PREPARING FOR HANDS-ON AND MINDS-ON EXPLORATIONS IN MATH & SCIENCE: The Tau Beta Pi MindSET Teacher Development Program

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Tau Beta Pi MindSET Teacher Development Program

Introduction

The Tau Beta Pi National K-12 Mathematics & Science Initiative is known as **MindSET**. This program applies a flexible design concept, where individual Chapters will develop and implement projects based on a framework established by Tau Beta Pi. The four Core Components of this framework are teacher development, parent development, student development, and metrics for continuous program assessment and evaluation. MindSET focuses on using kinesthetics to teach math and science in the K-12 classroom, coupled with relevant engineering laboratory activities designed to reinforce the concepts taught in the classroom. MindSET is data-driven and premised on the observation that fully equipped teachers and active and involved parents are critical to the success and progress of our K-12 students.

Objective

The objective of MindSET is to partner with local school districts, to create and establish math and science intervention programs. The MindSET programs will assist students in making the connection between math and the world around them and pursuing careers in Science, Technology, Engineering, and Mathematics (STEM) disciplines. MindSET encourages the use of kinesthetic or hands-on delivery strategies in these activities. Such strategies have been shown to contribute to improved math and science performance of students in the K-12 system, particularly in assisting students to understand the connections between math, career opportunities, and their daily lives. MindSET teacher development focuses on the preparation and training of teachers in hands-on, minds-on teaching techniques. This involves the using manipulatives and other kinesthetic activities in classroom instruction. Tau Beta Pi has developed training modules that are available for delivery to teachers in your target schools.

For more information, visit http://www.tbp.org/pages/about/programs/k12/mindsetfaq.cfm#5

ENGINEERING DESIGN: "Central Activity of Engineers"

(National Academy of Engineering and National Research Council, 2009)

_____1. Identify the problem.

_____2. Generate ideas for solving the problems.

_____3. Consider potential solutions (or models)

_____4. Evaluate trade-offs between the solution and solving the problem.

_____5. Share the solution

SCIENCE AND ENGINEERING PRACTICES (National Research Council, 2011)

_____1. Asking questions (for science) and defining problems (for engineering)

_____2. Developing and using models

_____3. Planning and carrying out investigations

_____4. Analyzing and interpreting data

_____5. Using mathematics, information and computer technology, and computational thinking

_____6. Constructing explanations (for science) and designing solutions (for engineering)

_____7. Engaging in argument from evidence

_____8. Obtaining, evaluating, and communicating information

STANDARDS FOR MATHEMATICAL PRACTICE (Common Core State Standards for Mathematics, 2010)

_____1. Make sense of problems and persevere in solving them

_____2. Reason abstractly and quantitatively

_____3. Construct viable arguments and critique the reasoning of others

_____4. Model with mathematics

_____5. Use appropriate tools strategically

_____6. Attend to precision

_____7. Look for and make use of structure

_____8. Look for and express regularity in repeated reasoning

It's a Hold Up!

You have been asked to engage in an exercise to apply for a job as a Manufacturer Process Engineer.

<u>Task</u>

You have been assigned to a group of other applicants. The task assigned to your group is to manufacture two bookends.

<u>Conditions</u>

- Total Budget: $35
- Must "purchase" at least five different (category) materials from the list below:
  - Scissors ($8)
  - Construction paper ($4/page)
  - Tape ($3 per pack)
  - Glue stick ($6)
  - Yarn ($1 per foot)
  - Ruler ($3)
  - Rubber bands ($.50 each)
  - Popsicle sticks ($.50 each)
- Must provide a sketch of the bookend model before building - Changes between the sketch and the bookend model should be noted.

<u>Goal</u>

The bookends that are most effective (when compared to other models) will serve as a mold for mass production for consumers.

<u>Follow up</u>

1. Explain the reasoning behind the items chosen for purchase.
2. What are the strengths of the bookend model?
3. What are the weaknesses of the bookend model?
4. What materials not purchased perhaps could have been helpful?

