A whole-systems simulator for teaching foundational mathematical concepts in chemical engineering

A perennial obstacle facing anyone attempting to increase the throughput of our education systems is that many students have difficulty visualizing the relationship between the mathematical equations they are taught and the physical processes described by those equations.

Within chemical engineering education we have particular difficulty in that we are dealing with processes that need to be accurately described across many different scales ranging from molecules with sizes measured in terms of angstroms, particles that occur on the micrometer scale, to reactors that are several meters across all the way up to giant refineries the size of small cities rivaling any other human artifact in their size and complexity.

To compound this problem, on each level of scale that interaction within a reactor system occurs we need to take into account changes in motion and structure of molecules and particles as well as the overall state of energy transfer between system components.

When we do not have ways of visualizing and relating such interactions within the context of the total problem we are teaching students to solve we find that mathematical equations remain hazy and frustrating ‘black-box’ abstractions in the minds of many students, serving only to inspire fear at exam time!

It is ironic that the very tools which are intended to set the student free so often end up being seen as a collection of seemingly arbitrary rules and methods which resists efforts by the student to unpack and understand deeply enough to apply the contents to the creative act of solving brand new problems.

To help overcome this problem we have developed the proof-of-concept of a simulation system capable of modeling the different mathematical descriptions used to describe various aspects of physical processes occurring across a range of physical scales and integrating them into a single coherent simulation.

To date, we have used our simulation system to develop a model of particle interactions in a stirred tank reactor that produces results which are aligned with theoretical predictions.

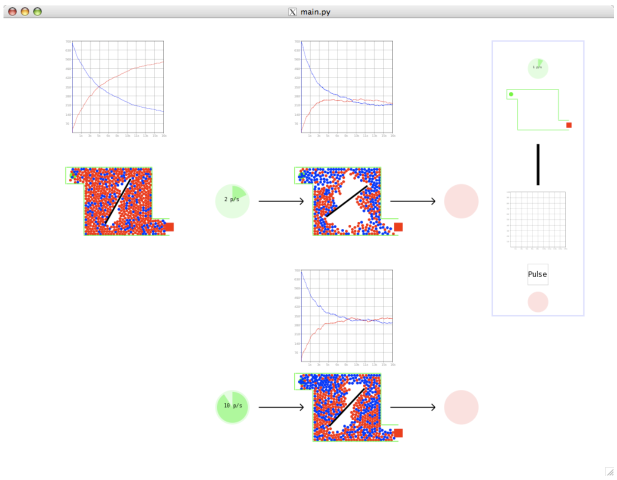

Figure 1. Simulation of particle interactions in a stirred tank reactor.

We have worked with two fourth year students to instruct them in the use of the simulation software to prepare a lesson and quiz based for third-year students on the topic of Residence Time Distribution.

Using the aforementioned material we have performed an introductory assessments of this simulation system within a classroom setting, exposing one half of the class to the simulation and the other half to a lecture on the same topic and then testing the whole class on the material.

On average, the students exposed to the simulation system scored 17% higher than the students exposed to the lecture.