Design Based Teaching for Science and Engineering Students

CANADIAN DESIGN ENGINEERING NETWORK
RÉSEAU CANADIEN DE LA CONCEPTION EN INGÉNIERIE


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Contents

• The Big Picture
• Engineering Interdependencies
• Traditional Design Method
• Classroom Design Method
• Analysis of Design
• Questions
The BIG picture
Preliminary for Design
Science
The BIG picture...

Preliminary for Design...

Science

- Pure Science
- Applied Science
- Social Science
The BIG picture...

Preliminary for Design...

Science

- Pure Science
  - Mathematics
  - Physics
  - Chemistry
  - Biology

- Applied Science

- Social Science
  - Philosophy
  - Psychology
  - Political Science
  - Economics

Electrical Eng.
The BIG picture...
Preliminary for Design...

Science

- Pure Science
  - Mathematics
  - Physics
  - Chemistry
  - Biology

- Applied Science

- Social Science
  - Philosophy
  - Psychology
  - Political Science
  - Economics

Engineering

- Mechanical Engineering
- Computer Engineering
- Electrical Engineering
- Civil Engineering
- Chemical Engineering
The BIG picture...

Preliminary for Design...

Science

- Pure Science
  - Mathematics
  - Physics
  - Chemistry
  - Biology

- Applied Science

- Social Science
  - Philosophy
  - Psychology
  - Political Science
  - Economics

Engineering

Computer Eng.
Electrical Eng.
Civil Eng.
Chemical Eng.

Telecom & DSP
The BIG picture...

Preliminary for Design...

Science

- Pure Science
  - Mathematics
  - Physics
  - Chemistry
  - Biology
- Applied Science
- Social Science
  - Philosophy
  - Psychology
  - Political Science
  - Economics

Electrical Engineering


Computer Eng.

Electrical Eng.

Civil Eng.

Chemical Eng.

Electrical

Electronics

Electromagnetics

Telecom & DSP

Power

Control & Systems
The BIG picture: WHY???

Preliminary for Design...

Think Outside the Box!
OPEN MIND!!
Collaborate!!

Think Inside the Box! FOCUS!!
Contents

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Engineering Interdependencies
Motivation for Design
Engineering Interdependencies

Motivation for Design

**Example:** Mobile Phone
Engineering Interdependencies

Motivation for Design…

Example: Mobile Phone…

Mobile Phone

Acoust. Eng.
Engineering Interdependencies

Motivation for Design...

Example: Mobile Phone...

Mobile Phone

Engineering Interdependencies

Motivation for Design...

Example: Mobile Phone...

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
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</tbody>
</table>

Mobile Phone
Engineering Interdependencies

Motivation for Design...

Example: Mobile Phone...

Mobile Phone


RF Eng.

Antenna
Engineering Interdependencies

Motivation for Design...

Example: Mobile Phone...

Mobile Phone

RF Eng.

Antenna


VLSI Eng.

Implementation
Engineering Interdependencies

Motivation for Design...

**Example**: Mobile Phone...

- RF Eng.
- Antenna

**Mobile Phone**

- Acoust. Eng.
- DSP Eng.
- Comm. Eng.

**Implementation**

- VLSI Eng.
- Comp. Eng.
Engineering Interdependencies

Motivation for Design...

Example: Mobile Phone...

Mobile Phone

RF Eng.

Antenna


Interface

Soft. Eng.

Implementation

Engineering Interdependencies

Motivation for Design…

**Example:** Mobile Phone…

≈ 7 Engineers !!!
Contents

- The Big Picture
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Traditional Design Method

Input

I₁  I₂  \ldots  Iₘ

System

Output

O₁  O₂  \ldots  Oₙ

Engineering

Reverse Engineering
Contents

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  - Questions
Classroom Design Method

Assignments or Projects → OK
Teaching → NO!!!

This method **TELLS** you what to do and does not make you **THINK**!!
Classroom Design Method...

**Traditional Design Teaching** – THEORY

Tell, Show
System Design

v.s.

