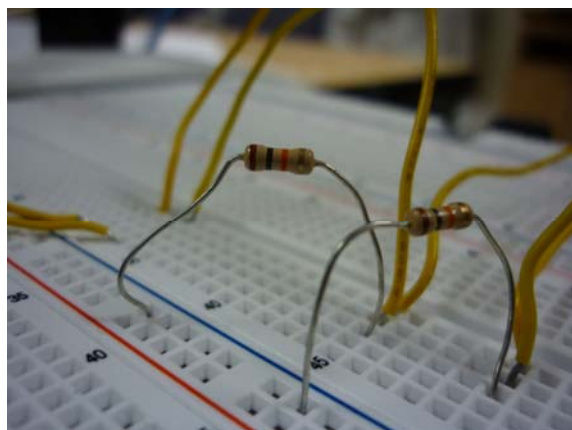
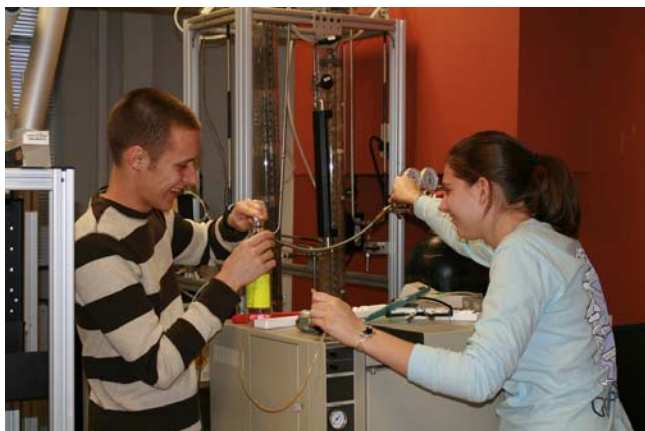




Process Control: Learning It and Doing It Through LabVIEW™ Based Design

Heidi B. Martin and
R. Craig Virnelson

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Case Western Reserve University



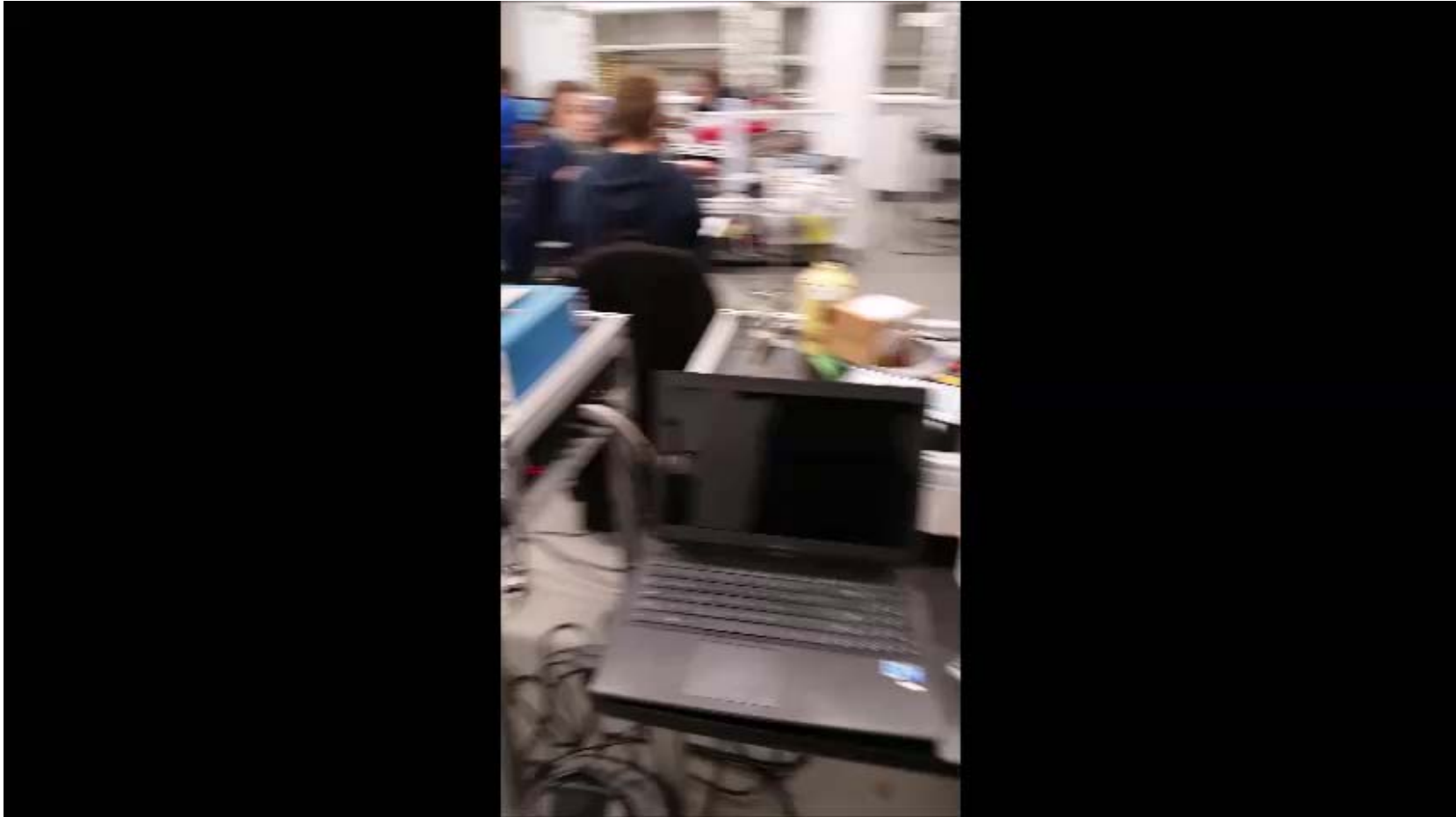
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Our Process Control Class...



