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Hands-on, Screens-on, and Brains-on Activities for Important Concepts in Heat Transfer

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Dr. Michael Prince is a professor of chemical engineering at Bucknell University and co-director of the National Effective Teaching Institute. His research examines a range of engineering education topics, including how to assess and repair student misconceptions and how to increase the adoption of research-based instructional strategies by college instructors and corporate trainers. He is actively engaged in presenting workshops on instructional design to both academic and corporate instructors.

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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.

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Abstract
We have created analogous versions of our inquiry-based activities for misconception repair in heat transfer to ease faculty adoption into just about any type of instructional situation. Activities now work as laboratory experiments, in-class demonstrations, collaborative studio sessions, or simulations that can be assigned as homework. In our paper, we discuss each of these modes in detail and how they may be accessed through the AIChE Concept Warehouse. We also have measured the impact of each of these modes on the conceptual understanding of students; we know from previous work that student-conducted experiments are effective at repairing misconceptions. In our presentation, we will share the effectiveness of the alternate modes of presentation, as well as data on how easy these new modes are for faculty and students to use. We invite everyone who is teaching a heat transfer course or another course where ideas about radiation heat transfer, or factors influencing the rate and amount of heat transfer, to access these activities and freely use them in class.

Background
Engineering students encounter a number of challenging concepts throughout their studies. For some of these key concepts, many students hold preconceptions that inaccurately describe the physical world; for example, many people believe a tile floor is actually at a lower temperature than a carpet that is in the same room, because their experience tells them that a tile floor "feels colder" to bare feet (Prince et al., 2012b). Prior work indicates that a good way to overcome these misconceptions is through the use of inquiry-based activities (IBAs). For example, students who take a typical heat transfer course increase from a Heat and Energy Concept Inventory (HECI) score of 49.2% to one of 54.5% by the end of the course (Prince et al., 2012b), while those that use a collection of eight IBAs based on those concepts improve to a score of 66.3% (Prince et al., 2012a). IBAs involve small experiments that usually contain discrepant events – what really happens in an experiment is not what students with a misconception would predict. In the example just cited, students could measure the surface temperature of a number of materials and observe that they are identical.

Our previous work found IBAs based on such experiments to be effective. However, many chemical engineering courses covering heat transfer concepts do not have an associated laboratory section, making IBA implementation challenging. In the absence of a lab section, it might be easier to run an IBA as a demonstration – however, we didn't know if that implementation would maintain the effectiveness of the original student-run experiments. In this work, we sought to do three things. First, to re-write the activities into versions that would be easier for faculty to implement. Second, to test those versions to assess their educational effectiveness and ease of use. Finally, we are releasing all of these versions to the community for adoption through the AIChE Concept Warehouse.

Activities and Implementations

The goal in activity re-design was to capture the essential elements of each inquiry-based activity while allowing instructors maximum freedom for implementation. Every inquiry-based activity (IBA) starts with a description of a physical situation, and then a request for students to predict what will happen in that situation. Then, in our original implementation, students perform that exact experiment and observe the actual outcome directly. Finally, students answer a series of reflection questions that ask them to engage with their original ideas and revise them based upon what happened. The situations are specifically chosen to be those where students often hold misconceptions that lead them to predict incorrectly. Table 1 below describes the experimental situation at the core of each of the four activities.

Table 1: Activity Overview

Concept Area	Description
Radiation	Steam Pipe: Steam condenses in a polished metal pipe, and pipes painted black and white; students predict then observe the rate of liquid water accumulation, which is proportional to energy loss through radiation.
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	Cooling Beverage: 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.

As an example, when presented with the situation predicted in the Cooling Beverage activity, students often correctly predict that the chipped ice cools the drink more rapidly, but then incorrectly predict that the chipped ice will cool the drink to a lower final temperature (actually, both the chipped ice and snowball result in the same final temperature). Originally, the IBA was created with an experiment as the central activity. As this activity only requires a scale, water, ice, foam cups, and two thermometers or thermocouples, it can be done without significant investment of space or equipment, the addition of data logging software and computer display is a nice but optional feature. Even so, it is challenging to do with a large class or even a small one without access to lab space or tables or sufficient thermometers. Instructional time can also be an issue; this is rapid for an experiment, but would take ~1/4 of a standard class period. Feedback from faculty at a variety of institutions indicated that it would be helpful if it was possible to do the activities in ways that required a combination of: less equipment, less class time, and/or less setup time.

