AC 2007-1189: SOAP CASTING MATERIALS EDUCATION ACTIVITY

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Soap Casting Materials Education Activity

Abstract

This research originated from the principal author’s interest in casting process and an interest in materials education. A recent National Science Foundation ‘Advanced Technology Education Center’ in Materials Education (MatEd) has created a materials concept inventory (including heat transfer and phase changes), and requested activities to support these concepts. Fortuitously, Central Washington University offers an annual ACES (Aerospace, Construction, Engineering and Safety) summer weekend camp for girls. So an activity involving soap casting was developed and taught at the 2006 camp. The activity was supported by the NSF (MatEd) Program and was documented for use in their resource database.

An attractive feature of making soap is the use of glitter, colors and other additives resulting in a product the students take home. The activities’ engineering content involves tracking time and temperature during solidification. Students were asked to predict the relationship of temperature vs. inverse time before starting to cast. After making soap the student data was plotted, results were discussed and soap was compared.

In consultation with the Central Washington University Human Subjects Review Committee, assessment questions were delivered to the group verbally, and responses were privately recorded by the instructors. Students unanimously indicated that the relationship (T vs. 1/t) ought to be a ‘curve’. Results showed the linear relationship. Post-activity assessment showed a complete reversal from the student’s earlier prediction to support the linear relationship. Student comments indicated support for this activity as having an ‘engineering’ component as opposed to other just ‘fun’ camp activities.

Introduction

This effort is directed at creating a meaningful engineering activity for middle school girls. The vehicle used for presentation was an established summer academy hosted by the university. As part of a continuing education and recruiting effort, the ACES Academy (Aviation, Construction, Engineering, & Safety) has been annual summer event at Central Washington University (CWU) starting in 2003. It is a long weekend event hosting a few dozen girls from around the state. The Academy, its mission, and a description of activities were previously presented at the ASEE 2005 Annual Conference.

Another motivation for the effort was to generate data to support a National Science Foundation (NSF) grant directed at creating an Advanced Technology Education (ATE) Center in Materials Technology Education: the MatEd Program (MatEd). Most NSF ATE Centers are ‘portals’: websites that redirect inquiries to other hosts (where the education activity information is retained). The principal author is a ‘Technical Partner’ on the MatEd Program and is concerned that primary education information be stored on and made available at the ATE website. An example of a portal is Merlot, as opposed to primary education information available at the NDE.
site hosted by Ames Iowa. Thus, the education activity information for this effort supports the
mission of MatEd, and is planned to be stored and hosted at the future MatEd ATE website.

Soap Casting:

Casting is a solidification process. The principal author is a Key Professor with the Foundry
Educational Foundation, and administers a Cast Metals Industrial Technology Program at the
University. Casting is also a knowledge that is of interest to the NSF MatEd program. One of
the initial accomplishments of MatEd was to inventory related knowledge, concepts and skills
related to materials technology. The resulting document by Mott included Solidification as part
of ‘Physical Science Skills’ and ‘Apply Concepts of Heat’, with a numerical designation of
6.010. This research effort was propelled by the coincidence of the principal author’s interest in
casting, the secondary author’s interest in ACES activities, and the connection with MatED.

Identifying a concept for an ACES activity led to the logical question of what specific casting
process would be appropriate at CWU. The department has a foundry, so metals could be cast.
In fact, demonstrations and activities with middle school students are done on a regular basis.
But there are also a number of other possibilities, such as food (candy, chocolate, gelatin, etc.)
and products (seals, soap, etc.). It can also be instructive to list materials. At ‘cooking’
temperatures (for easier and safer class operations), some materials are wax and soap. Soap was
chosen when the last criterion was considered: ‘girl-appeal’. From our discussions glitter was
favored, and it could be put in soap. At this point, an activity was created.

Class Content: There was a search for a significant engineering concept related to solidification.
The search started with defining and quantifying the process. If the process is done in a fluid (air
or water), then convection is prominent and can be described in the equation below:

\[ q=\frac{Q}{t}=A*h*\Delta T \]

where:  
- q is the heat flow rate (amount of heat per time) 
- Q is the amount of heat 
- t is time 
- A is the area of contact between the two objects (cast material and cast mold) 
- h is the ‘film coefficient’ (related to the interface of cast and mold) 
- and T is the Temperature (\( \Delta T \) is the change in temperature)

