‘How *not* to teach’

Physics in Engineering Curriculum

Condensed Matter Science & Technology

*Sharing Concerns with Fellow Instructors*

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Physics & Engineering: 
*Debate & Dilemma of Curricula*

**Physics as paradigm**
- Too much of theory?
- Who teaches?
- Prerequisite?
- Abstract
- *Excitement based?*

**Physics as tool**
- What to include?
- Which year?
- Concurrent?
- Artifact
- *Need Based?*

*Significant Changes needed but principles of change must be understood.*

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Physics & Engineering: Orientation

Overlapping (EX: I-V)

- Content
- Tools
- Phenomena
- Explore
- Abstract

Distinct (Ex: Electronic Materials)

- Orientation
- Purpose
- On Demand
- To Design
- Artifact

Pushing boundaries at the extreme

Transnational across valley of death

Teaching the same course in completely different styles.

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<table>
<thead>
<tr>
<th>Waves</th>
<th>Particles</th>
<th>Excitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea</td>
<td>Rock</td>
<td>Interactions</td>
</tr>
<tr>
<td>Electron</td>
<td>Photon</td>
<td>Polaron</td>
</tr>
<tr>
<td>Exciton</td>
<td>Polariton</td>
<td></td>
</tr>
</tbody>
</table>

Physical foundations built on quantum objects.

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Waves : Dispersion Relationship

String :
\[
\frac{\delta^2 \phi}{\delta x^2} = \frac{1}{(T / \rho)} \frac{\delta^2 \phi}{\delta t^2}
\]
\[
\phi = Ae^{i(kx - \omega t)}
\]
\[
\frac{1}{v^2} = \frac{1}{(\omega / k)^2} = \left( \frac{1}{T / \rho} \right)
\]

EM :
\[
\frac{\delta^2 E}{\delta x^2} = \varepsilon \mu \frac{\delta^2 E}{\delta t^2} + \sigma \mu \frac{\delta E}{\delta t}
\]
\[
E = E_0 e^{i(kx - \omega t)}
\]
\[
\frac{1}{v^2} = \varepsilon \mu + i \frac{\sigma \mu}{\omega}
\]

QM :
\[
\frac{\delta^2 \Psi}{\delta x^2} = -i \left[ \frac{2m}{\hbar} \right] \frac{\delta \Psi}{\delta t}
\]
\[
\Psi = Ae^{i(kx - \omega t)}
\]
\[
\omega = \frac{\hbar k^2}{2m}
\]

Lattice :
\[
\eta \phi_{n-1} - 2\eta \phi_n + \eta \phi_{n+1} = \frac{\delta^2 \phi}{\delta t^2}
\]
\[
\phi = Ae^{i(k\alpha - \omega t)}
\]
\[
\omega = 2\eta^{1/2} \left[ \sin \frac{ka}{2} \right]
\]

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One Level Up
&
One Level Down

Heat as motion: Coupled Spring
Phonon (Harmonic)
Thermal Expansion

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Glass Box of Concepts

NOT

Black Box of I/O

Example: Band Structure of Materials

Simple E-k diagram to Real Systems

*Physics as tool box of concepts, and not as mindful of balckboxes*

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Provider of Heuristics

One Dimensional Solid
Configuration Co-ordinate Diagram

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Meta-organization of Concepts:
Teacher’s Perspective

- Not just sequencing of topics
- Connections **planned** *(meta)*
- Connections **demonstrated** *(sequence)*
Characterization
Rope or a Snake?

Probe

Response

Control Parameters?

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All knowing is Scattering?

Electrons
Or
X-rays

Bandstructure
Or
Structure

Periodic

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Resolving: Two Essential Ways

Spatial: Microscopy

Energy: Spectroscopy

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Changes in Space

Potential

Flow

Drift and Diffusion Equations:

Continuity Equations:

Conservation Equations:
Mass, Momentum, Energy
Changes in Time

Steady State

Transiente

ITO/PEDOT:PSS/MEH-PPV/Al

Current density ($A/cm^2$)

Voltage (V)

EL Transient
Current Transient

Current density (mA/cm²)

EL Intensity (a.u.)

Time (µs)

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Multiple Modes of Appreciation:

Artefact vs. Abstract
Physics makes the LINK between these apparently opposite vs. Pairs.

