The Science of Boat Design

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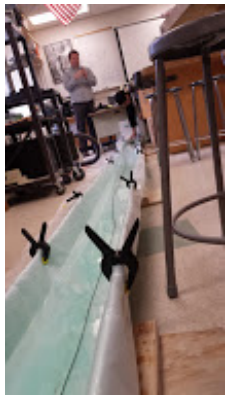
Can Engineering Be Fun?

- In this brief session we will:
  - Get our hands wet,
  - Build and tow some very small boats,
  - Learn about resistance, and
  - Learn how to make and use a small model tank.
- Small model tank projects provide:
  - Better understanding of how boats are designed;
  - Fun for any age level;
  - Experience collecting data and running experiments;
  - Stimulation of STEM interest; and
  - A bit of excitement.



Session Approach

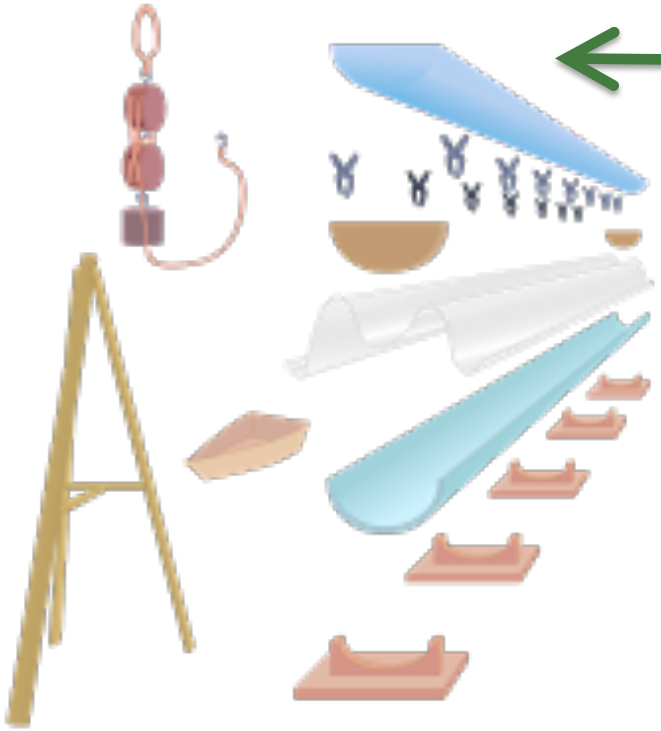
Goal: See and use a small tow tank that you can build yourself; obtain some reference materials to use; gain confidence to do similar projects with your students.

1. Orientation – hear some engineering background
2. Demonstration – run some tests
3. Model Construction – carve some foam boats
4. Project Ideas – discuss potential related activities
5. Wrap Up

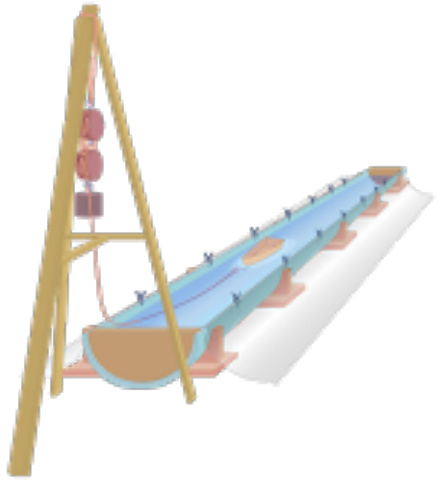
Orientation: Resistance Theory

- Don't worry, you do not need to be an expert.
- Boats resist motion through the water:
  - Friction Drag; as a function of surface area and speed
  - Wavemaking; as a function of size, shape, and speed
  - Some other factors we do not need to worry about!
- Tests on models can be "scaled up" to predict the resistance of larger boats or ships; to complicate life, friction and wavemaking scale differently.
- We can learn a great deal by observation without doing any scaling; for two boats of same weight but different shape, which goes faster when pulled by the same force?

