How to MST Science and Mathematics Materials

Answer the following questions:

1. **What are the students going to explore?**
2. **What is the nature of the inquiry?**
3. **Is it learner driven?**
4. **Where is the design challenge?**
5. **What planning process is in place?**
6. **How will the students be assessed (e.g., a design portfolio)?**
7. **Where does mathematics present itself?**
8. **What are the science ideas that emerge?**
9. **Where are the interdisciplinary connections?**
10. **What is the real-life context (i.e., the reason for the journey)?**

Source: Dr. Janice Koch, Hofstra University

Assessing Elementary School Design Portfolios

Introduction

"Assessment drives curriculum." As educators we are very cognizant of this adage and find that technology education programs may be given less importance in student's educational experience because assessment in other areas–reading, mathematics, science–receives greater societal attention and hence a greater part of the school day.

One of the challenges facing the discipline of technology education is the lack of reliable means of assessing student performance on design projects. Design is fundamental to the study of technology education. Wright (1996) points out that technology has a mode of inquiry that is focused on creating as contrasted to science's mode of inquiry centered on discovery.

Yet, the assessment of design projects is often very subjective and inconsistent as teachers may examine the end product's creativity or performance or the completeness of a design portfolio/report as the primary grading criteria. Design has two main elements: the design process that students follow in creating the design project and the product itself. Educationally the process is the more important factor. The project is the incentive for students to become enmeshed in the process, stimulating their creativity and mathematical and scientific skills.

Design Portfolios

Design portfolios and accompanying assessment rubrics and benchmarks have been created for student use in upper elementary and middle schools. The portfolio and assessments have been field tested in about 20 elementary school classrooms by teachers in the Hofstra University MA/MST program. The portfolio included in this Guide has been critiqued and refined by 50 additional elementary and middle school teachers in the MSTe Project and is currently in use with their students. A design portfolio is much more than a collection of student work; it provides a design process framework for the student as well as documenting key points of the process.

The design portfolio reflects the belief that technology education can enhance student comprehension and ability in math and science as these understandings are necessary for the design process to be done well. Technology education is an integrative discipline, which can support many other fields as well as standing on its own. In New York State it is difficult for a new discipline to stand alone; a key element to its success will be its support of core disciplinary knowledge, particularly mathematics and science knowledge.

In conceptualizing the design portfolio, a folder format was envisioned with the pages denoting folder sections. The idea was to open student creativity as to what could be placed on one page by using these sections as topical guides. There is a rationale for each of the sections, with the caveat that all sections need not be completed for all projects; additional sections may be warranted in certain cases, perhaps on a project connected to history, and some deleted on narrowly focused topics.

The design project is developed to solve a problem, a problem whose genesis is often found from another area of the curriculum, such as reading, science, or social studies. This provides the context for the solution and creates a motivation for designing a device. Often students in upper

Source: Dr. M. David Burghardt. To be published in *Technology Teacher*

elementary will write a short essay describing the context for their solution. Dunn and Larson (1990) point out that the design process fosters the interplay between reading and writing. In the research and investigation phase children compare and contrast information from different sources, as well as write in daily logs or journals and in their portfolios.

With every problem, in every design, there are constraints and specifications that further specify and define the problem. As the designs evolve, these will be used to evaluate the acceptability of the solution.

A knowledge base in the area is required for engineers and scientists, hence research and investigation of what has been accomplished provide the basis for creating new designs. This can include clippings of devices from magazines and newspapers as well as literature searches in the library and on-line. Research and investigation are also elements of the scientific process, so there is reinforcement of mutually supportive concepts occurring.

Once a knowledge base has been created, then fruitful brainstorming for ideas can occur. The students sketch some of their ideas and then justify which one they think will be best. This is always a difficult step in the design process as students (and teachers, too) want to seize on one idea and stop thinking about alternative solutions. Students should be encouraged to expand upon that idea, think of ways to improve it, change it. Note that a formal sketch is not required at this point, but only later on for the final project. We have found that sketches of *what might be* are not as valuable as sketches of the final project, *what is*. There is much greater motivation to present that which was just created than an imagined design.