Today's Toothpaste

Materials:

- Equipment
  - Measuring spoons
  - Eyedroppers
  - Bowls or cups
  - Stirrers
  - Storage containers
    - Students can bring empty tubes from home
    - Use plastic bottles or make foil pouches
- Chemicals
  - From grocery store
    - Baking soda
    - Salt
    - Essential oils or extracts
    - Food coloring
  - From drug store
    - Glycerine in first-aid aisle
    - Household hydrogen peroxide (3% concentration)
  - More difficult to obtain
    - Powdered chalk at a sports store
    - Castile soap flakes are available online
- Recording materials
  - Grid paper
  - Classroom posting paper or overhead transparencies

Objectives:

- To practice the scientific method of problem solving
  - Identify a hypothesis
  - Make a plan
  - Execute the plan
  - Record results
  - Test the product; analyze results
  - Evaluate the result; make recommendations
  - Plan further studies
- To measure accurately and appropriately
- To calculate ratio and proportion accurately
- To identify the properties of particular chemicals

- To distinguish between a mixture and a compound
- To anticipate the problems of manufacturing toothpaste on a commercial scale

Possible ways to proceed:

1. Limit the variables and test all possibilities
2. Proscribe the ingredients and focus on measurement and proportional calculations for various quantities
3. Research the chemicals before experimenting.

Resources online:

- How to make toothpaste with step-by-step pictures http://www.wikihow.com/Make-Toothpaste
- Making Homemade Toothpaste http://tammysrecipes.com/homemade_toothpaste
- How to make *your own* toothpaste or tooth powder http://mizar5.com/toothpst.htm.
- How to Make Toothpaste http://www.youtube.com/watch?v=1ILM4oQvsWA
- Toothpaste <http://en.wikipedia.org/wiki/Toothpaste>.

Suggested questions to ask the students, for written or oral response:

- What do you consider when you are making a bigger batch of toothpaste? How can you simplify the process? What problems may cause you difficulty?
- How did you know that your mixture is stable? If it wasn't at first, how did you change it to stabilize it?
- What was your plan of action? Was it successful? Would you make changes? What changes and why?
- Could a graph be helpful for finishing this task? What variables would you track?

Suggestions for assessment activities:

- Write an advertising campaign for your product.
- Create a set of trials to test the cleaning capacity of your product.
- Describe the process of creating toothpaste to a younger student in a letter or videotape.
- Write a scientific report about the product for the CEO of the company. Discuss problems and potential for the product.

Method I: Limit the variables

Test all the possibilities

- Divide the class into groups. Each group will have different possibilities, differing combinations of ingredients.
- Here are suggestions:
  - Baking soda and salt, a flavoring, and a food color. Water is needed.
  - Soap, glycerine, flavoring, food color, water.
  - Baking soda, glycerine, hydrogen peroxide, peppermint oil, water
  - Coconut oil, baking soda, stevia powder or xylitol, peppermint oil
  - Baking soda, salt, glycerine, and flavoring.
- The groups create a tasty and attractive product, keeping records of each attempt. Require that the measurements are exact, because we are looking for replicability. The group then needs to create a larger sample so that the entire class can test it.
- Students will devise tests for each toothpaste to determine the best product.
  - Which cleans best? How do you know?
  - Which tastes best?
  - What part does appearance of the product play?
  - Is the product stable? Can it be easily stored? Can it be easily dispensed?
- The class can then determine the best recipe for a toothpaste.

Method II

Proscribe the ingredients

Focus on measurement and proportional calculations for various quantities

- Groups of 3 or 4 work together to follow a recipe dictated by the teacher. Choose one of the suggestions offered in the resources.
- The educational goals here are less open-ended and more procedural. You want to be certain that the students measure accurately.
- The products of this project will be batches of toothpaste in different sizes. The students are responsible for calculating the correct amounts of ingredients, in the correct proportion as the original ratio.
- You can offer the students individual choice through flavoring and colors. The product then could be presented to the class as it might be in a marketing context.

Method III

Research the chemicals before experimenting.

- Begin with a full-class discussion of the purposes of toothpaste and the essential requirements.
- Students would investigate the characteristics of common ingredients.
  - What purpose does baking soda serve?
  - What is the best cleaning agent?
  - Which chemicals scrub? Which polish?
  - Which mixtures bind well?
  - Are there storage issues that relate to the typical consistencies of the product?

After the research is complete, groups would develop a recipe that met their pre-determined needs. This investigation would proceed much as the one described in Method I.

Resources

Book/Journals

National Academy of Engineering and National Research Council. (2009). Engineering in K-12 education. Washington, DC: National Academies Press.