Once the cast material (soap) and molds were chosen, the film coefficient and area is set. The
available heat is also set by the melt temperature. The only variables we can address are Time
and Temperature. But that brings up a question: how do Time and Temperature relate? If we
change the temperature of the mold (via the bath), how will that affect the amount of time it takes
to solidify? Will it be linear? Will it be a curve? This would be the question asked of the
students, aided by a graphic (shown below).
Class Pedagogy: Constraints with the activity included a capacity target of 12 girls in the session, with hands-on activities of three to four girls. The activity would be done in an hour. Resources included room use in the engineering technology building and whatever equipment and consumables brought on-site. A lab/classroom was available that included a large (4’x4’) water table. Since no student ‘learning-style’ data was available, it was decided to use multiple teaching-style pedagogy. First, students would listen to concept information lecture style. Then a discussion, with the concept question posed. Following this was the activity and a final discussion.

Documentation: An ‘Activity Sheet’ was created (Appendix A) that contained four types of information: safety, content, scheduling, and assessment. The sheet is formatted by time, starting with five minutes of introductions followed by 10 minutes of background. An oral concept inventory is done to determine math capabilities and some physics of heat transfer. Then a description of the activity is presented, with the above quantification, followed by the Key Query (T vs. t: linear or curve?). The activity is performed over the next half hour, starting with a safety briefing. The last fifteen minutes is a collection of data and group discussion centered about the Key Query.

A student ‘Soap Casting Procedure’ sheet starts with safety information, and then describes a step-by-step procedure for the soap casting process.

A resource ‘Inventory’ was tracked and documented for both cost and source. Appendix B shows this as well as set-up information. This was not an exhaustive process, but details a viable route to support the activity. This first activity cost about $200. Most of that was the cost of the glycerin soap. This type of soap is available at many local craft stores, but has a wide price range.

Feedback was sought from both students and instructors. The university Human Subjects Review Committee supported a group, oral interaction. Thus the instructors recorded student
responses during the activity. The instructors also pooled group data for the Temperature vs. inverse delta time curves. Finally, the instructors reflected on other aspects of the activity.

NSF MatEd: The MatEd Program requested activities to support their concept inventory. So they were supplied with the activity documents. The MatEd Program is in the process of creating a resource database, including activity descriptions, forms, instructions, etc. Since MatEd did not have a set format for activity information, all the Soap Casting activity documents were submitted. Then specific information may be integrated their database.

Appendix A (embedded):
SOAP CASTING ACTIVITY SHEET AND SCHEDULE

Date:________

0:00-0:05 Introductions: Instructor, Students, Others

Instr:________

0:05-0:15 Background, Concept Inventory, Soap Casting Process
Background: Q: How many of you have had geometry? _____ of _____
Background: Q: How many of you have had algebra? _______.
Concept: Q: Consider cooling soap in water baths of different temperatures. If you think the soap cools faster in colder or hotter water, thumb down or up (VOTE______)
Concept: Q: Would you consider the mold surfaces rough (fist) or smooth (open hand)?

Description of Soap Casting: We have soap right here in the hot-pot! All we have to do is mix in any additives (color, fragrance, etc.), pour it into molds, and then cool them! Our task is to quantify the process. Does the cooling bath temperature really make a difference? How much? Let’s find out by using different cooling bath temperatures and measuring the time it takes to cast the soap bars.

Instructor: Convective heat transfer is: q=Q/t=A*h*ΔT where ‘h’ is film coefficient.
Concept: Instructor – draw a Temp vs. Time plot with a 45 degree line, and a parabola.
Q: Consider our three cooling temperatures. The points may make a line or a curve. If you think our cooling trend will be a line or a curve raise open or cupped hand. _____
Instructor: Plot T vs. (1/t) to get slope of Q/Ah

0:15-0:45 Safety Briefing: The hot liquid soap can burn your hands, so take care!
Form teams of three students. Each team has a mixing cup and three molds. Use the ladle and pour some soap into your mixing cup. After additives are mixed in, pour into the molds. Place the mold into a bath and record both temps. and the time (and repeat).

Pour Temp:_____ Time:_____ Solid Temp:_____ Time:____
Temp:_____ Time:_____ Temp:_____ Time:____
Temp:_____ Time:_____ Temp:_____ Time:_____ To determine a casting time, periodically poke the bars. When they are solid enough to pop out of the mold, again record the time & temp difference. Plot all results to the board.