The testing and evaluation section allows an excellent opportunity to connect to mathematics and continue the science ties. The testing should be done in a scientifically appropriate manner, changing only one variable at a time. Students need to understand what a hypothesis is in science; the use of it in this situation reinforces this important scientific concept. Many of the mathematical connections are found in creating and interpreting the test results. Graph creation and interpretation are important in elementary school mathematics; standardized tests in mathematics frequently include interpretation of graphs and the creation of graphs from tables of data.

The final section supports science with conclusions reached from evaluation of test data. Of course, this is an important part of the design process and one that children enjoy completing and thinking about. Standardized tests in science have questions that require an embedded understanding of scientific inquiry–investigation, generation of hypotheses, testing and evaluation, and reaching conclusions. Again, the design process, as documented in the portfolio, reinforces these concepts.

Teachers often have students maintain a journal. In this case the daily learning log need not be included as part of the portfolio. If a journal is not used, then the daily learning log has proved valuable to both students and teachers in reinforcing accountability, troubleshooting problems, and providing for reflection.

Assessment of Design Portfolios

The assessment of long-term projects is challenging, particularly in technology education, where each student may have a different project and the solutions will be different, unlike in mathematics, where 56 divided by 7 is always 8.

As Wright indicated, the design process is part of the knowledge base of technology education, so we should be evaluating how well that process is understood. The students value the process if it helps them in creating "neat" designs and they receive recognition for them. One of the problems teachers face is the desire by many students to "gadgeteer" – to think of a possible design and fiddle with the parts until it works. This is certainly "hands-on" but not much in the way of "heads-on."

Developing rubrics and benchmarks in support of them is a very time-consuming process in which the developer must think about what is valued, how that is demonstrated, and how what is demonstrated can be quantitatively assessed. There is a rationale for each of the rubrics given in this section. They evolved with much discussion and deliberation; the benchmarks received similar analysis. Refinement can and should occur as teachers use these rubrics. The rubric revision will be based upon actual student work and the teacher's analysis of that work. They are self-explanatory. All need not be used for a given project, as the portfolio might become quite time-consuming to grade. Some teachers have students perform a self-assessment, using the rubrics and benchmarks, followed by the teacher's assessment. Certainly discussing the rubrics ahead of time with the students, perhaps refining them for a given problem, is important and causes students to think conceptually about the design process.

Elementary School Classroom Management

For technology education to flourish in elementary school and become institutionalized, it must be taught by classroom teachers, not by specialists. Just as many classrooms have a science resource center, a technology resource center with tools and materials is virtually a requirement for students to design and construct projects. Science and technology centers can readily be combined, as space is often limited in classrooms.

Chaos is possible when 25 students are working on design projects. There are some techniques that have proved effective in managing what is naturally a very constructivist environment. Have students develop a plan, which is teacher approved, before using the materials or tools. This prevents students competing for materials and taking more than they need. Students can turn in the design portfolio at different stages before proceeding to the next phase; the teacher stamps the pages indicating approval and students move on to the next phase. A recommended first stage, prior to the start of construction, asks students to turn in the portfolio with their problem statement, research, brainstorming, and materials and tools sections completed. Other stages may include monitoring of the students' activity log or journal, approving the testing and evaluation process, and reviewing the final sketch.

Source: Dr. M. David Burghardt. To be published in *Technology Teacher*

Conclusion

The design portfolio and its assessment strategies have proved useful for MST projects. Students are active learners in this situation. Science and mathematics connections with technology occur naturally in this constructivist learning environment. Elementary school teachers have also found it is possible to implement technology education experiences in conjunction with their science activities, often as a culminating feature. Parents and administrators in schools where teachers have used the design portfolio have been very impressed by student enthusiasm, learning, and the connections and understandings they have achieved.

References

Dunn, Susan and Larson, Rob. *Design Technology--Children's Engineering*. The Falmer Press, New York, 1990.

Wright, Thomas. "Technology: An Intellectual Discipline," *The Technology Teacher*, vol. 56, no. 2, October 1996.