The Institute of Electrical and Electronics Engineers (IEEE) includes subscriptions to over 150 quality journals, magazines, and research collections. The IEEE Education Society publishes *IEEE Transactions on Education* quarterly.

The following journals are publications of the International Technology and Engineering Educators Association (ITEEA). The articles are archived online for members only at http://www.iteea.org/Publications/ttt.htm.

a. *Children's Technology and Engineering* (CTE) is an electronic journal for elementary school teachers. The earlier journal *Technology and Children: A Journal for Elementary School Technology Education* was renamed in 2010.
b. *Technology & Engineering Teacher* is the flagship journal. It is a part of ITEEA membership.
c. *Journal of Technology Education* is a referred scholarly journal that provides a forum for discussion of technology education. Conceptual as well as research-based articles are published.

The National Science Teachers Association publishes these journals: (1) *Science and Children;* (2) *Science Scope;* and (3) *The Science Teacher* for their members. A recent search found 26 articles related to "engineering."

The National Council of Teachers of Mathematics (NCTM) publishes three journals for the classroom teacher: (1) *Teaching Children Mathematics*; (2) *Mathematics Teaching in the Middle School*; and (3) *Mathematics Teacher*.

Buhrman, J. (2006). Projects: Extraordinary Women Engineers Project (EWEP). *Mathematics Teacher,* 283.

Dengerud-Au, M., (2000). Strength of Wood Beams: An Engineering Application. *Mathematics Teacher,* 544.

Englard, L. (2010). Raise the bar on problem solving. *Teaching Children Mathematics,* 156.

Herron-Thorpe, F., Olson, J., & Davis, D. (2010). Shrinking Your Class. *Mathematics in the Middle School, 386-391*.

Lucey, L.P., Jennings, S., Olson, P., Rubenfeld, L., & Holmes, A.E. (2007). The Power of String: Building a Conceptual Foundation for Measuring Rate. *Teaching Children Mathematics,* 18.

Rule, S. (2006). Trigonometry Saves Engineer's Time. *Mathematics Teacher,* 484.

Sharp, J., Zachary, L., & Luttenegger, G. (2006). Using Engineering to Understand Reciprocal Functions. *Mathematics in the Middle School.* 390.

Weiss, M., Dodge, B., Harden, K., Hempstead, A., Lloyd, J., & Pott, B. Using a Model Rocket-Engine Test Stand in a Calculus Course. *Mathematics Teacher,* 516*.*

Online Resources

“Engineering for Kids—DIY for Kids,” is a resource site for several interesting projects, like “Newspaper Forts.” http://www.biglearning.com/treasureengineering.htm.

The *Engineering is Elementary*® project has produced 20 curricular units for grades 1-5. Additional information is available at this website. http://www.mos.org/eie/20_unit.php.

“A House is a House for Me: Hands-on Activity,” contributed by the Center for Engineering Educational Outreach, Tufts University http://www.teachengineering.org/view_activity.php?url=collection/wpi_/activities/wpi_a_house_for_me/a_house_for_me.xml.

Project Lead the Way (PLTW): A Pre-engineering Curriculum that Works is reviewed in a research brief by Gene Bottoms and Karen Anthony found at <http://publications.sreb.org/2005/05V08_Research_PLTW.pdf>.

Rogers, Chris and Portsmore, Merredith, “Bringing Engineering to Elementary School,” *Journal of STEM Education, Vol.5, Issue 3 & 4, July-December, 2004.*

http://www.greenframingham.com/bring_engr_elem021505.pdf. This resource is specific to a toolset LEGO/ROBOLAB developed at Tufts http://www.ceeo.tufts.edu.

In the same journal edition: http://www.integratingengineering.org/stem/research/item2_engr_k4_outreach.pdf draws attention to Swift and Watkins “An Engineering Primer for Outreach to K-4 Education”.

Virginia Children’s Engineering Council has a site for teachers to find design briefs, lessons in English, Mathematics, Science, and History for the elementary school grades. http://www.childrensengineering.org/technology/designbriefs.php.

PBS – Parents and Educators Online Workshop available at http://pbskids.org/designsquad/parentseducators/workshop/welcome.html includes videos of students engaged in activities modeling engineering design.