0:45-0:55 De-briefing
The data shown on the board is temperature (any unit) and time (sec). It turns out that heat is transferred by different methods: conduction (touching), convection (blowing), and radiation (shining). Heat flow rate depends on the difference in temperature with conduction & convection, q/t~ΔT, but with radiation it’s, q/t~T^4.
Concept Q: If you make ΔT bigger, will the cooling rate be bigger or smaller, (raise your thumb up or down)? _____
Concept Q: Since q/t=Area*h*ΔT, is ‘h’ (the film coefficient) for air-cooled vs. water-cooled molds (at same temps), higher or lower (raise your thumb up or down)? _____
Concept: Q: Is the surface of your soap smooth or rough (raise open hand or fist)? Why?

0:55-1:00 Farewell! Enjoy your soap and have fun.
Appendix B (embedded):

RESOURCES AND SET-UP

ACQUIRE:

Human Resources:
One Instructor (preferably two).
Four groups of three students (twelve total).

Infrastructure:
Water bath trays (positioned to access taps and drain)

Equipment:
12 molds (three for each group)
(12) bath trays with connection to water taps (4-hot, 4-cold, 4-ice) or three large baths
25# glycerin soap (with suspension)
Color dyes, Glitter, and other cool additives
(4) infrared thermometers
A chalkboard, whiteboard, or computer-projector

SET-UP:

WEEKS AHEAD: Schedule a classroom/lab and get help.
At least two (eight taps is best) sinks are needed (one for a hot bath, one for a cold bath)
Ice cubes can be made or bought for the ice bath.
The eight bath trays can be set out and water started. As long as there is a trickle of water flowing off the tray, the
flow is sufficient to heat/cool the molds.

Order Consumables:
Most supplies are available via internet.
www.chemistrystore.com June 28, 2006
Item 32025 25# Suspension Melt & Pour Glycerin Soap $37.25
Item 75202 Glitter (various) 1oz $2.99 each
www.candylandcraft.com June 28, 2006
Item AO-107 Mold Squares, 6 in a tray, $1.99 each.

DAYS AHEAD: Visit the class room. Plan the bath tray lay-out. Put supports in the trays to keep the molds
surrounded by water. Make sure the thermometers work.

AN HOUR BEFORE: Turn on the hot-pot and melt the soap. Lay out your ladle, mixing cups, additives, etc. Make
sure you have a board that is usable (for plotting). Get your ‘Activity Sheet’ ready so you can fill in the blanks.

EVENT TIME! Enjoy the fun.

Casting Soap:

Two authors were instructors for this activity. All three authors worked concurrently to develop
the activity, though only the instructors were at the ACES Academy. Documentation and
procedures were developed to utilize the resources available. Within two months of the event,
the basic materials list was finalized and sources determined. Many supplies were acquired via
internet due to lower costs and an associated flexibility of higher quantities. Some materials,
such as the hot-pot, were acquired locally, and others were donated (e.g. coffee cups from an
ACES sponsor). Figure 2 shows the basic items, while Figure 3 shows a casting being poured.
Figure 2: Basic soap casting equipment: hot-pot, ladle, cups, molds bath tray, etc.

Figure 3: Soap being cast in a mold.

The Thermo/Fluids lab (Hogue Technology Room 215) was determined suitable and featured a large water bath. Molds would cool efficiently in the large bath. Temperature probes were available, as well as other basic needs such as a sink, towels, and clean-up supplies.

A dry run was done within a week of the event. Wooden stir sticks were determined appropriate to mix the glitter. Light weight plastic molds (gelatin molds) offered a minimum barrier to heat transfer, and would float easily in the bath.

Equipment was taken to the site a day prior to the event. And before the Friday afternoon session, handouts were readied and the freezer filled with bags of ice. A coffee pot was used for the hot bath, and tap water used for the third temperature.

**Results and Discussion:**

The first session was comprised of 10 girls. The activity progressed slower than the schedule. Not all of the groups were able to get data for all three temperatures. Since the data was pooled at the end, the activity was not compromised. A sample picture of the girls around the water bath is shown below:
The second and third sessions (on follow days) were of 12 and 11 girls. Each group of girls had a procedure handout, and data was recorded on those sheets. Temperature was obtained with thermocouples. The hot-pot temperature did change throughout the session due to adding more soap at intervals. The baths also changed due to influxes of hot water or changes in tap water. But the inverse temperature spreads were calculated and times collected with stopwatches (e.g. cell phones). At the end of each session, the data was pooled and plotted on the front board as shown below:

Assessment of, and student feedback on this activity was planned through four concept questions. These questions reflect inquiries into an appropriate concept, and are inspired by the work of
The questions can be delivered easily in different modes (verbal, in this case), and provide a quick assessment as shown below:

<table>
<thead>
<tr>
<th>Question</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think the soap cools faster in colder or hotter water? (Show with your thumb down or up)</td>
<td>Up (colder): 10 of 10</td>
<td>Up (colder): 12 of 12</td>
<td>Up (colder): 11 of 11</td>
</tr>
<tr>
<td>Would you consider the mold surfaces rough (show your fist) or smooth (open hand)?</td>
<td>Smooth (open): 10 of 10</td>
<td>Smooth (open): 12 of 12</td>
<td>Smooth (open): 11 of 11</td>
</tr>
<tr>
<td>Do you think our cooling trend (T vs 1/t) will be a line or curve (raise your open or cupped hand)</td>
<td>Curve relation: 10 of 10</td>
<td>Curve relation: 12 of 12</td>
<td>Curve trend: 11 of 11</td>
</tr>
<tr>
<td>If you make ΔT bigger, will the cooling rate be bigger or smaller, (raise your thumb up or down)?</td>
<td>Bigger rate, up 10 of 10</td>
<td>Bigger rate, 12 of 12</td>
<td>Bigger rate, up 11 of 11</td>
</tr>
<tr>
<td>Is the surface of your soap smooth or rough (raise open hand or fist)? Why</td>
<td>Smooth (open): 10 of 10</td>
<td>Smooth (open): 12 of 12</td>
<td>Smooth (open): 11 of 11</td>
</tr>
</tbody>
</table>

Table 1: Assessment data showing concept questions and responses.

First, you may notice that all the responses were unanimous. The two instructors observed that the students did not depend on peer influence, so it appears to be valid. Also, some questions were more straight-forward than others. The first two questions were meant to be embracing, but the Key Question of ‘curve vs. line’ relation resulted in unanimous responses of ‘curved’. Even with the equation stated and the parameters explained, as well as the plot axes drawn; the students voted for the curve. It appears that the student’s skills in basic math are limited and insufficient to recognize the equation of a line. Of course, this made the resulting data quite interesting, as a line could be drawn through their data points. The girls were asked and convinced that the relationship was linear.

The reader may have noticed that one question was omitted (shown below). The instructors chose not to use it because they felt it was not clear enough. On reflection, a semicolon could be used after the equation (see the next row). Also, the scope of the effort was an issue, and this was a way to cut it back. This also prompted additional information for the MatEd deliverables. A list of questions and extensions to the activity were included to offer choices of depth and scope depending on the users needs.

Table 2: A concept question that was not used

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since q/t = Area * h * ΔT, is ‘h’ (the film coefficient) for air-cooled vs. water-cooled molds (at same temps), higher or lower (raise your thumb up or down)?</td>
<td></td>
</tr>
<tr>
<td>Since q/t = Area * h * ΔT; is ‘h’ (the film coefficient) for air-cooled vs. water-cooled molds (at same temps), higher or lower (raise your thumb up or down)?</td>
<td></td>
</tr>
</tbody>
</table>

Student comments were also received as a part of the ACES program survey. In general, at the end of the ACES weekend during the closing event, the ‘Engineering’ activities got the loudest applause. Specifically, comments such as, ‘they had real engineering’ were heard with regard to the Engineering (vs. the other discipline activities).
Future Issues

The MatEd Program requested the activity procedure information, but not feedback or other statistical data. Other NSF ATEs that are portals do indeed generate activity feedback data. This data is not directly germane to the activity content (student performance), but is user (instructor) driven. This brings up a valid issue regarding the worth of the activity. The authors believe that ‘concept inventory’ assessment is appropriate to evaluate these activities. Though some work has been accomplished in this area, the authors suggest that the NSF ATEs may wish to combine assessments with their resources.

The authors also perceive a need for standardized assessment tools. The ‘tools’ portion of that sentence reflects Central Washington University Human Subjects Review Committee protocols that are now a constraint of all activities. Professors of engineering are not commonly versed in assessment tools to the extent that may be required, so a standardized protocol and tool seems appropriate.

Conclusions

This research was successful in developing an activity directed at middle school girls, and delivering that information to the NSF MatEd program. The activity was delivered at a university summer weekend event, to three sessions (~12 girls each) and assessed. The concept questions were administered verbally in accordance with university human subjects review committee policy. Responses were unanimous for all five questions, but completely wrong regarding the trend prediction. The assessment process, and how it progressed, prompted the authors to envision standardized assessment processes. They also envision this assessment correlated to the ATE databases, so users could easily access and use them with education activities.

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Bibliography