**Creative Design Teaching** – INTUITION

Build, Think, Re-discover
System Design

✓
“Everything should be made as simple as possible, but not simpler”

— Albert Einstein
# Classroom Design Method…

## Steps used in Design Based Teaching

<table>
<thead>
<tr>
<th>Step #1</th>
<th>Explain a design question in its simplest possible form ever.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step #2</td>
<td>Engage students for feedback and show open mindedness to all suggestions no matter how far-fetched it seems.</td>
</tr>
<tr>
<td>Step #3</td>
<td>Build gradually the system and the theoretical knowledge required to comprehend it.</td>
</tr>
<tr>
<td>Step #4</td>
<td>Add natural and manmade limitations to the system gradually one after the other [not all in one shot]. And explain ways to modify the system to cope with these changes.</td>
</tr>
<tr>
<td>Step #5</td>
<td>Show parallel systems and compare them to identify advantages and disadvantages of each.</td>
</tr>
</tbody>
</table>
Classroom Design Method...

Example: Telecommunications
Classroom Design Method...

Example: Telecommunications...

I want bits to go from “A” to “B”.

<table>
<thead>
<tr>
<th>1</th>
<th>Point A</th>
<th>Point B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...10110</td>
<td>Physical Separation</td>
</tr>
</tbody>
</table>

Classroom Design Method...

Example: Telecommunications...

Say we use a wire!
Classroom Design Method...

Example: Telecommunications...

Wire or channel is not perfect!
Classroom Design Method...

Example: Telecommunications...

Signal power is small w.r.t. noise!
Classroom Design Method...

Example: Telecommunications...

I still have bits detected in error!
Classroom Design Method...

Example: Telecommunications...

<table>
<thead>
<tr>
<th>Semester #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.e. 4 months of Design Teaching</td>
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<table>
<thead>
<tr>
<th>1</th>
<th>Point A</th>
<th>Point B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...10110 ← Physical Separation → ...11101</td>
<td></td>
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<table>
<thead>
<tr>
<th>2</th>
<th>Point A</th>
<th>Point B</th>
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</thead>
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<tr>
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<td>...10110 ← wire → ...11101</td>
<td></td>
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<tr>
<th>3</th>
<th>Point A</th>
<th>Point B</th>
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<tbody>
<tr>
<td></td>
<td>...10110 ← noise → ...11101</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th>Point A</th>
<th>Point B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...10110 ← modulator → Demodulator → ...11101</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5</th>
<th>Point A</th>
<th>Point B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>...10110 ← Encoder → modulator → Demodulator → Decoder → ...11101</td>
<td></td>
</tr>
</tbody>
</table>

Digital Communications
4 Credit Course
Classroom Design Method...

Example: Telecommunications...

Reflection, Scattering, Rain, Snow, Buildings, Pedestrians, Cars,...
Classroom Design Method...

Example: Telecommunications...

I want the device to be mobile!
Classroom Design Method...

Example: Telecommunications...

Merge the bits from others!

```
8

Point A

...10110 → Multiplexer → Mobile Tx

from other users

to other users

Point B

Mobile Rx → Demultiplexer → ...11101
```
Classroom Design Method...

Example: Telecommunications...

I want to increase the range!
Classroom Design Method...

Example: Telecommunications...

I want to increase “Speed”.
Example: Telecommunications...

Semester #2
i.e. 4 months of Design Teaching

Wireless Communication
4 Credit Course
Classroom Design Method...

MORAL OF THE STORY

Ask a Simple Design Question

Point A

...10110

Physical Separation

...11101

Point B

Design a Very Complex System

Point A

...10110

Mobile Tx

from other users

Point B

Mobile Rx

to other users

...11101

8 Months

move SLOWLY

CREATIVE Design Teaching

Intuition
NOT MATH!
Contents

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  - Analysis of Design
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Analysis of Design...

- Software
- Design Based Teaching
- Hardware

Cycle Diagram:
- Simulation
- Analysis
- Implementation
To be on a quest is nothing more or less than to become an asker of questions.

— Sam Keen