Source: Dr. M. David Burghardt. To be published in *Technology Teacher*

MSTe Design Portfolio

Name___________________________

Team Name_____________________

Team Members **Role**

____

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Problem Statement *(Description of problem I/we need to solve)*

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Specifications *(What are the project requirements? What must my solution do?)*

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____

____

____

Constraints *(Things that limit my solution, such as size, weight, time, materials, cost)*

____

____

____

Funded in part by the National Science Foundation

Research/Investigation *(What do I know about the problem? What do I have to find out?)*

____

____

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____

____

What did you find out? *(You can glue pictures here too)*

____

____

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____

Brainstorming/sketches of my ideas

Circle your best idea/sketch

What will you need to make your design?

Materials____

____

____

Tools____

____

____

How will you test your design to meet specifications and constraints?

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How will you record the results?

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____

My Hypothesis (*What I think will happen when I test the design)*

____

____

____

____

____

Test Results--How did the design work?

(What I found: Please display data in the form of graphs, tables, charts)

A Drawing of My Design as I Built It

Drawing Conclusions/Recommendations

Aspects of my design I was happy with *(and why you were)*

____

____

____

____

As a result of this experience, I learned that... ____________________

____

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____

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Next time, I would...*(Tell about some things that you would change or improve.*

Include why and how you would do this.)

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Daily Learning Log

Day___

This is what I did today:_______________________________________

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This is what I learned today:___________________________________

____

____

Day___

This is what I did today:_______________________________________

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This is what I learned today:___________________________________

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Day___

This is what I did today:_______________________________________

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This is what I learned today:___________________________________

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Day___

This is what I did today:_______________________________________

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This is what I learned today:___________________________________

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Integrating Mathematics, Science and Technology
in the Elementary School