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Approach

Reliance on LabVIEW and data acquisition as user-friendly tools for the integration of concepts in controller modeling and implementation

Motivation

Traditional Process Control courses focus mostly on process control theory



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Our Reinvented Course

- Recitation Time Switched to Lab Session
(Overall Course is 4 Credit Hours)
- Heavy Use of LabVIEW for both Data Acquisition and Process Modeling
- Training in LabVIEW, Data Acquisition
- Design Project – Couples Modeling & Implementation
- Ongoing Emphasis - Connection Between Theory & Practice
(Process Modeling, Transfer Functions, Linear Feedback Control Theory, Feedforward & Cascade Control)



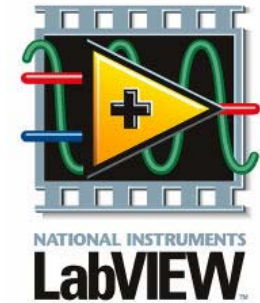
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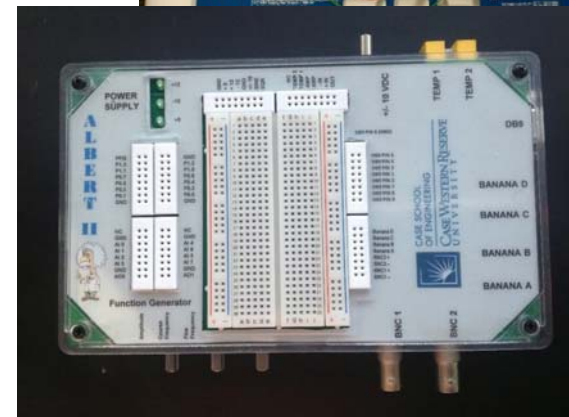
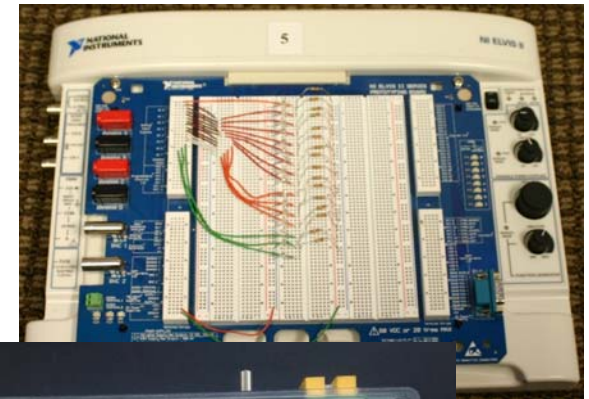
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Coupling Data Acquisition with Feedback Control



- LabVIEW software - Graphical Programming, User Friendly
- Data Acquisition Teaching Platform (*National Instruments NI-ELVIS II*)
- Custom Built Data Acquisition Platform (Uses *NI* board)
- Supply Room – Project Equipment



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Early Incorporation of LabVIEW

WEEK OF THE SEMESTER	DESIGN PROJECT ACTIVITY	LABVIEW TRAINING/ASSIGNMENTS	
		For Data Acquisition	For Modeling
1		<i>In-class Tutorials</i>	Control Lab, Part 1
2			
3		<i>Training Programs 1-3* Analog Inputs</i>	Control Lab, Part 2
4			
5	Preliminary Project Proposal Submission		Introduction to the Simulator
6	Team Meeting with Instructor	<i>Training Programs 4-7* Analog & Digital Inputs & Outputs</i>	<u>Process Simulations</u> • Time Domain • Non-Linear Systems
7			
8	Final Project Proposal Description with Gantt Chart		<u>Process Simulations:</u> • Transfer Functions • Linearization • Relating Transfer Functions to Instrumentation
9			
10	Written Status Report 1	<i>Training Program 8 PID Control</i>	