Orientation: Test Apparatus



These parts go together like this:



The cost ranges between $500 and $800 but creativity with “found materials” can reduce the cost considerably; see materials list.

Orientation: Data Collection

- The general idea is to measure the time the model requires to travel a certain distance when pulled by a known force.
- Set-up data:
  - Describe the purpose of the test.
  - Describe the model being tested; Measure and record its mass (Model Name? Model Material? Dimensions? Mass?)
  - Describe the conditions (“It was a dark and stormy night . . .”)
  - Good practice would include type and temperature of the water.
  - Mark, measure, and record “start” and “finish” points for time measurement.
  - Describe the number of parts in the block & tackle ; measure and record the mass of the “falling weight.”
  - For extra credit you can measure the towing force if you have a suitable spring scale; any friction losses?

Orientation: Data Collection

- Test Data:
  - Have the students create a data table (or spreadsheet if you feel the urge to go digital; but, really, the manual method is just fine.)
  - The table should list the set-up data, test run, and the measured time(s).
    - If you have multiple students in the group you can have more than one student record times; then the students can average the recorded times (There is an important lesson here in accuracy and precision.)
    - For students that participate in swim teams, the methods used to record event times can be copied.
  - Plot the data AS YOU GO!

Orientation: Plots

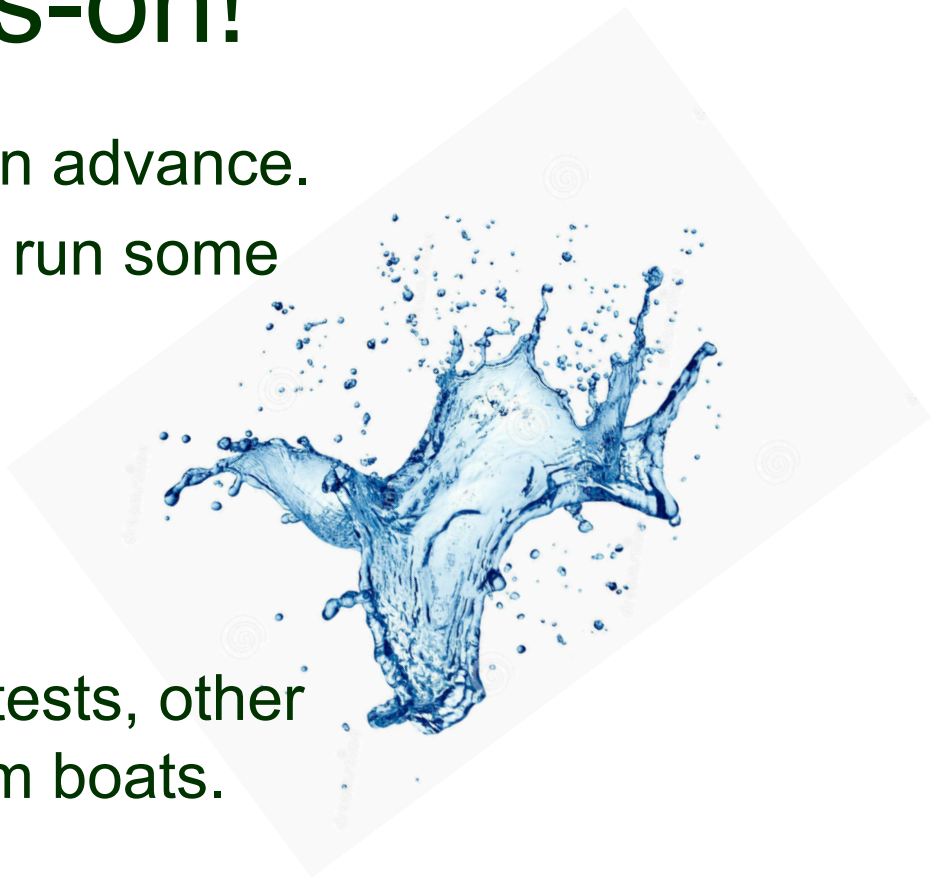
- Data Plots will vary depending on the test you are performing.
- When comparing a set of models, times can be plotted vertically with each model listed on the horizontal axis.
- If you vary the tow force and measure the time, plot one against the other.
  - Try plotting time vs. force and then force vs. time.
  - For extra credit, calculate boat speed (ft/sec) and plot tow force vs. speed. Discuss the shape of the curve.