MSTe Design Portfolio

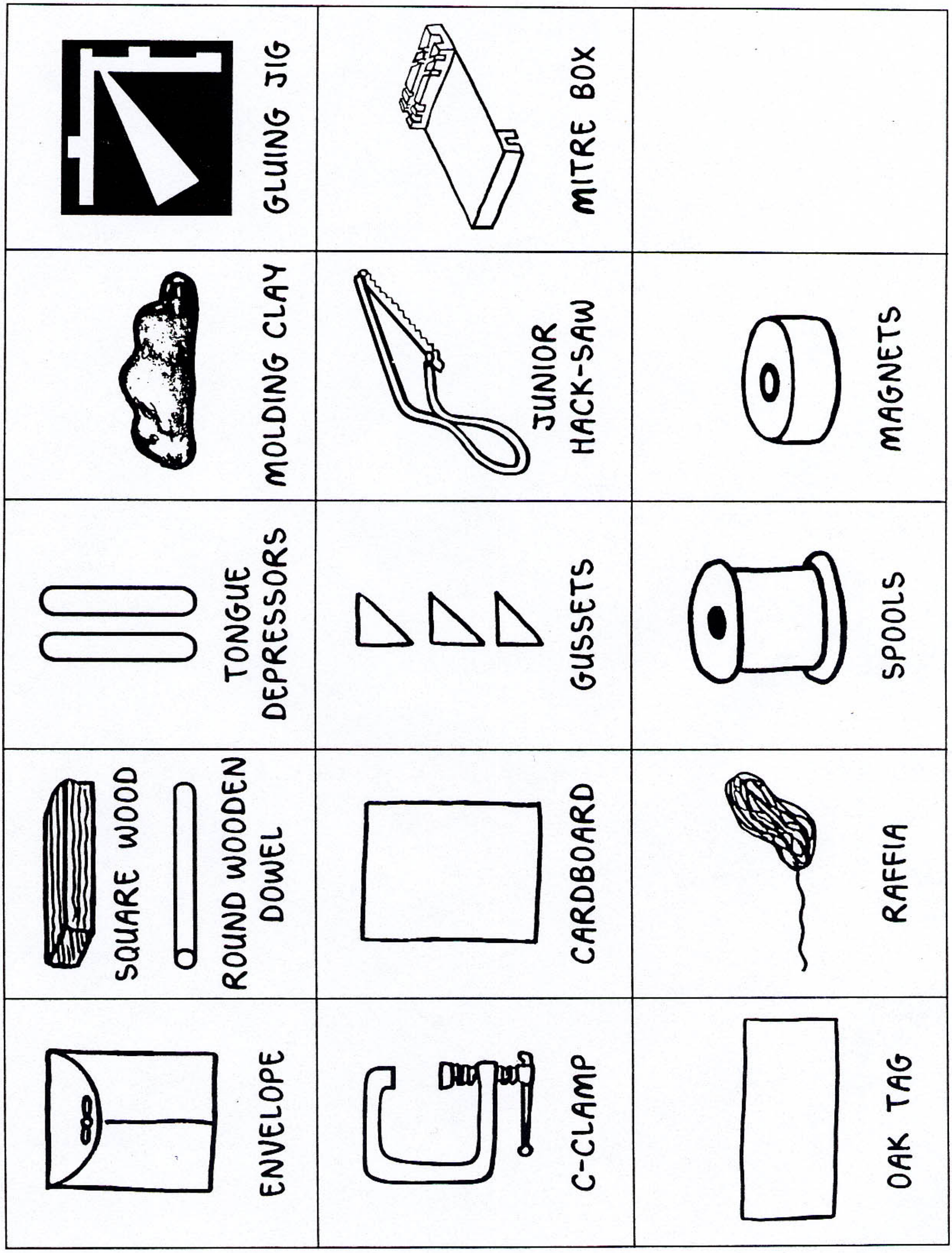
NAME

IT WILL LOOK LIKE:

THINGS I NEED:

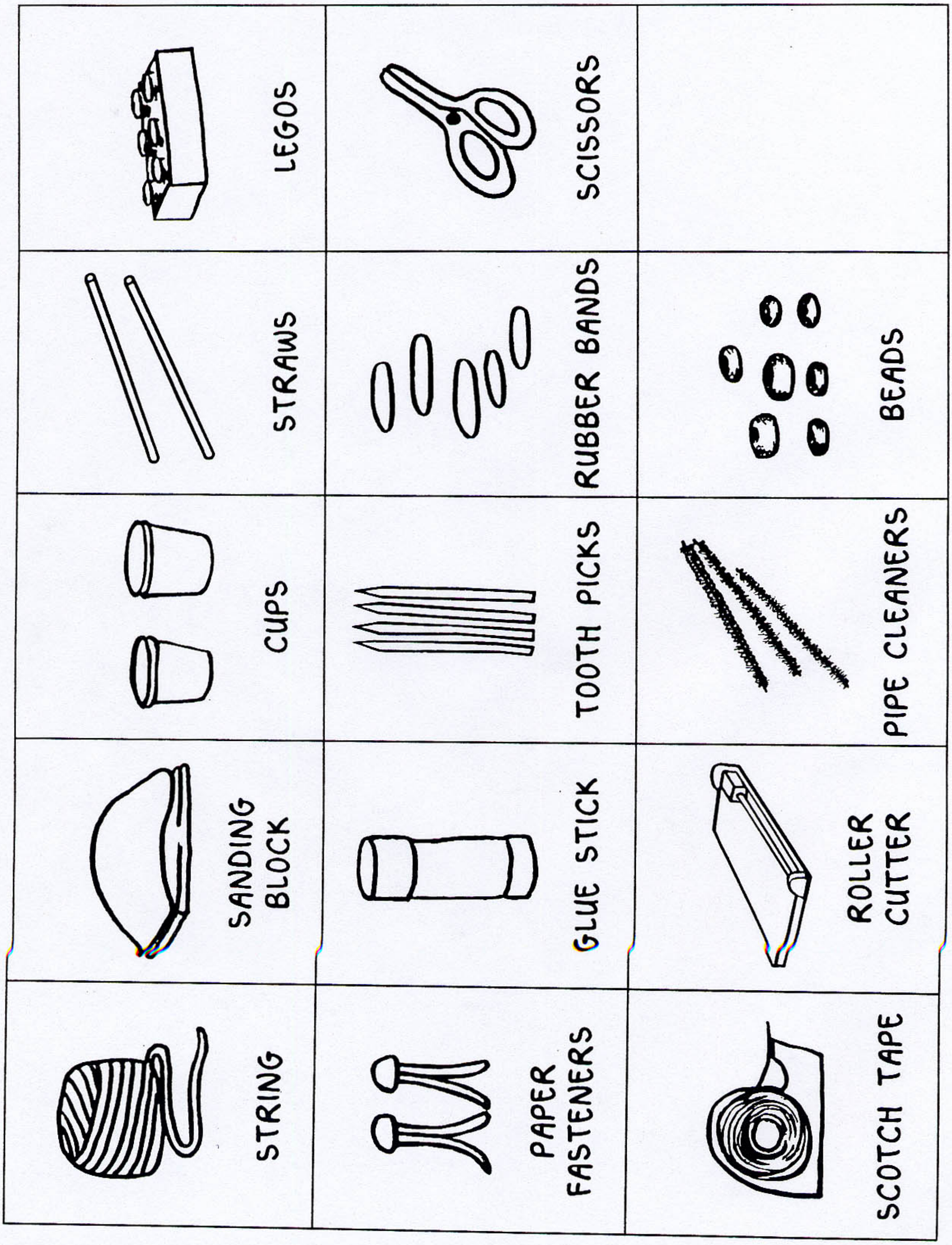
THINGS YOU MIGHT NEED

Cut out and paste pictures of the things you need.



THINGS YOU MIGHT NEED

Cut out and paste pictures of the things you need.



COLOR 3 STARS IF YOU LIKED MAKING THE PROJECT.

COLOR 2 STARS IF YOU LIKED SOME OF THIS PROJECT.

COLOR 1 STAR IF YOU DID NOT LIKE MAKING THIS PROJECT.

Design Assessment Rubrics

The assessment of student design portfolios considers many factors and focuses on the process as well as the product. A scoring scale, consistent with the National Council of Teachers of English, is used.

4--exceeding the level that you target in teaching
3--meeting the level you target in teaching
2--developing to the level you target in teaching
1--emerging

It is recommended that at least ten rubrics be used, with a minimum one rubric from each section in assessing student work. The following set of rubrics are, of course, general in nature. These can be tailored to a particular assignment. They should be discussed with students so they are aware and a part of the process by which they are evaluated.

Design Process

A. Explained problem and identified constraints and specifications.

4. Explained the problem in detail and from this context illustrated the necessary constraints and specifications.
3. Explained the problem in a few sentences, provided two constraints and two specifications.
2. Briefly explained the problem, provided one constraint and one specification.
1. Did not explain the problem, provided no or only one total constraint and specification.

B. Researched the problem and gathered information from a variety of sources.

4. Information gathered from at least five sources, with several pictures attached illustrating variety of commercial solutions.
3. Information gathered from three different sources, pictures attached.
2. Either information from fewer than three sources or only one picture attached.
1. Little or no information gathered; no pictures attached.

C. Sketched a variety of solutions, selected the best design.

4. Provided five or more sketches with good detail with all important elements included.
3. Provided four sketches which showed detail of various solutions.
2. Provided two sketches which showed some detail, but missing important elements.
1. Provided few sketches that did not show sufficient detail, missing several important elements and quality of information presented was poor.

Design Solution

A. Drew an accurate sketch of your final design, as built.

4. Drawing on graph paper to scale with all elements included. Multiple views are shown (top, side, front) or isometric view.
3. Drawing on graph paper to scale with all elements included. Shows the design in two dimensions, a flat view.
2. Drawing on graph paper reasonably to scale with most elements included.
1. Drawing not to scale and with important elements missing.

B. Planned and used materials and tools appropriately in constructing project.

4. Listing of materials and tools and how they would be used with the appropriate materials.
3. Prepared complete list of materials required and tools necessary to fabricate with these materials.
2. List of materials was essentially complete, some tools required were not mentioned.
1. Mentioned only a few materials and no tools.