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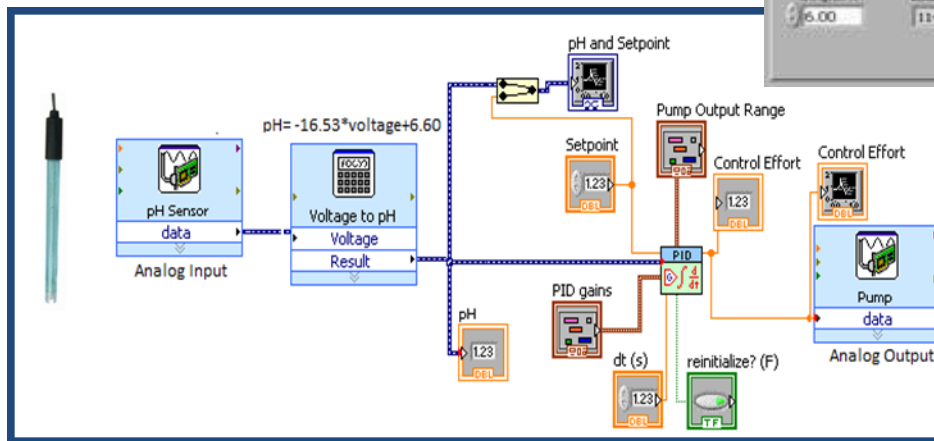
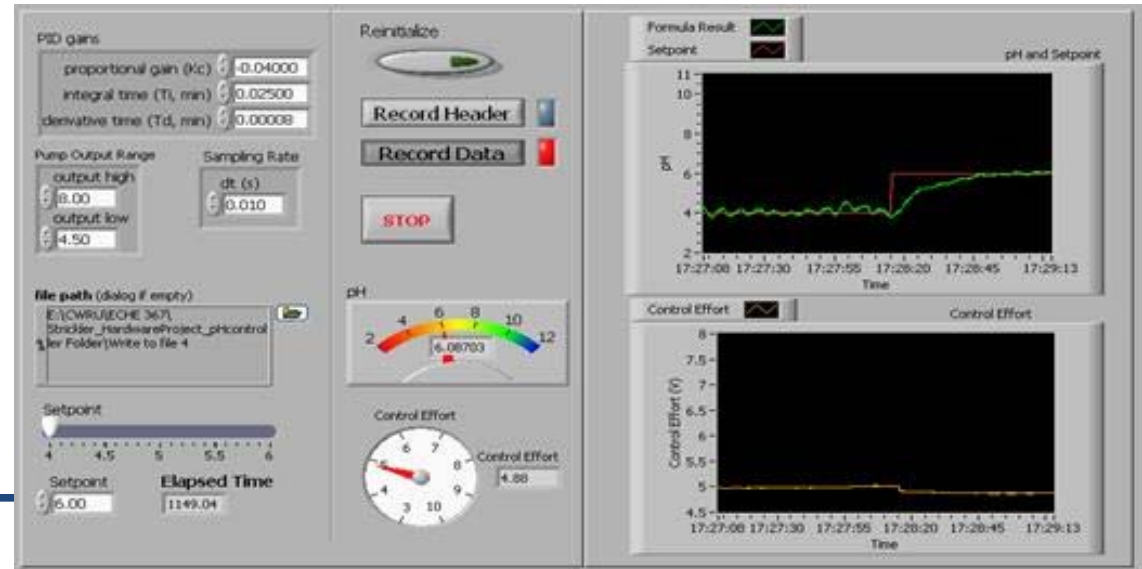
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Stage 1: Predetermined Project– pH Control

- Design Program
- Tune Controller



- Non-Linear System
- Less Creativity

$$p(t) = \bar{p} + K_c \left[e(t) + \frac{1}{\tau_I} \int_0^t e(t^*) dt^* + \tau_D \frac{de(t)}{dt} \right]$$



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Stage 2: Student-Selected Topics



*Baby Rocker-for
Restful Sleep*

*Dissolved
CO₂ in
Aquariums*



Pancake Producers

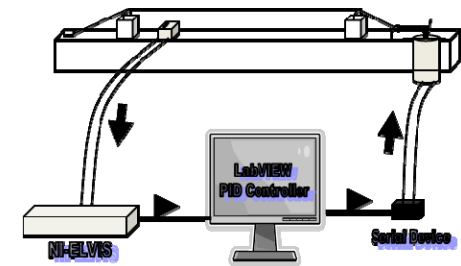


*Solar Panel-
Rotation & Tilt*

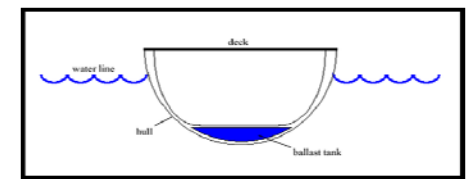


Smart Umbrella

Guitar String Tuner



Venetian Blinds



*Ballast Tanks –
Waterline of Ships*



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Stage 3: Team Projects



*Hydroponics
(pH & T Control)*



Public Demo Session



*Violin Tuning
(3-D Printing of
Peg Clamp)*

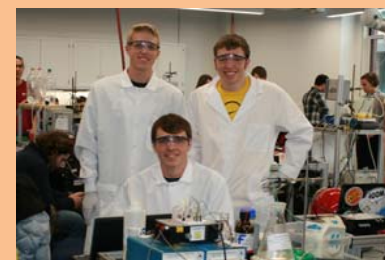
*Drink Composition
(Switch Valves- Integrate Flow)*



*Sugar Content
(Auger)*



Reaction Yield (Conductivity)