Table 2 shows the approach to varying each of the activities. In each case, the first step (written prediction) and final step (written reflection) remain the same. The central activity is changed to address the spectrum of faculty concerns. For example, the lower left option, instructor demonstration, requires class or lab time, but requires only one set of equipment and minimal setup time. In the center column, having students run a simulation requires no lab equipment and no setup time, but does require student access to computers. The far-right option, thought experiment, requires no equipment and no computers and is optimized for use in a studio or problem session where student groups are working semi-independently on problems.

Table 2: Five Activity Modes

<table>
<tr><th></th><th>Physical Activity</th><th>Simulated Activity</th><th>Thought Experiment</th></tr>
<tr><td>Student as active agent</td><td>Student Experiment (original implementation)</td><td>Student Simulation (can be homework)</td><td rowspan="2">Instructor presentation with student studio work</td></tr>
<tr><td>Instructor as active agent</td><td>Instructor Demonstration</td><td>Instructor Demonstration of Simulation</td></tr>
</table>

Continuing the example of the Cooling Beverage activity, Figure 1 shows what this looks like when performed as a physical experiment. This can be done either by students in small groups or by the instructor as a demonstration (for which we recommend projecting at least the temperature profiles to the class).

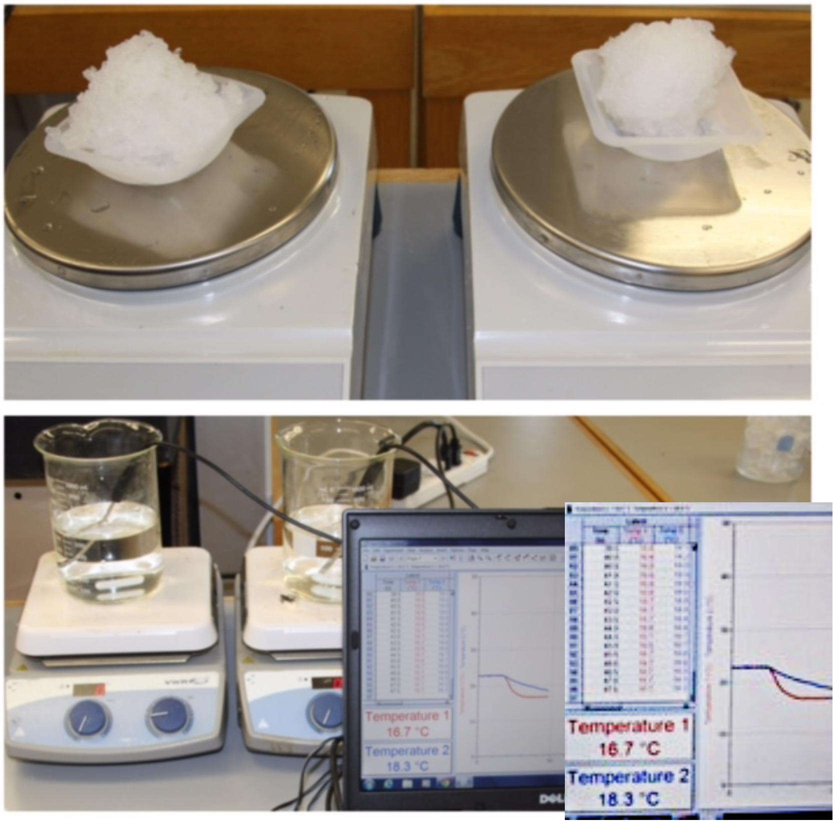


Figure 1: Physical Experiment for Cooling Beverage activity.
Top: On the left, the chipped ice, on the right, the "snowball" formed from compressing the ice.

Bottom: Experiment in progress after ice was placed in equal-masses of room temperature water; Inset shows computer screen where chipped ice has cooled faster but both cups are headed to same temperature.