C. The solution worked. It met the design specifications and constraints.

4. The solution solved the problem statement; this was explained in the write-up along with how the specifications and constraints were met and/or the design modified to assure their being met.
3. The solution solved the problem statement and the constraints and specifications were met.
2. The solution solved the problem but not all constraints and specifications were met in doing so.
1. The solution did not solve the problem; constraints and specifications were not met.

D. Creativity of the design.

4. The solution was unique; never or seldom has this design been formulated.
3. The solution was functional, but not unique. Similar solutions were common.
2. The solution was similar to others; it may have been a modification or interpretation of another's solution.
1. The solution was copied from another.

Mathematical Connections

A. Presented results in graphs and charts.

4. Graphs and charts neatly drawn with graphic illustration. May include the use of graphing software.
3. Graphs and charts were drawn neatly on graph paper. Labels appropriately shown.
2. There were some graphs and charts drawn with moderate care.
1. Charts and graphs poorly done, information missing.

B. Accurate measurement and calculation.

4. Rulers, protractors, compasses etc. used appropriately in measuring material before fabrication. Correct use of formulas for calculation of such values as area, volume, speed. Explanation of proper use included in discussion and why results seem reasonable.
3. Rulers, protractors, compasses etc. used appropriately in measuring material before fabrication. Correct use of formulas for calculation of such values as area, volume, speed.
2. Measuring devices used with few mistakes during fabrication. Some mathematical calculations done correctly, others missing or not completed.
1. Errors in measurement; errors in calculations that were done.

Science Connections

A. Stated and justified hypothesis for evaluating the design.

4. Hypothesis clearly stated with justification in terms of meeting the constraints and specifications of the design. The science principles of the testing are discussed.
3. Hypothesis clearly stated with justification in terms of meeting the constraints and specifications of the design.
2. Hypothesis stated with some justification in terms of constraints and specifications of the design.
1. Hypothesis not justified or superficial justification.

B. Tested the design.

4. Conducted the test in a reliable and scientific fashion with multiple tests to demonstrate repeatability. Discussed why the testing was reliable and efforts made to assure it would be.
3. Conducted the test in a reliable and scientific fashion with multiple tests to demonstrate repeatability.
2. Conducted the test once, did not show reliability or repeatability of data.
1. Did not perform testing of design.

C. Provided conclusions based on the testing and made recommendations for improvements.

4. Analyzed the results from testing and made sense of them. Based on this made recommendations for design improvements and then modified the design and re-tested to show the benefit of the modifications.
3. Analyzed the results from testing and made sense of them. Based on this made recommendations for design improvements.
2. Analyzed the results and suggested design improvements but justification missing.
1. Did not reach conclusions from testing or recommend design modifications based on the testing.

Work Habits

A. Worked collaboratively with classmates.

4. Worked cooperatively with others both as a leader and a follower. Helped focus the group to the task at hand and assisted others.
3. Worked cooperatively with others, assisting occasionally.
2. Worked alone, completing assignment.
1. Worked alone, did not complete assignment.

B. Completed assigned tasks in a timely fashion.

4. Maintained a journal/daily log of project; personal assignments were completed on time; assisted others in keeping group on time.
3. Maintained a journal/daily log of project; personal assignments were completed on time.
2. Most personal assignments completed on time; journal/daily log maintained erratically.
1. Assignments turned in late or incomplete; journal/daily log not maintained.

Communication and Presentation

A. Design portfolio completely and neatly accomplished.

4. All sections of portfolio completed; portfolio typed; sentences complete, grammatically correct, with no spelling errors.
3. All sections of portfolio completed; handwriting neat; sentences complete, grammatically correct, with no spelling errors.
2. All sections attempted with most completed; handwriting legible; use of phrases and sentences, some grammatical/spelling errors.
1. Not all sections attempted, work incomplete; handwriting illegible; grammatical/spelling errors.

