Education Innovation in the College of Engineering

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Development of Demonstration Materials for NEEP 411 - Nuclear Reactor Engineering

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1. Project Description

I would like to develop a set of experimental and numerical modeling demos for the NEEP 411 course, Nuclear Reactor Engineering. I will attempt to develop these demos with input from the industry. These demos are designed to be used in a "blended learning" classroom format, where the class time is party used for lecturing, and partly used for in-class exercises.

- *My first goal is for the students to have a better fundamental understanding of the physical concepts taught in the class.*

For example, the students would be given an interactive computer simulation of heat conduction in a slab, where they can vary thermo-physical properties of the solid and observe the effect on the temperature profile. Changing the thermal conductivity, they will observe a change in the temperature gradient; changing the thermal diffusivity, they will observe no effect in a steady state solution. The values of the thermo-physical properties will be referenced to common materials: wood, steel, glass etc. This should provide them with a intuitive understanding of the thermo-physical properties that they are learning about. A parallel experimental demo can be constructed, showing conduction in a slab using thermo-chromic paint that changes color with temperature, helping them correctly relate their new understanding of the thermo-physical properties to intuition that they already have from day-to-day life.

Through my experience previously teaching this course, and mentoring graduate and undergraduate students in research in the field of heat transfer and fluid flow, I have found that there are many misunderstood concepts that are rooted in a disconnect between the material studied and their previous intuition for the phenomenology. For example, the temperature gradient at an adiabatic surface is necessarily zero; this boundary condition is also often where the hottest temperature occurs – so students will draw sharp temperature gradients at this interface, confusing in a sense "high temperature" with "high temperature gradient." Some students understand their mistake from an explanation that is abstract or mathematical, and course-correct. Many students do not. They repeat their mistake, falling back on their "intuitive" understanding that "the most extreme conditions" must be occurring at this surface; their intuition is correct, but it is incorrectly aligned with the language of the theory that they study in class. **I hope that through a combination of interactive physical demos and computer simulations, I will be able to engage the students at the intuitive level, helping them appropriately use their intuition for the physical phenomena with the abstract understanding of the underlying theory.**

- *My second goal is engagement with the profession. This is the first course in which the students are introduced to reactor systems, and it is followed by the capstone design project in their senior year.*

For example, showing a pump impeller that has been damaged by fluid cavitation demonstrates the concept of cavitation, and challenges the intuition that fluids may not be able to significantly damage solid materials in a short amount of time; it also very concretely demonstrates the importance of good engineering for correctly sizing pumps. Showing parts or components that have failed in operation will be used to exemplify phenomenology, to connect the students to engineering design, and to provide a motivation for the students to understand the phenomenology.

The types of demos that I would like to build can largely be grouped by what they demonstrate: (1) thermo-physical or thermo-mechanical properties; (2) physical processes; (3) abstract engineering concepts:

(1) Thermal conductivity, volumetric heat capacity, heat capacity, thermal diffusivity, absorptivity, viscosity, thermal expansion coefficient, young's modulus
(2) Conduction, convection, radiation, heat flux, momentum diffusivity, differential thermal expansion, thermal stress, friction losses in flowing fluids
(3) Heat flux, momentum flux, thermal resistance, gap resistance, scaled experiments, slip ratio, void fraction, steam quality, Pr, Nu, Re, Bi, momentum conservation, mass conservation, thermal energy conservation, temperature profile at an adiabatic boundary

2. Summary of goals

- Help the students engage their intuition in the learning process of new, challenging physical concepts, with the purpose of helping them better understand and retain fundamental concepts
- Provide a classroom environment in which students become independent learners. By using the demos and the models provided, they can explore the phenomenology and define it in their own terms. This approach will engage those students who are inclined to learn from practical examples, and hopefully make them curious to study the theory. This approach will enhance the learning of those students who are more inclined towards studying the equations and the abstract theories by connecting their skills to applied problems.
- Provide a potential avenue for industry-defined examples, thus making the classroom learning experience directly relevant to the nuclear and other related industries.

3. Target student population

Undergraduate students majoring in nuclear engineering are required to enroll in NEEP 411, Nuclear Reactor Engineering, during their senior or junior year. Graduate students in nuclear engineering who have not had an equivalent course in their undergraduate education will also have the option of taking this course. In Fall 2014, the course was attended by 29 students, 20 undergraduates, and 9 graduates. Over the past 5 years the enrollment was in the range of 21 to 40 students, with 85% to 43% being undergraduate students. This course is taught yearly, in the fall semester.

The demos can be made available for use in other courses where they may be applicable. Some examples could include: ME 364 - Elementary Heat Transfer, ME 520 – Two-Phase Flow and Heat Transfer, and NEEP 412 – Nuclear Engineering Design.

4. Sustainability

The demos and exercises developed will continue to be used every year that the course is taught. Feedback from the students using the demos will be used to better adapt their use in a blended-classroom environment. This continuous improvement of the use of the demos and the exercises will be part of the normal development and improvement work that is done for the course in preparation for each semester.

In order to continue to develop additional demos and tools, sponsorship or equipment donations could be sought from equipment and instrumentation vendors, or from industry entities. Having already demonstrated that such demos are effective classroom tools will be an important selling point in convincing industry partners to contribute. Furthermore, having had the experience of developing such demos, and having already established a relationship with some industry entities in the development of these demos, it will be easier to target sponsorship of additional demos that are most likely to be useful in the course.