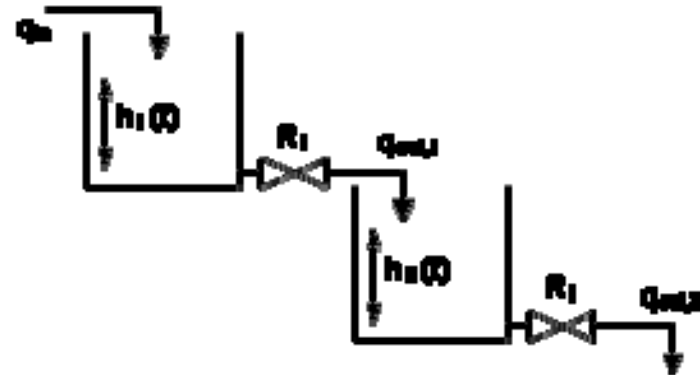
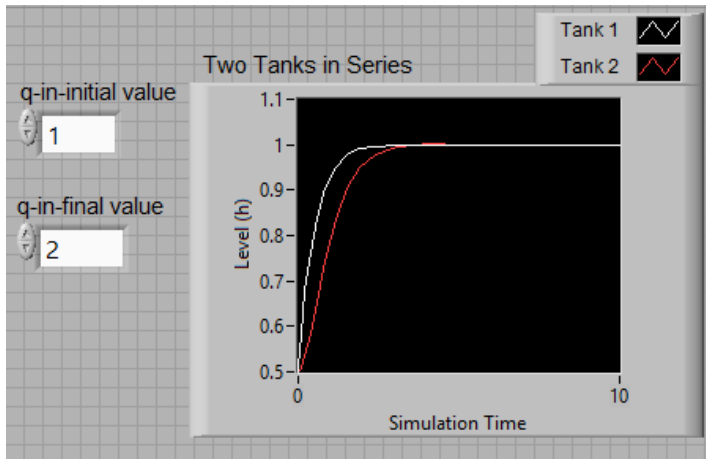
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Simulation & Modeling with LabVIEW



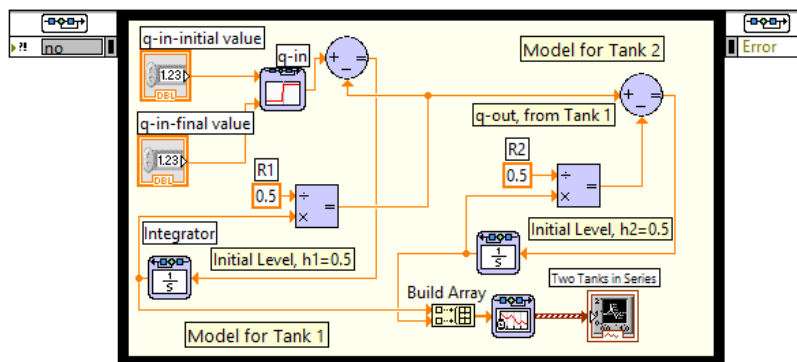
Tank 1: $q_{in} - q_{out,1} = A_1 \frac{dh_1}{dt}$

Tank 2: $q_{out,1} - q_{out,2} = A_2 \frac{dh_2}{dt}$

$q_{in}(0) = 1 \quad q_{in}(0^+) = 2$

$q_{out,1} = \frac{1}{R_1} h_1 \quad q_{out,2} = \frac{1}{R_2} h_2$

R = valve resistance; $R_1 = R_2 = 0.5$
 A = tank cross sectional area; $A_1 = A_2 = 1$
 h = tank level



Based on Example 4.4, Seborg *et al.*, **Process Dynamics & Control**

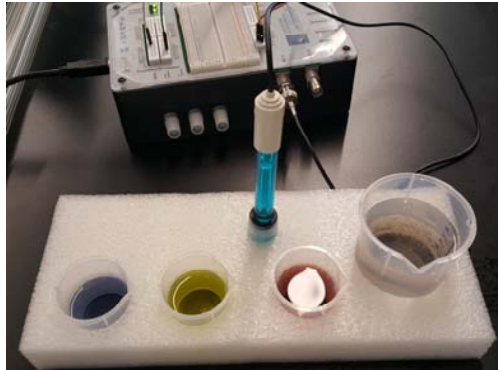


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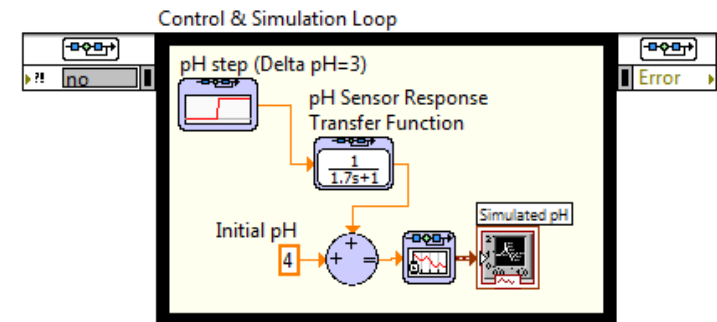
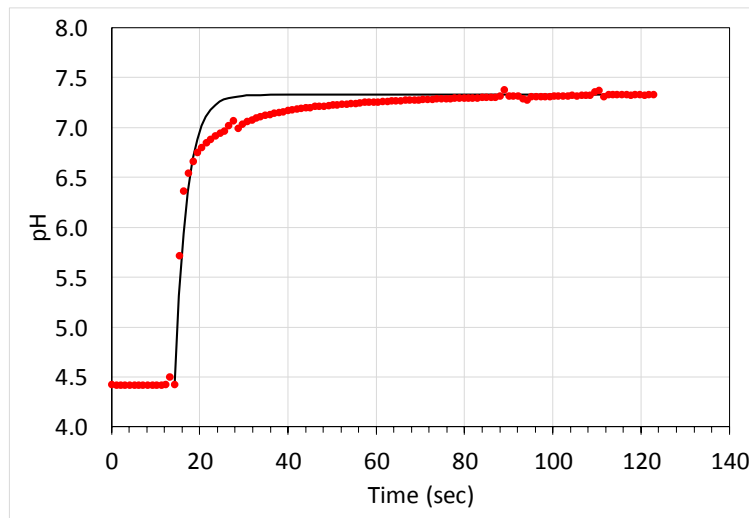
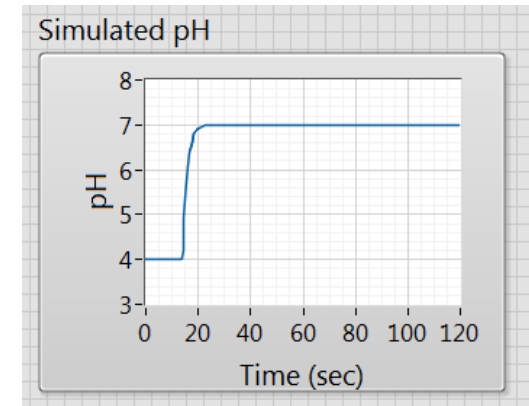
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Step Tests & Transfer Functions



