Development of Static and Dynamic Simulation-Based Active-Learning Modules for Chemical Engineering Curriculum

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Outline

- Challenges in STEM Education
- Motivation and Objective
- Approach
- Conclusions

Traditional STEM Pedagogy[1-4]

- Lecture-based learning has reigned supreme for many years.
  1) A new concept is introduced.
  2) A derivation is performed to create a useful tool for solving problems.
  3) An example problem is then propsed.
  4) The example problem is solved using the derived formula.
- However, the education literature suggests that this approach to teaching generally does not develop a conceptual understanding of the material.
- One of the contributing factors to this is the lack of active learning that takes place.
- This approach to teaching is also biased against students who prefer a focus on practicality (sensors) instead of abstract concepts (intuitors)[5]

Introduction of Process Simulators[6,7]

- As technology has advanced, chemical process simulators have become more commonplace in the classroom.
- Steady-state process simulators have given students the ability to design equipment for complex chemical processes faster than ever before.
- However, steady-state process simulators can equally hurt as much as help a student's learning when not utilized in education effectively.
- This is because students often equate these simulators to the real-world without critically thinking whether that is a proper use of the simulator, leading to misconceptions about chemical engineering, rather than lessons on it.

Motivation

- This does not mean that process simulators should be removed from the curriculum, but it does mean that more careful thought must be put into how they are incorporated in the ChE curriculum.
- The lecture approach to STEM education is still very prevalent because it is easier to perform for the educator, meaning any proposed education tool should have a low required effort to incorporate.
- Any new simulation-based education tool should also incorporate elements of active learning and connections between the real world and the simulator are necessary.
- **Objective: Develop a useful guide of standard active learning techniques for process simulators in the standard chemical engineering curriculum.**

Proposed Approach

- **Classes of interest in this guide:**
  - **Material and Energy Balances**
  - **Numerical Methods**
  - **Fluid Mechanics**
  - **Heat Transfer**
  - **Thermodynamics**
  - **Reaction Engineering**
  - **Separations**
  - **Process Safety**
  - **Process Control**
  - **Process Simulation and Design**
- **Each course has 4 active learning techniques developed using the AVEVA Process Simulation platform for a total of 40 modules in the guide.**

Proposed Approach

- **Structure of each module:**
  - General Module Info
  - Learning Objectives
  - Module Description
  - Background
  - Activity
  - Debrief

PID Controllers

Process Control

Total Time: 30 minutes

Background	10 minutes
Activity	15 minutes
Debrief	5 minutes

Learning Goals

- Introduce students to the concepts of manipulated variables, control variables, and feedback control.
- Introduce students to the PID controller and explain the purpose of each term (P, I, and D).
- Have students change the values of each gain to see how each term effects the response to a disturbance.

Description

This activity will introduce students to feedback control. A discussion is provided in the background that is designed to create an intuition for the PID controller. Once students develop the intuition, they then utilize AVEVA Process Simulation to see how changing the P, I, and D of the controller affects the response. Lastly, students are given the opportunity to experiment with the controller to improve the response.

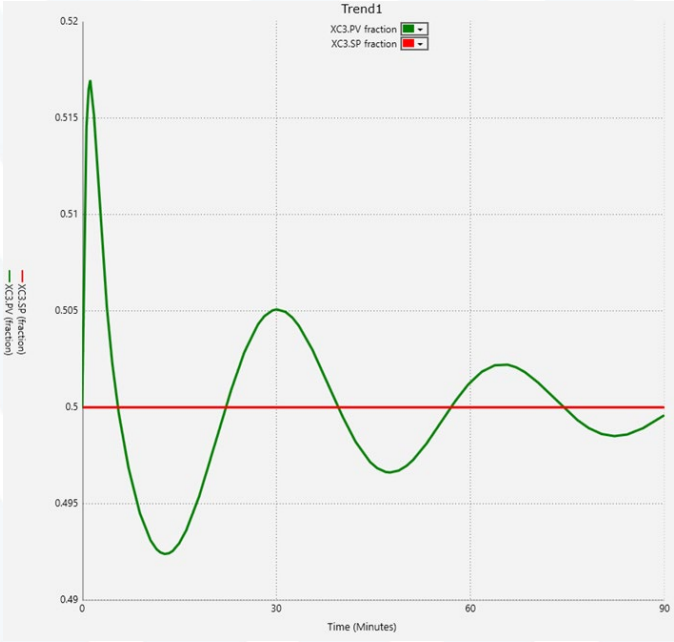
Proposed Approach

- **Background:**
  - Provides any necessary info for completing the student activity and is optional.
  - Background sections are limited to a maximum of 15 minutes as research shows students generally begin to lose focus after about 10 minutes of lecture-based learning.[4]

$$\Delta u(t) = K_p * \left[e(t) + \frac{1}{T_i} * \int_0^t e(\tau) d\tau + T_d * \frac{de(t)}{dt} \right]$$

Proposed Approach

- **Activity:**
  - A chemical process simulator is used in one of the following ways:
    - Validation of the theory from the background section (connect theory to practice)
    - Data collection for applying theory (electronic unit ops lab)
    - Digital twin for learning real world operation (education through practice)



Proposed Approach

- **Debrief:**
  - This gives students the chance to reflect on what they have learned and experienced in the activity.
  - It also offers instructors the opportunity to assess the learning objectives for the activity.
- Examples:
  - What was your thought process and approach for tuning the controller to get the desired response?
  - Why do we generally avoid using the derivative term if it can improve the response?

Highlighted Topics

- **Process Design:** Pressure-Driven vs Flow-Driven Simulation
- **Process Control:** Cascade Control
- **Process Safety:** Sizing Relief Valves
- **M&E Balances:** Dynamic Material Balances
- **Numerical Methods:** Regression
- **Reaction Engineering:** Multiple Steady States
- **Heat Transfer:** Multiple Shell and Tube Pass Exchanger

Conclusions

- Lecture-based teaching methods dominate the STEM curriculum but have been shown to be insufficient for learning concepts.
- Chemical process simulators have become more commonplace, but their misuse in ChE education can lead to a poor learning environment.
- In this work, 40 active learning modules were developed in AVEVA Process Simulation that require minimal effort for instructors to incorporate and the misuse of simulators in ChE education.

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Questions ?