Good things to discuss:

- How spread out are your data points for the same run? Why?
- Should any data points be thrown out? Was someone asleep at the switch?
- Remember that Tow Force is the force on the model not the mass of the falling weight.

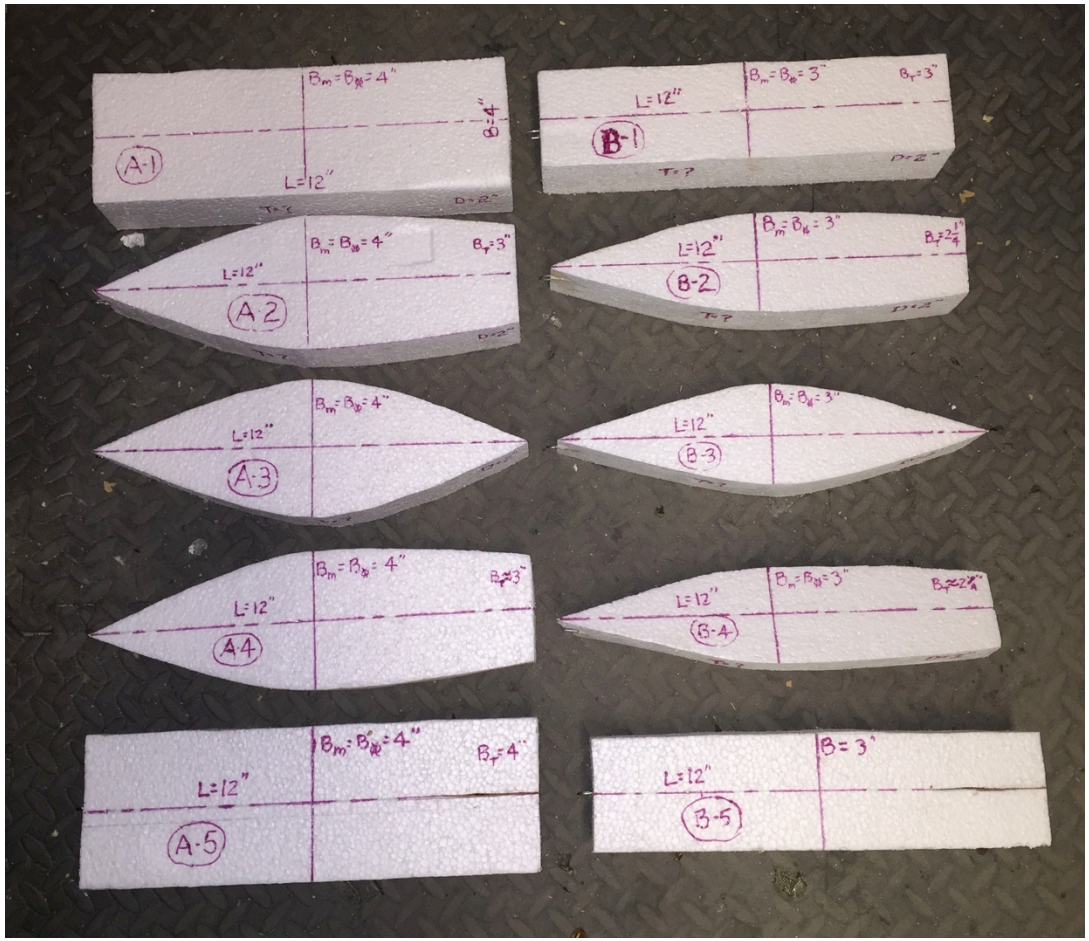
Hands-on!