Figure 2 shows the simulation version of the Cooling Beverage activity. The simulation is implemented in javascript and may be freely accessed and run on any computer, tablet, or smartphone connected to the Internet with an appropriate web browser. The simulation affords numerous repeat "experiments" that are too time consuming to do with the physical situation; for example, the impact of the shape of the "snowball" may be explored.

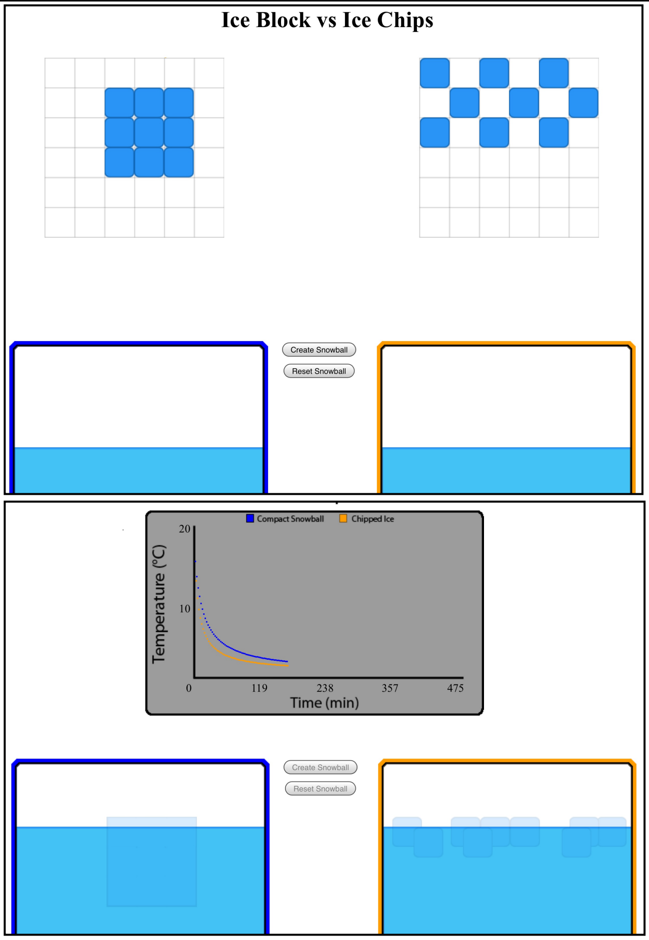


Figure 2: Simulation of Cooling Beverage activity.
Top: Forming equal masses of "snowball" and ice chips.
Bottom: Experiment in progress, chipped ice has cooled more rapidly, but both are reaching the same temperature.

Figure 3 shows parts of the Thought Experiment version of the activity. This may be implemented through a combination of instructor presentation and student writing or could even be done by students in a self-directed manner if instructed not to peek at the answer ahead of time.

Experiment 1

Ice Block vs. Crushed Ice

Objective: Investigate the cooling of a beverage by comparing crushed ice to cubed ice.

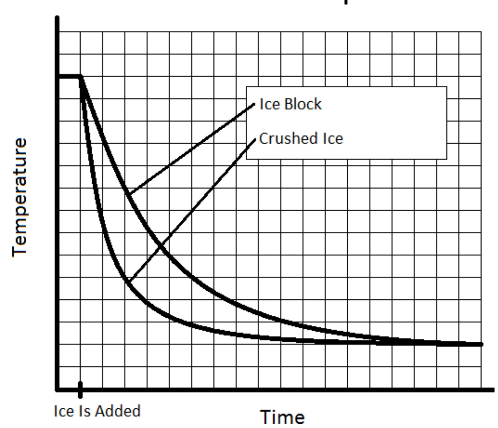
- Consider both the *rate* of cooling (i.e., how fast it cools) and the *amount* of cooling, as indicated by the final temperature.

Materials:

- beverage (mostly water) at room temperature
- crushed ice
- cubed ice
- thermometers
- stirrers
- stopwatches

Experiment 1

Ice Block vs. Crushed Ice: Temperature vs. Time



How do your predictions compare with these data?