Step Test (Δ pH)*	τ 63% of Step Response	τ Fit to First Order Model
4 to 7	1.8	2.7
4 to 10	1.7	1.7
7 to 10	1.9	2.3
10 to 7	2.7	4.2
10 to 4	1.5	1.6
7 to 4	1.0	1.3

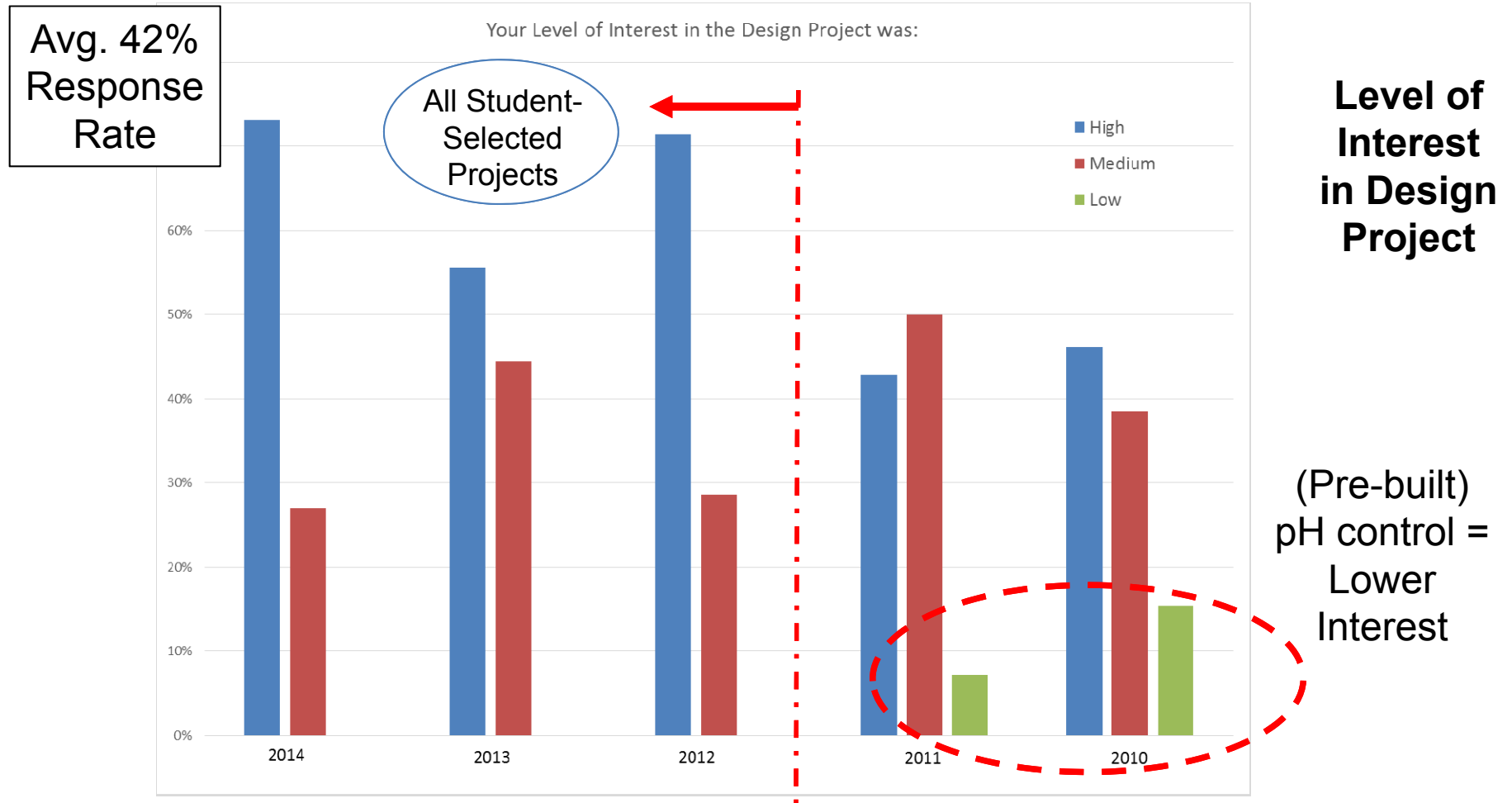


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Survey – Students from Past 5 Years



