf{V})_e$
	$\frac{d}{dt} q_{\text{sys}} = \sum_{\text{in}} \dot{q}_i - \sum_{\text{out}} \dot{q}_e$
	$\frac{d}{dt} \mathbf{P}_{\text{sys}} = \sum_{\text{external}} \mathbf{F}_j + \sum_{\text{in}} \dot{m}_i \mathbf{V}_i - \sum_{\text{out}} \dot{m}_e \mathbf{V}_e$

Written Format	Typical Questions
<ul style="list-style-type: none"> • Known • Find • Given • Analysis <ul style="list-style-type: none"> -- Strategy -- Constructing Model -- Symbolic Solution -- Numerical Solution • Comments 	<ul style="list-style-type: none"> • What's the system? • What properties should we count? • What's the time interval? • What are the important interactions? • What are the important constitutive relations? • How do the basic equations simplify? • What are the unknowns? • How many equations do I need?

Problem Solving Format and Questions

Historical References

- L. Prandtl's fluid mechanics work in the early 1900's. (Discussed in W. G. Vincenti.)
- "A Theoretical Tool for Design: Control-Volume Analysis, 1912-1953," Chapter 4 in *What Engineers Know and How They Know It*, Walter G. Vincenti, Johns Hopkins Press, 1990.
- Discipline of System Dynamics
- References from physics
 - H. Burkhardt, "System physics: A uniform approach to the branches of classical physics." *American Journal of Physics* 55, pp. 344-350, 1987.
 - H. Fuchs, *The Dynamics of Heat*. Springer-Verlag, 1996.

Textbooks

- C. J. Glover, K. M. Lunsford, J. A. Fleming, *Conservation Principles and the Structure of Engineering*, 5th ed, McGraw-Hill, New York, 1996.
- D. E. Richards, *Basic Engineering Science - A Systems, Accounting and Modeling Approach*, Rose-Hulman Institute of Technology, 2001. Available from the author.
- W. C. Reynolds, *Introduction to Engineering Analysis*, Stanford University, Spring 2000. Available from Prof. Reynolds at Stanford University.
- L. V. McIntire, A. Saterbak, and K-Y San, *Conservation Principles in Biology and Medicine*, underdevelopment for Prentice-Hall, Rice University. Curriculum described in A. Saterbak, K-Y San, L. V. McIntire, "Development of a Novel Foundation Course for Biomedical Engineering Curriculum," *Proceedings of 2001 ASEE Annual Conference*.