Number
Symmetry
Geometry

Graphs
Algebra
Equations

Insight
Innovation
Generalization
**Complexity Science** expresses itself in many languages:

- **Scale**
  - Quantum → Continuum
  - Stat Mech → Thermo
  - Sand pile → Mountains

- **Dimensionality**
  - 0
  - 1
  - 2
  - 3

- **Hierarchy**
  - Cauliflower
  - Cabbage
  - Onion
  - Fractal

- **Correlations**
  - Phase Transition
  - Instabilities
  - Disorder
  - Chaos
  - Domain
  - Interfaces

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Economy of organizing Principles
Parsimony of Concepts

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Hedgehog or Fox:

Know one big thing

Nimblefooted darting
We need to emphasize………

- **Frontiers of Physics** at various scales
- **Unifying Themes** and Tools of Physics
- **Significant Discoveries** which shape our current understanding of the Physical World
- **Physics Induced Technologies**
- Peep into Physics **Laboratories and Laboratory Life**.

……But how ???
How to?
Easier said than done...

- Like to be a witness
- Refine class room practice

Discuss & Document

Bring Case Studies to All Components: Lectures, Problems & Labs

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Bringing CONTEXT back....

To our TEXT

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Bringing CONFUSION back....

And lead purposefully so that CLARITY emerges

• If you can’t solve CELEBRATE !!!
  True Opportunity !

• Carving out a Mental Space : Who’s done it ?
  What’s wrong ?

• Pig and Diamond

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Bringing CARE back....

so that CONNECTIONS emerge

• Chapter Division too neat!

• Anneal the implantation........

• Connections within Concepts and not isolated concepts (ex. E-k )

• Eagerness to help is contagious (not how much of an expert I am)

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Can e-learning bring back?

- Context
- Connections
- Care

YES & NO?

Medium becoming Master?
Tools should be slave to our intents and purpose!

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The nature of Changes / Shifts

From my own practice

Text
Context
A ‘typical’ Student
Learning Tools

& What that may possibly mean for us?

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Multiple Tools:

- **Visualizable**: *(Projection of Ideas)*
- **Mappable**: *(Connecting Abstract to Artefact)*
- **Simulable**: *(Dramatization)*

Computer can be helpful servants – when used with care!

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Necessity of

- Multiple Views & Modes
  (No one way. Cognitive Coercion not possible)
- Intellectual Effort and Discipline
- Confusion & Discomfort
- Joy of “seeing” it (Illumination)

Learning is intensely personal.
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Rigidity & Unlearning

Once learned it is not given up easily

- Cartesian to Polar
- Band to Bond
- Delocalized states to Localized

Loosening up needs promise of higher goal. Retooling is expensive and difficult

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Shifts in Text/Practice

💎 Technology as PROOF

'\textit{show me w’atch ya got ?}'

💎 Commerce as SUCCESS

'\textit{patentability of ideas}’

💎 Control as PROGRESS

'\textit{unambiguous criteria for selection of Research Programs}’ (empirical content ? Explanatory power ? – things of past)

\textit{Hence increasing merger of context within text.}

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Transformative Technologies

- From infra-structure to supra-structure
- From living aids to thinking aids
- Centralized but decentralizing tools
- From Products to Services

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Shifts in General Learning Tools

- Multiprocessing
- Navigation in info-space as literacy
- Distributed Knowledge assets
- Changing genres of texts and textual relationships: Image Manipulation
- Vanishing hierarchies in ideas
- Shrinking divide: Consumption & Production of Knowledge

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Physics helps

- Building Bridges in **Dendritic Delta** of Ideas

- Teach **Learning Tools** rather than produced knowledge

- Critical examination of **implicit**
Learning Laboratory

- Neglect of Experiment
- Stemming the rot at the roots
- Easy to convert to mindless recipe
Experiments: enjoy & gain

Components: specifications, varieties

Concepts: vivid and memorable

Context: Nature (explanation), Technology (applications)

Care & Control: Alert & Thinking

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How to Choose Experiments?

- Progression in a Programe
  - Straitjacket
  - Multiple Turns
  - Monkeying Around
  - Projects

- Not appendage to theory
- Something new in each
- Conclusions not foregone

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When to Automate?

Critique your purpose:
- Spring-Mass
- E-M Induction
- Coupled Pendulum
- Diffraction

Repeat: It must be slave to my Purpose & Intent

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My Feelings

- Both Art & Science

- Learning to teach can be truly creative

- Getting a sense of how much learning has happened? Devising measures is a challenge.

- Sincerity is sensed even by the most ignoramus. Techniques come automatically.
My Recommendations: 
"Debate & Dilemma of Curricula"

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**Prerequisite by Physicist:**
Excite, Explore, Experiment

**Concurrent by Engineer in Academia:**
'Meta'

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Teaching Tools are in a flux,

Learning to teach?

Should we be doing...........

What?