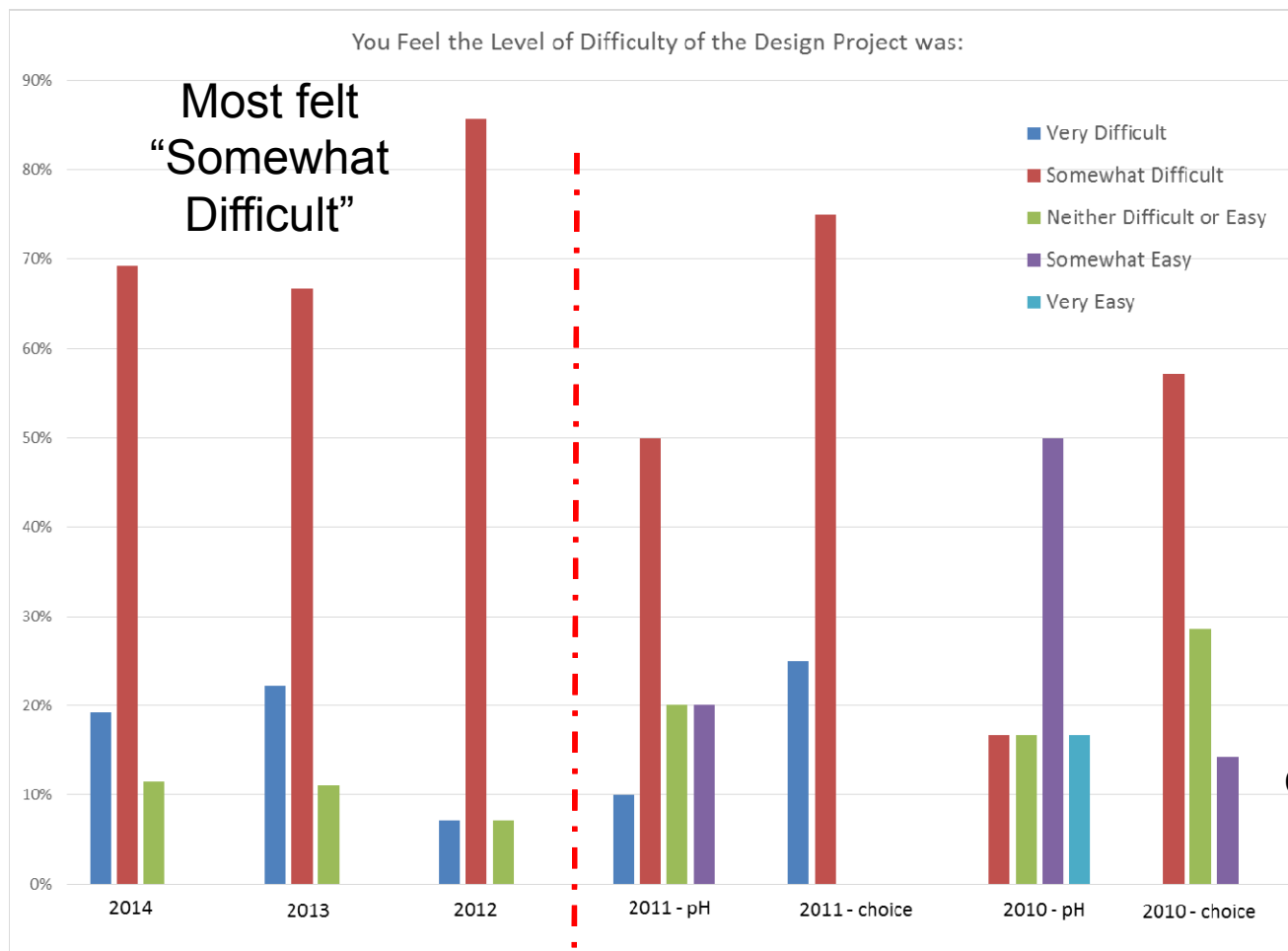
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Project Difficulty Worth the Effort