Figure 3: Thought Experiment for Cooling Beverage Activity

Top: Setup slide from instructor presentation, describing the situation the students are to imagine.

Bottom: Reveal slide from instructor presentation, shown after students have both predicted and thought about the situation.

A natural question to ask of these revised activities is if they attain their desired objectives? To what extent are they more usable for instructors, and what is their impact on student learning? Some data are available from the original testing of these activities as physical experiments conducted by students. To establish baseline effectiveness of the newer activities, each of these variations was tested in Heat Transfer one or two instances of heat transfer courses at one of four universities in the 2013-14 and 2014-15 school year. Educational effectiveness was measured with a pre-/post- administration of the Heat Transfer Concept Inventory (Prince et al., 2010).

Table 3: HECI sub-test scores for IBAs as student-performed physical experiments, thought experiments, and no intervention. From (Prince et al., 2012a), (Prince et al.,2012b) and (Koretsky et al., 2015).

	Rate vs. Amount, Experiment N=463	Rate vs. Amount, Thought Experiment N= 37	Rate vs. Amount, no intervention N=373	Radiation, Experiment N=463	Radiation, Thought Experiment N=37	Radiation, no intervention 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%

Table 3 summarizes some of the results on the effectiveness of these IBAs. In every case, students experience a significant improvement from pre- to post-, indicating that normal instruction does result in some improvement in these areas. However, the improvement is greater when IBAs are used. From prior work (Prince et al., 2012a), we know students experience significant improvements in conceptual understanding when they perform the IBAs themselves in small groups ("Experiment" in Table 3). We also know that thought experiments result in significant, but smaller, improvements in understanding (Koretsky et al., 2015). For the simulations and demonstrations, results are still pending, but will be shared both in the presentation and on the AIChE Concept Warehouse.

Implementation in the AIChE Concept Warehouse

All five versions of each of the four IBAs in Table 1 are available through the AIChE Concept Warehouse (https://jimi.cbee.oregonstate.edu/concept_warehouse/) (Koretsky et al., 2014). All materials are available and organized through the "Instructional Tools" tab. An advantage to using the Concept Warehouse to implement any of these activities is that they may be assigned and results collected directly through the website – both the student prediction and the student reflection may be completed online through the warehouse, as is also the case for the simulations and the concept inventory itself. PDF versions of all materials are also available for off-line implementation of activities.

It can be a little overwhelming to have so many varieties of educational intervention to work with, so the Concept Warehouse provides easy-to-digest ratings of both how effective and how easy to use each IBA is, so you may select the version best suited to your situation. As seen in Figure 4, there is a summary word/color speaking to both ease of use and effectiveness. If you mouse over the word, you get the more in-depth description of what that brief term means. If you are teaching heat transfer concepts in your course, we recommend you implement both activities for a given concept for maximum educational benefit.

