



## **Design for Impact: Reimagining Inquiry-Based Activities in Heat Transfer for Effectiveness and Ease of Faculty Adoption**

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Margot Vigeant is a professor of chemical engineering and an associate dean of engineering at Bucknell University. She earned her B.S. in chemical engineering from Cornell University, and her M.S. and Ph.D., also in chemical engineering, from the University of Virginia. Her primary research focus is on engineering pedagogy at the undergraduate level. She is particularly interested in the teaching and learning of concepts related to thermodynamics. She is also interested in active, collaborative, and problem-based learning, and in the ways hands-on activities and technology in general and games in particular can be used to improve student engagement.

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Dr. Nottis is an Educational Psychologist and Professor of Education at Bucknell University. Her research has focused on meaningful learning in science and engineering education, approached from the perspective of Human Constructivism. She has authored several publications and given numerous presentations on the generation of analogies, misconceptions, and facilitating learning in science and engineering education. She has been involved in collaborative research projects focused on conceptual learning in chemistry, chemical engineering, seismology, and astronomy.

### **Dr. Milo Koretsky, Oregon State University**

Milo Koretsky is a Professor of Chemical Engineering at Oregon State University. He received his B.S. and M.S. degrees from UC San Diego and his Ph.D. from UC Berkeley, all in Chemical Engineering. He currently has research activity in areas related engineering education and is interested in integrating technology into effective educational practices and in promoting the use of higher-level cognitive skills in engineering problem solving. His research interests particularly focus on what prevents students from being able to integrate and extend the knowledge developed in specific courses in the core curriculum to the more complex, authentic problems and projects they face as professionals. Dr. Koretsky is one of the founding members of the Center for Lifelong STEM Education Research at OSU.

## Introduction

While standard lecture-based educational approaches improve students' computational abilities, they are of limited effectiveness in repair of students' misconceptions. Educational efforts to improve conceptual learning using approaches such as inquiry-based activities have been effective, but have not been widely adopted by engineering educators. The goal of this work is three-fold: first, we will re-create our inquiry-based activities for heat transfer by specifically modifying them in ways that make them easier for faculty to implement in the classroom; second, we will measure the effectiveness of these modified activities as they are implemented by our partner institutions; Third, we will provide both the full menu of activities and the effectiveness data to faculty broadly and monitor the adoption "in the wild".

In previous work, we developed inquiry-based activities to address students' common misconceptions in heat transfer. These activities involved three parts – first, a description of a situation and a request for students to individually make a written prediction about how that situation would resolve. For example, predict which lowers the temperature of a cup of water more: a single large ice cube, or an equal mass of chipped ice? Then students worked in small groups to replicate the experiment as described and record observations. Finally, after discussing what they had experienced, students would complete an individual written reflection on what they'd observed and how it differed from their prediction.

While these activities were highly effective as promoting students' conceptual change (Prince, Vigeant, & Nottis, 2012a; Prince & Vigeant, 2007; Prince, Vigeant, & Nottis, 2009a), they found somewhat limited adoption in the broader engineering faculty. Further, when faculty were adopting the activities, they were modifying them to make them better fit their particular situations. For example, some faculty members were using the experimental part of the activity as an in-class demonstration rather than having small groups of students complete the experiment themselves.

This work seeks to address two questions. First, what changes in the inquiry-based activities would best spur widespread adoption by faculty? Second, what effect would these changes have upon the educational effectiveness of the activities themselves? To address these questions, we have gathered a faculty advisory group from diverse institutions who are willing to use modified versions of our existing activities in their courses. They have also assessed our current activities and given us feedback upon which aspects are most challenging to implement. Ultimately, once we have assessed the effectiveness of the modified activities, they will be published and adoption "in the wild" will be noted.

Based on this feedback, we have produced four new variations on the inquiry-based activities. These involve: a) replacing the students' experiments with simulations; b) replacing the students' experiments with the students observing the experiment

as an in-class demonstration; c) the students' watching the simulation as an in-class demonstration and d) replacing both simulation and experiment with an in-class thought experiment.

### **Progress**

In the first year of the project, we surveyed our advisory board for their feedback on the ease (or lack thereof) with which they were able to implement existing activities. The previous activities required 5-20 minutes of time for a small experiment that could be performed by a group of 3-5 students. The equipment required for these was generally simple (pipes, heat lamp, thermocouples, stir-plates) and readily available at most engineering schools. The feedback indicated that, even though this was the case, the activities were cost-prohibitive for large classes. Further, most classes on heat transfer did not have a laboratory section and it was particularly challenging to find time for students to complete even short experiments. In addition to class time, set-up time was a challenge as well.

To address these challenges, we have re-developed our activities in the following ways:

- Web-based computer simulation of the activity
- Thought experiment replication of the activity

These specifically remove the expense of laboratory equipment, and the second removes the expense of web-accessible computers/phones.

We are testing these activities through several implementation approaches:

- Faculty-led demonstration
- Student completion
- Student group studio work

These impact both the space and class-time requirements. A faculty demonstration requires class time but is far less space intensive and generally more rapid than student-conducted experiments. Student group studio work leverages time students were already expected to be working in small groups on activities. And while student completion of experiments is time and space intensive, assignment of student completion of simulations is typically as homework and thus uses no class time at all.

Preliminary results on student studio group work are presented in Koretsky et al, 2015, also submitted to this conference.

Faculty and student instructions and handouts for each variation and both concept areas were created. In year two, most of these variations were tested in heat transfer classes at volunteer institutions in the US. In year three, testing is ongoing.

## Future Work

In the coming semesters, the modified activities will be tested at four institutions. Data on educational effectiveness of the activities will be gathered from pre- and post- administration of the Heat and Energy Concept Inventory (Prince, Vigeant, & Nottis, 2009b; Prince, Vigeant, & Nottis, 2012b; Prince, Vigeant, & Nottis, 2010), as well as student answers to post-activity reflection questions. Faculty using these activities will be surveyed both for the amount of time they spent on each particular topic as well as about their sense of how much they liked the approach they were testing. Once this is complete (anticipate Summer 2016), we will share the documentation and simulations for activity variations with faculty, along with information about each variation's educational effectiveness and the amount of time, space, and equipment needed for each. We will then track faculty adoption to assess which factors are most important in the adoptability of this educational innovation.

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