Design For Impact: Inquiry-based Activities for Important Concepts in Heat Transfer that Faculty Will Actually Use

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Abstract

In previous work, we documented that inquiry-based activities could be very effective tools for misconception repair in heat transfer and thermodynamics. However, since many courses in heat transfer do not have laboratory sections, or are very large, it is challenging for instructors to adopt these activities. Instructors may modify the activities to adapt them to their context, but in that case, the effectiveness of the activities as educational tools is unknown. Our goals in the current work are to first, to create versions (modes) of the activities that are easier for faculty to use, and second, assess their educational effectiveness. To what extent does delivery mode impact conceptual learning? Our third goal is to share all modes of all activities, with sufficient information that faculty can make good choices about their adoption, and learn which factors are most important for faculty adoption.

The first two tasks towards these goals, creation of multiple modes for each activity, assessing each mode's educational effectiveness, have been completed. Each activity comes in five modes – as an experiment conducted by student groups, as an experiment demonstrated by an instructor, as a simulation used by students, as a simulation demonstrated by the faculty, and as a thought experiment. For each of these activities / modes, we have compiled effectiveness data and ease of use information. In the third and final phase of this work, we are about to begin sharing all modalities of these activities as downloadable packets/online assignments through the AIChE Concept Warehouse. This final phase of the project focuses on tracking faculty adoption and the factors (effectiveness, ease) that impact their adoption.

We invite instructors teaching heat transfer to log in to the Concept Warehouse and use the activities for free in class and let us know what you think of them.

Background

Our earlier work focused on repairing students' misconceptions about key areas in heat transfer by the use of inquiry-based activities in the form of short hands on activities [1; 2]. These misconceptions were widespread and resistant to change through traditional lecture and homework [3]. Each activity started with a student prediction, was followed by an experiment or simulation that often upset that prediction, and concluded with a reflection. These activities were successful in improving students' understanding [4].

Because the activities each require 10-20minutes of class or lab time, and some common equipment for each student group, few institutions were able to implement the activities as written. Feedback from initial tests at eight institutions indicated that class time, available space, class size, and expense of equipment were all factors hindering faculty adoption.

This final portion of our work seeks to answer two questions for engineering education. First, how is educational effectiveness of our activities changed by delivery mode? And second, how do faculty balance effectiveness and ease of use when selecting educational tools for their courses? We hypothesize that by changing the activities to address these problems, we could increase faculty adoption, and that faculty will be willing to accept some decrease in effectiveness in return for greater usability.

This work focuses on two specific heat transfer misconceptions. Student's misconceptions about "radiation" stem from the assumption that surface color is the most important factor in radiative heat transfer. Student's misconceptions of "rate vs. amount" are based on the assumption that factors which increase the rate of heat transfer ultimately lead to more energy transferred and vice versa. In phase one, we revised the two "radiation" activities and the two "rate vs. amount" activities into each of the four delivery modes, for a total of five versions of each of the four activities. Delivery modes are: student experiment (original approach), faculty demonstration, student simulation, faculty demonstration of simulation, and thought experiment. The modes are largely self-explanatory – in all "student" approaches, students conduct the experiment or simulation themselves, while in the "demonstration" modes, instructors conduct the experiment or simulation. Thought experiments start with a prediction and end with a reflection, but in the middle feature the instructor talking students through imagining the experiment. In phase two, we ran small-scale tests of each activity in each mode. In the final, ongoing, phase, we are making all of these teaching materials available through the AIChE Concept Warehouse [(5)], along with data representing the effectiveness of each mode and the amount of effort required to enact each mode.

Methods

Four instructors of Heat Transfer at four different institutions participated in the second phase of this work. A heat transfer concept inventory (HECI [(3)]) was used to assess change in student conceptual understanding of the "radiation" and "rate vs. amount" concepts. The concept inventory was given to students within the first and last two weeks of the course, with the activities occurring sometime in between. Faculty were surveyed to determine their perceptions of the activity and also the effort required to implement that activity.

Table 1 describes the activities overall (for more detail, please see [(4)]). For more detail on how each mode of each activity is implemented, please see "Hands-on, Screens-on, and Brains-on Activities for Important Concepts in Heat Transfer" in the Chemical Engineering Division, ASEE 2016.

Table 1: Activity Overview

Concept Area	Description
Radiation	Steam Pipe: Steam condenses in a bare metal pipe, and pipes painted black and white; students predict then observe the rate of liquid water accumulation.
Radiation	Sun Lamp: Both heating and cooling curves are predicted and observed for bare copper tubing, and white and black painted tubing, heated by a lamp or allowed to cool on a lab bench.
Rate vs. Amount	Snowball: Students predict/ observe both the rate of cooling and final temperature of cups of water cooled by either a "snowball" or chipped ice of equal mass.
Rate vs. Amount	Melting Ice: Students predict/observe how much ice can be melted by heated metal blocks, they control the number, size, and thermal properties of the metal blocks. This is only available as a simulation.

Results and Discussion

Effectiveness of each mode is defined as the fractional improvement of student's HECI scores in the relevant concept area. Table 2 summarizes concept inventory results compiled to date. As has been previously published [(6)(3)(4)], students who perform the activity in the "student performed experiment" mode improve significantly relative to students enrolled in heat transfer courses where no activities are performed. Prior work on preliminary data in the "thought experiment" mode suggests that in the case of Rate vs. Amount, students perform similarly to the courses where no activities were performed, but for Radiation, students demonstrate significant gains [(7)].

Table 2: Concept Inventory Scores on relevant sub-tests for two interventions and control. Data from [6], (Prince et al.,2012b) and [7]. Table adapted from [8].

	Rate vs. Amount, Student performed experiment n=463	Rate vs. Amount, Thought experiment n= 37	Rate vs. Amount, no intervention ("control") n=373	Radiation, Student performed experiment n=463	Radiation, Thought experiment n=37	Radiation, no intervention ("control") n= 373
Pre-	33.5%	42.5%	36.9%	40.9%	45.4%	44.4%
Post-	62.9%	50.0%	42.6%	63.0%	68.2%	49.5%

For ease of use, a variety of measures were applied. Our metric for overall ease of use is based upon instructor preparation time, and is shown in Table 3 below. For faculty who would like to base their decision on student time or cost, those data are also available at the AIChE Concept Warehouse.

Table 3: Ease of Use. Low effort = less than 15 minutes prep time; Moderate effort = about 30min prep time; Higher effort = an hour or more of prep time

Topic and Experiment or Simulation	Student action	Faculty action
Steam Pipe, experiment	Higher effort	Higher effort
Steam Pipe, simulation	Low effort	Low effort
Sun Lamp, experiment	Moderate effort	Moderate effort
Sun Lamp, simulation	Low effort	Low effort
Snowball, experiment	Higher effort	Moderate effort
Snowball, simulation	Low effort	Low effort
Melting Ice, simulation	Low effort	Low effort

The activities, in each of their modes, will be published on the AIChE Concept Warehouse by the end of the Spring semester in 2016.

We consider January 2016 as the "zero" point for faculty adoption, because the only faculty to use these activities in their current forms are those paid to participate in this test. Going forward, we will track downloads of each activity to assess which of these is the most popular, and survey those who are using the activities to learn why they picked the mode they picked.

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