- We have set up a test tank in advance.
- Let's get our hands wet and run some tests.



- While one group is running tests, other groups can make some foam boats.

Example Test Model Series



Target Displacement
~ 1lb

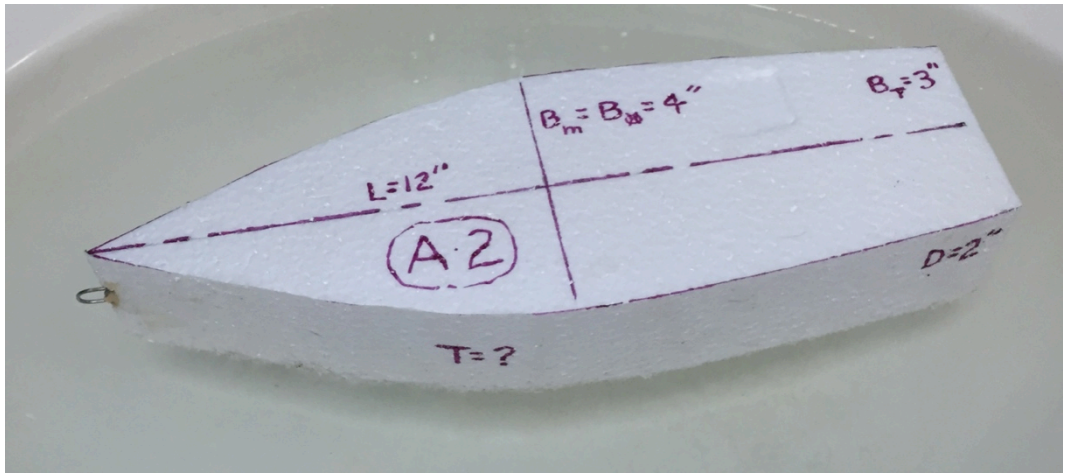
Comparative Tests
Varying Beam
Varying Waterplane Shape
Varying Prism

Have students design their own and compare.

Example Model Parameters

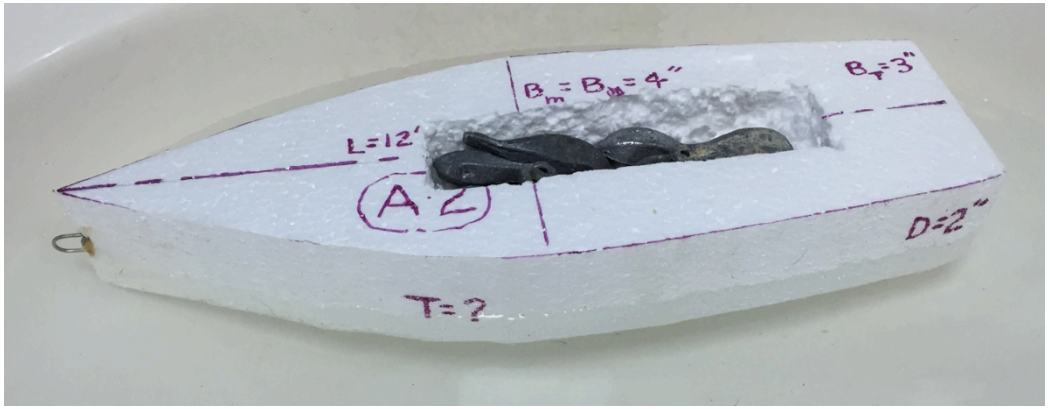
Model	Length	Beam	Depth	Draft?	Disp?	~Cb
A1	12”	4”	2”	TBD	TBD	1.00
A2	12”	4”	2”	TBD	TBD	0.79
A3	12”	4”	2”	TBD	TBD	0.66
A4	12”	4”	2”	TBD	TBD	~0.52
A5	12”	4”	2”	TBD	TBD	~0.88
B1	12”	3”	2”	TBD	TBD	1.00
B2	12”	3”	2”	TBD	TBD	0.79
B3	12”	3”	2”	TBD	TBD	0.66
B4	12”	3”	2”	TBD	TBD	~0.52
B5	12”	3”	2”	TBD	TBD	~0.88

Ballasting



Fishing Sinkers
Used as ballast;
Carve hold for the
ballast with knife.