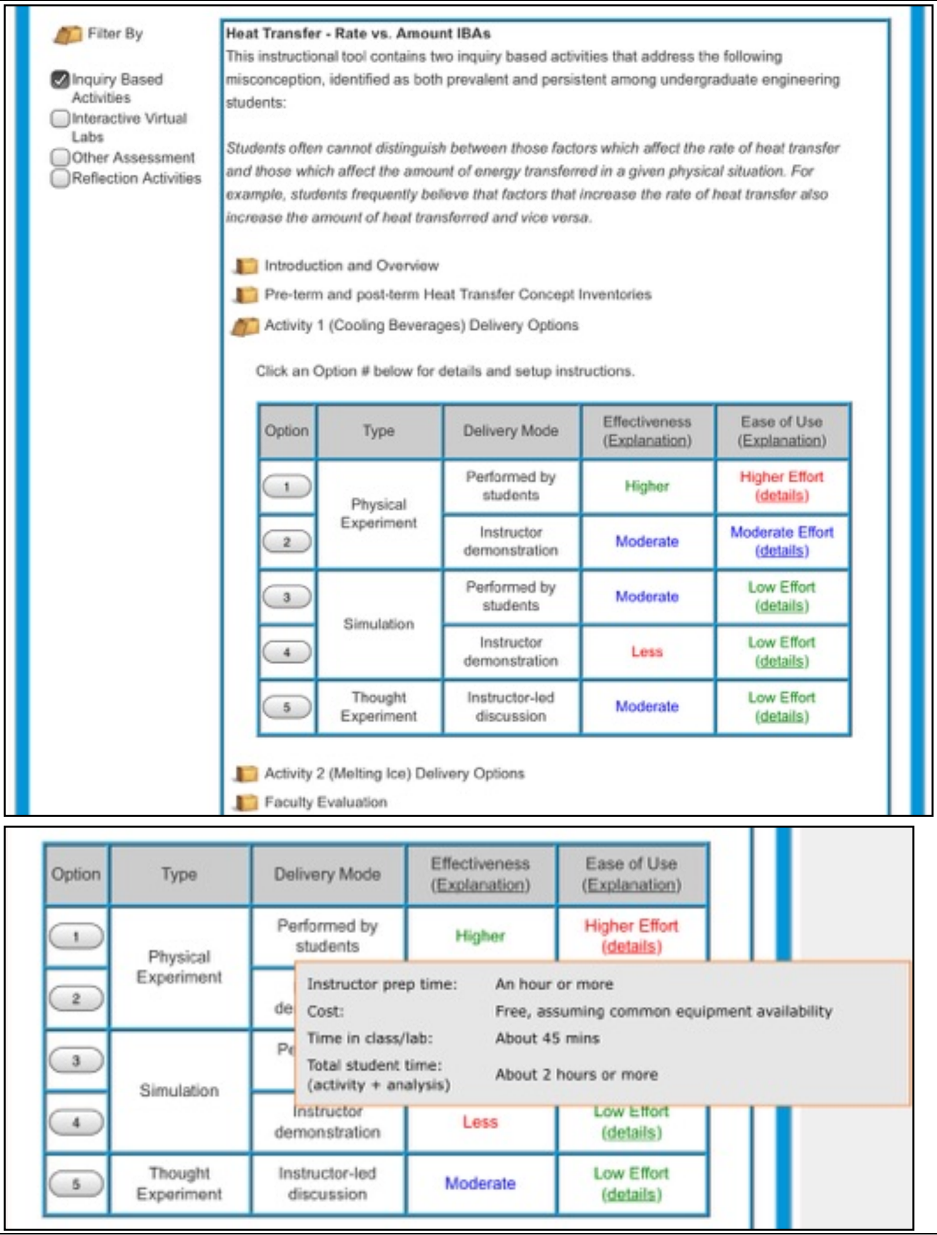


Figure 4: Screen shots from Concept Warehouse.
Top: Overview of Cooling Beverage IBA page.

Bottom: Zoom on table, showing pop-up from "Higher Effort."

Note – Effectiveness rankings shown here are placeholders

We are curious about the extent to which ease of use and educational effectiveness impact which version of these activities faculty choose to use. We will be tracking this through downloads from the Concept Warehouse, where any faculty member can sign up and access the materials for free.

Acknowledgement

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References

Koretsky, M, Falconer, J, L., Brooks, BJ, Gilbuena, D, 2014, "The AIChE Concept Warehouse: A Tool to Promote Conceptual Learning" *Advances in engineering education* **4**(1)

Koretsky, M, S Mihelic, M Prince, M Vigeant, K Nottis, 2015, "Comparing pedagogical strategies for inquiry-based learning tasks in a flipped classroom", paper presented at American Society for Engineering Education Seattle, WA, https://peer.asee.org/comparing-pedagogical-strategies-for-inquiry-based-learning-tasks-in-a-flipped-classroom

Prince, M, M Vigeant, K Nottis, 2012a, "Using inquiry-based activities to repair student misconceptions related to heat, energy, and temperature", paper presented at Frontiers in Education

Prince, M, Vigeant, M, Nottis, K, 2010, "Assessing misconceptions of undergraduate engineering students in the thermal sciences" *International Journal of Engineering Education* **26**(4) 880–890

Prince, M, Vigeant, M, Nottis, K, 2012b, "Assessing the prevalence and persistence of engineering students' misconceptions in heat transfer" *Journal of Engineering Education* **101**(3) 412–438