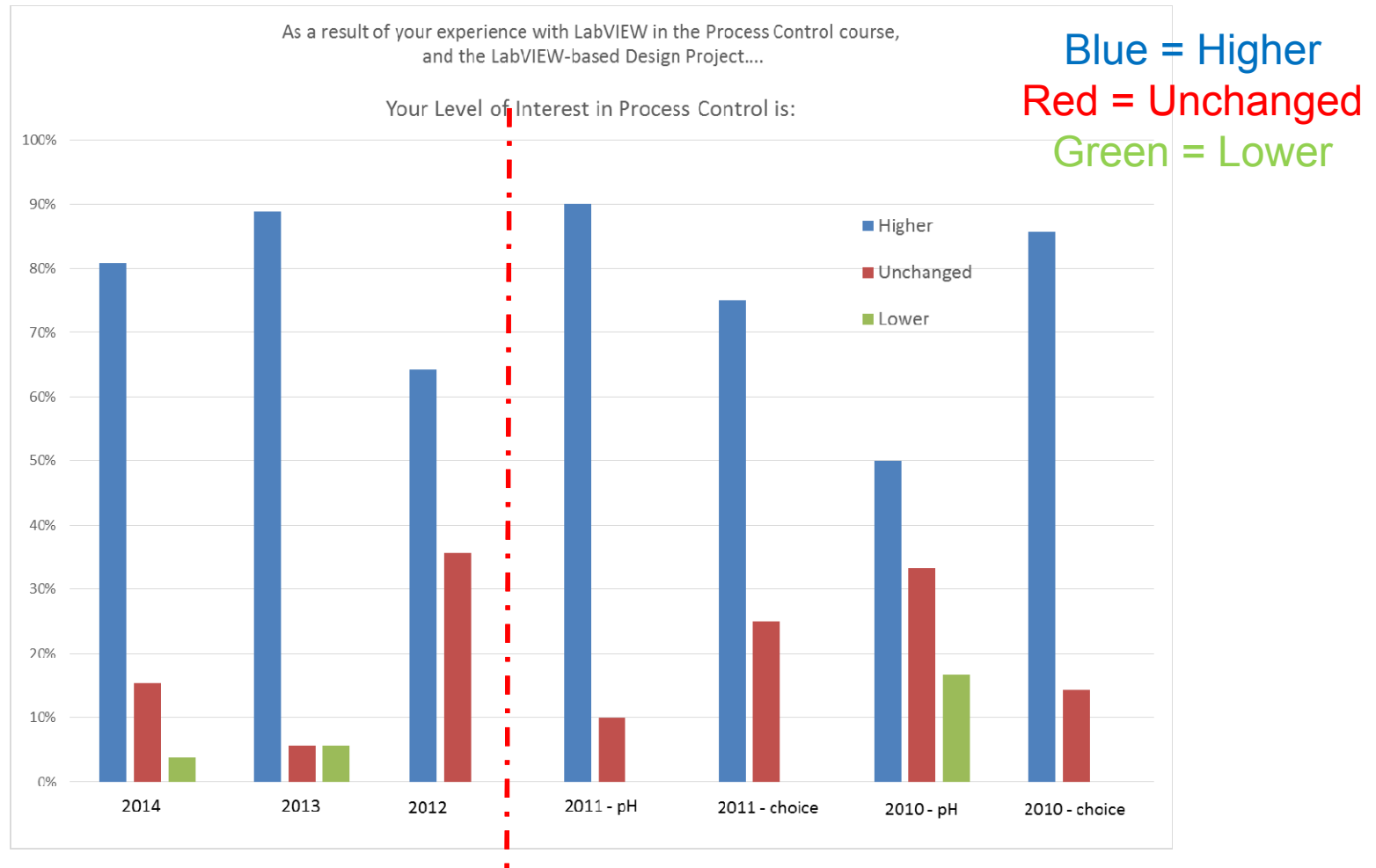


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LabVIEW Motivated Interest in Control



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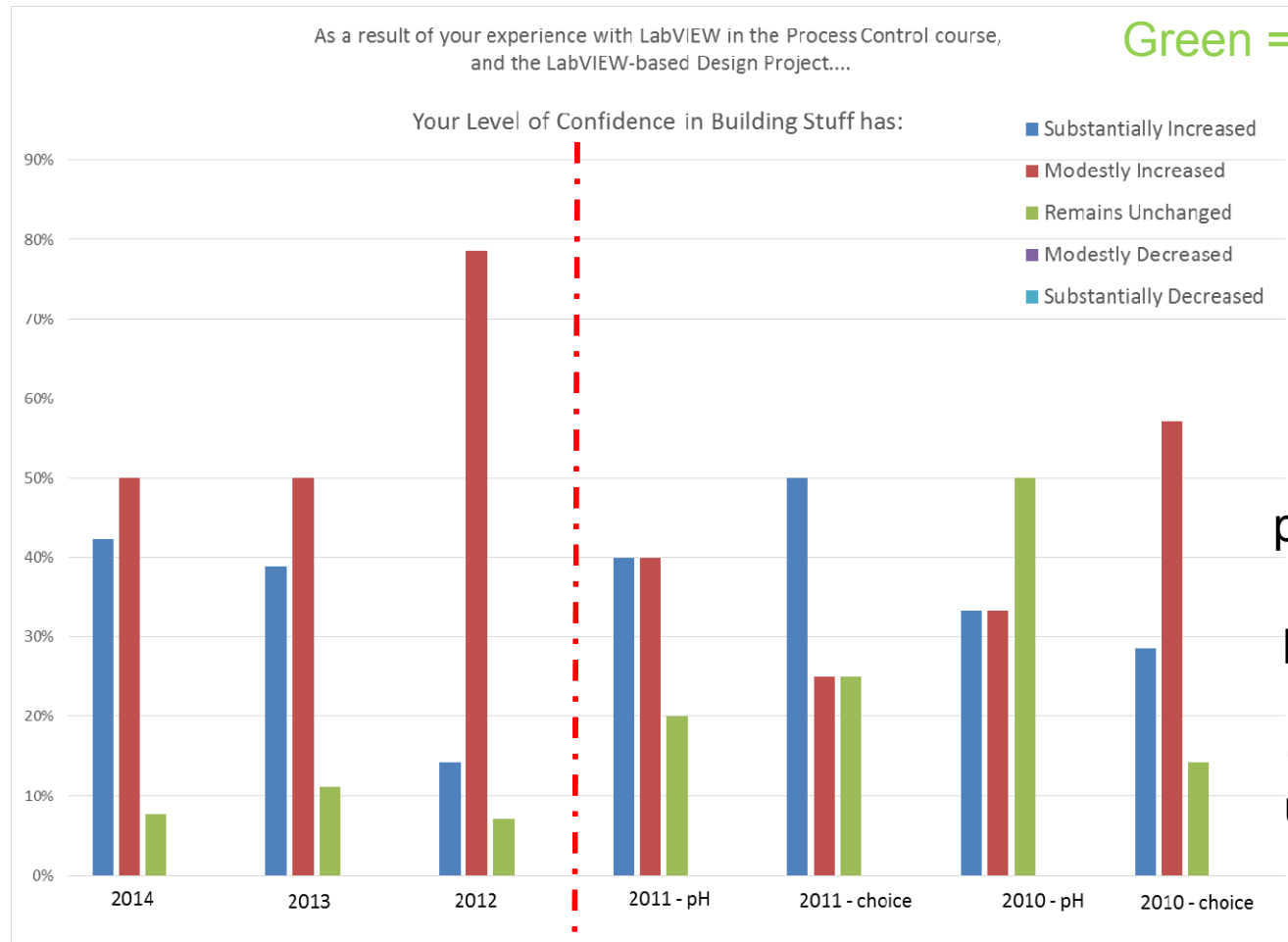
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Students Gained Confidence