Measure Displacement using digital postal or household scale.



Project Ideas

- Students can perform the following tests:
  - Using a set of models of similar mass, students can predict which will tow fastest (with same force), run the tests, gather data, and assess the results.
  - Vary the mass used to apply the towing force and measure how the tow times vary as a function of the tow force.
  - Using some foam or wood (depending on skill level and available tools) students can make their own boats, ballast them to a target displacement (using pennies, washers, or other standard objects), and see which boat performs best.
  - Using the student's foam boats (after testing!) they can be weighed on a postage scale, then cut at several station points to obtain section areas; the displacement can then be calculated using various techniques and compared with the mass measurements. (Talk about water density!)
  - A series of models can be constructed to test hypotheses about how resistance will vary.

Any Questions?

- Is the small scale a concern? *Boat resistance includes friction drag and wavemaking resistance. The drag of fins, rudders, and small parts of a boat may not be predicted accurately at small scale, but the proposed projects are not intended to produce accurate engineering results. Your projects should emphasize general concepts, experimental methods, data collection, observations, and thinking about the results.*
- Can we use a smaller pipe or different set-up? *You should use whatever materials are cost effective. 10" pipe has been used. 16" pipe is better but costs more. If you have scrap plywood you could build a box and make it watertight with plastic sheet in the same manner. A 2:1 block system is good but requires a taller mast. Be creative!*
- What is a good weight to use to provide towing force? *A hiking water bottle with a cap that has a loop is a suitable weight and the amount of water inside can be adjusted to suit the set-up.*

Any Questions?

- Do you recommend specific timing procedures?
  - The procedures used for Swim meets are reasonable.
  - The Northern Virginia Procedures are as follows:

d. The Head Lane Timer shall verify the name of the swimmer and shall determine the official time as follows: (1) If the times from two watches agree, that is the official time. (2) If all three watches disagree, the time of the intermediate watch is the official time. (3) If only two watch times are available, the official time is the average of those two watches. The digits representing thousandths of a second shall be dropped with no rounding.

  - http://mynvsl.com/documents?folder_id=20536
- As an alternative, all recorded times may be averaged.
- Where an obvious timing error has been made, the time should be thrown out.

What Next?

- Use the TWSBA Lesson Plan, reference material provided, and shared experiences of other TWSBA organizations to guide your project design.
- The following sites are useful for learning about resistance and project approaches:
  - www.sname.org
  - www.buildingtoteach.com
  - www.teachingwithsmallboats.org
- Share your project information with the community.
- Consider collaborating with other organizations.

Summary

- **You can do this!**
- Towing tank projects are fun and interesting.
- The test apparatus is built of common materials, although large pipes require some searching to find a local vendor (or donor!)
- The apparatus requires some investment but can be re-used; good design supports easy assembly and storage.
- The apparatus is reasonably safe and students can be creative.
- There are many spin-off projects and research efforts that interested students can tackle after doing the tests.

One last thought

- The proposed small model tests align with common core standards, and with *common sense* teaching objectives.
- When doing this project you can explore:
  - Direct measurement skills
  - Math Skills:
    - Averaging
    - Calculating area & volume
    - Calculating speed
  - Data Collection & Presentation of Results
  - Experimental Method; hypotheses & tests; what happens when . . .
  - Making things with your hands
  - Thinking
  - Further research

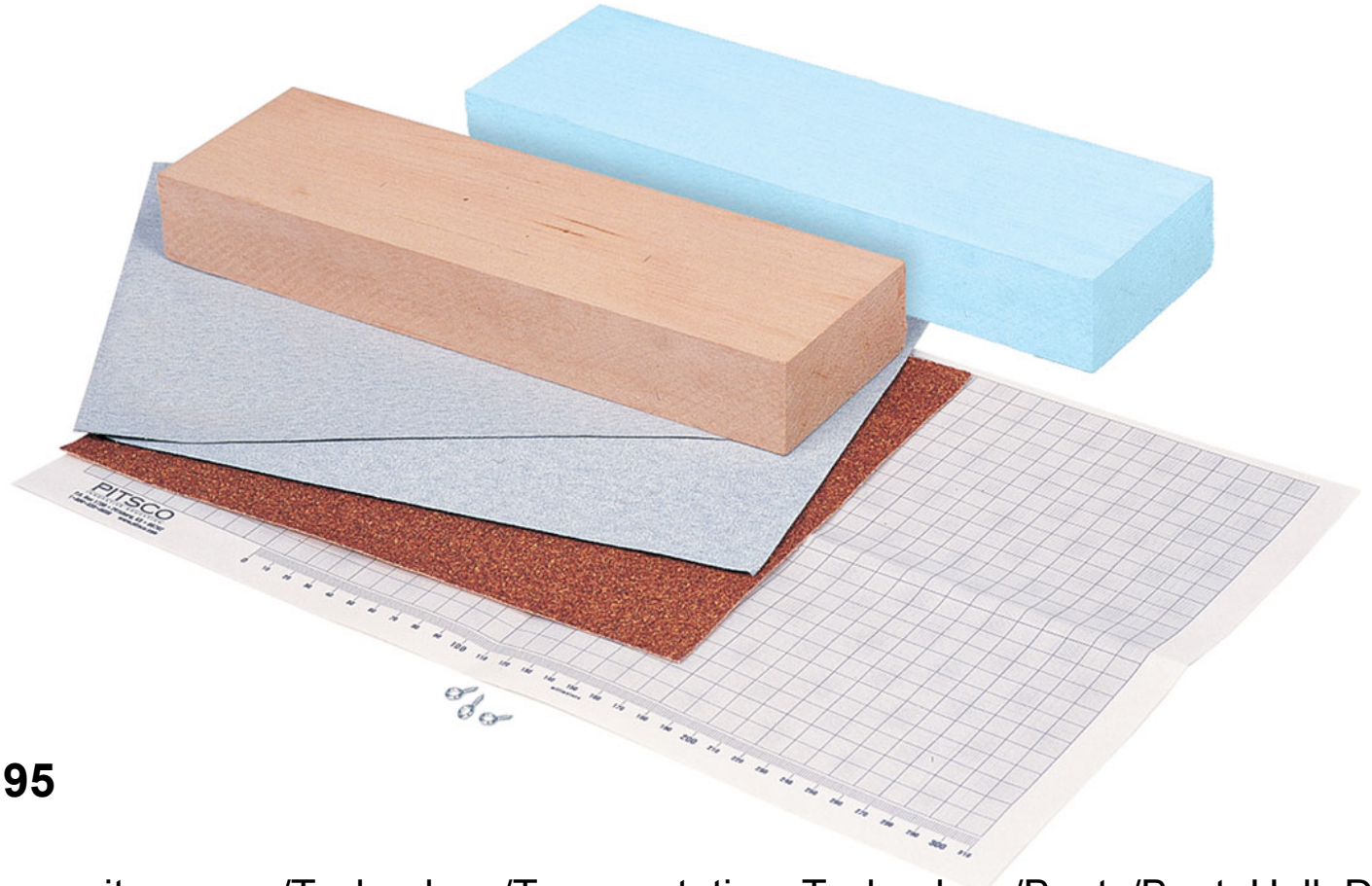
Additional Materials

The following slides include images and reference materials of potential interest. As you implement Science of Design projects, please contribute your materials to the TWSBA website.

Photos from Prof. Paul Miller, USNA & Joe Youcha, B2T

Commercial Products: Pitsco Education

Commercial Kits; Pitsco Education



$17.95

https://www.pitsco.com/Technology/Transportation_Technology/Boats/Boat_Hull_Design_Kit

Spray Foam!