Blue = Substantial

Red = Modest

Green = No Change



(Pre-built)
pH control =
Higher
percentage
felt
confidence
unchanged



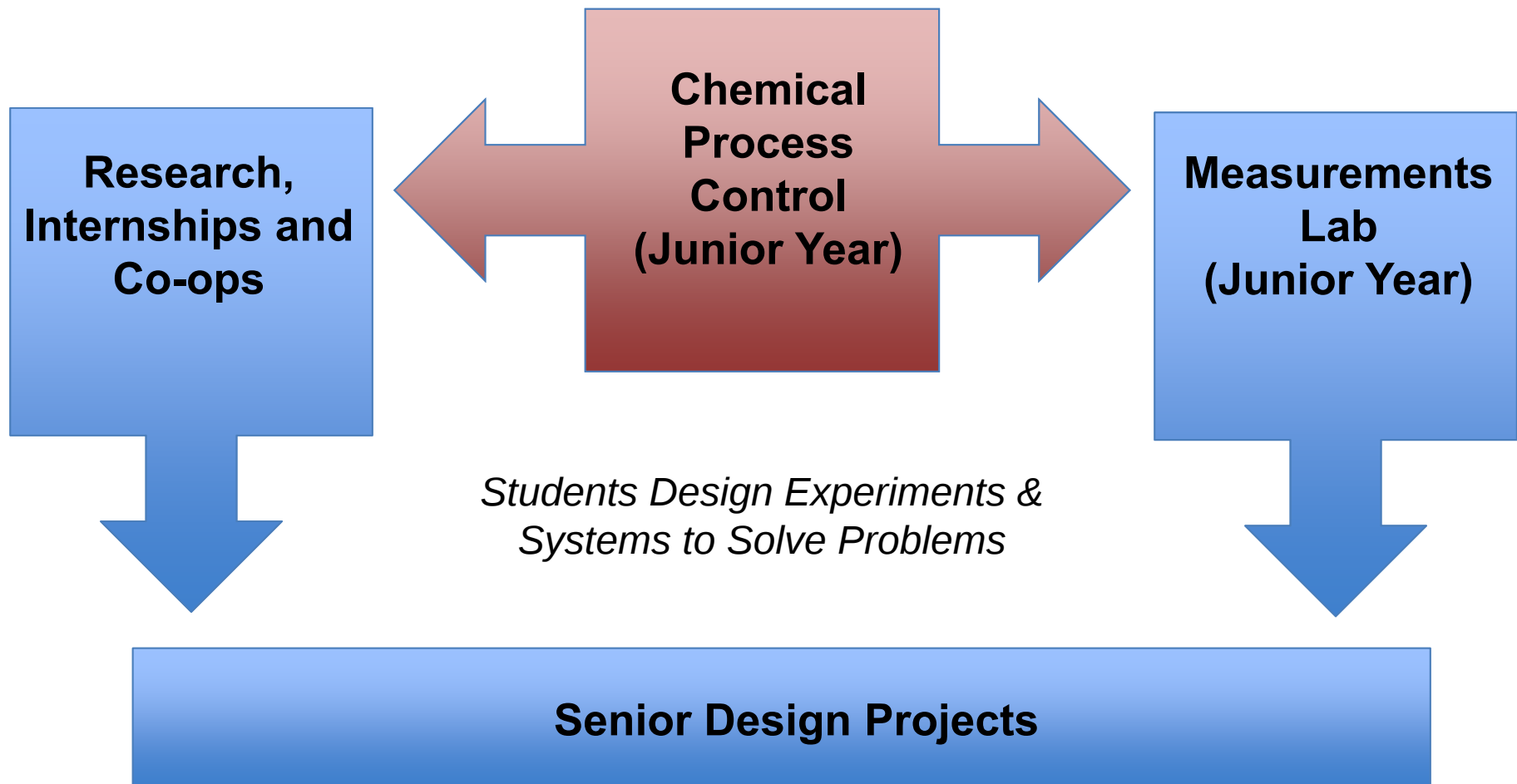
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Impact throughout Curriculum



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Process Control is Fun & Relevant

- *Bridge Gap between Theory and Reality*
- *Provide Design Project Experience*
- *Train with a New Skill Set to Address Design Problems*

Acknowledgments

- *Chemical & Biomolecular Engineering Dept.*
- *William James (BS, Case 1964)*
- *Students of ECHE 367, Process Control*



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