B. Actively participated in the presentation of results.

4. Knowledgeable of own material and clearly presented same; good language skills; interacted with others; acted as group leader with support of group.
3. Knowledgeable of own material and clearly presented same; good language skills; interacted with others.
2. Knowledgeable of own material and clearly presented same.
1. Did not actively participate; information misunderstood.

Goals 2000 MST Performance Assessment Project

The following scoring sheets and rubrics for engineering design and inquiry were designed by a team of American and British educators to assess inquiry and design tasks that are of limited length, in this case 12 hours.

These scoring sheets and rubrics can provide a structure for elementary school inquiry and design activities.

Engineering Design Scoring Sheet

DRAFT 11/23/98

Total time = 12 hours

		Minutes	P	S
Introduction to the task (by the teacher)				
a	The purpose and rules for engaging in the task.	10		
b	Present the task statement and the context of the task.	5		
c	Present preliminary activities to promote engagement in the task.	30		
	Subtotal	**45**		
Phase one: Product development (allow 3 hours)				
1.1	Brainstorm and develop early ideas for possible starting points for the task.	30	4	
1.2	Identify, record, and prioritize criteria for judging the effectiveness of ideas.	15	4	
1.3	Search for information (i.e. scientific, mathematical, technological, etc.) to inform and support designing.	60	4	
1.4	Develop a design solution and a plan to guide prototyping.	75	4	
	Subtotal	**180**	**16**	
Phase two: Prototype modeling (allow 3 hours)				
2.1	Develop a detailed work-plan.	30	4	
2.2	Work together to produce your first prototype.	150	8	
	Subtotal	**180**	**12**	
Phase three: Prototype testing (allow 2 hours and 15 minutes)				
3.1	Devising and planning tests to evaluate the performance of the prototype.	30	4	
3.2	Conducting tests and recording data.	75	4	
3.3	Interpreting test data to inform the redesign of the prototype	30	4	
	Subtotal	**180**	**12**	
Phase four: Prototype refinement (allow 3 hours)				
4.1	Develop your design using all the information now available making revised drawings or models to portray your final design.	130	8	
4.2	Summarize and record the strengths and weaknesses of your design.	20	4	
4.3	If you were to tackle this task again, what would you do differently and why?	30	4	
	Total	**180**	**16**	
	Grand total	**720**	**56**	

*Note – P = Total Possible Score
S = Actual Score

Source: Goals 2000 MST Performance Assessment Project

Engineering Design Scoring Rubric

DRAFT 11/23/1998

		Accomplished	Proficient	Developing	Beginning
1.1	**Early Ideas** ***Divergent Production***	Diverse and innovative in producing and developing clear early ideas or starting points (More that 2 ideas) 4	Identified some early ideas or starting points with appropriate development (More that 2 ideas) 3	Identified some early ideas or starting points with some development (More that 1 ideas) 2	Very limited and/or poorly developed early ideas or starting points 1
1.2	**Design Criteria and Issues** ***Thoughtful, Analytical***	Develops many pertinent design criteria and constraints are identified and described in detail 4	Develops some of the pertinent design criteria or issues are identified and described 3	Identifies few of the criteria and issues that need to be considered 2	Very limited and/or poorly developed design criteria or issues 1
1.3	**Searching for Information** ***Thoroughness***	Develops and clearly presents a broad range of information from many diverse sources. Includes pertinent scientific, mathematical, and/or technological principles 4	Develops and presents a range of information from some multiple sources. Includes pertinent scientific, mathematical, and/or technological principles 3	Identifies and presents some information from limited sources. Includes some scientific, mathematical, and/or technological principles 2	Very limited presentation of information 1

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
1.4	**Developing a Design Solution** ***Thoroughness***	Develops and elaborates design ideas leading to a clear presentation of the prototype design in a form that can be made 4	Design ideas are developed appropriately and the prototype design is presented – but development and presentation lack detail and/or quality 3	Design ideas are left undeveloped, but a basic design is presented in a recognizable from 2	Limited evidence of the development of design ideas 1
2.1	**Work-Plan** ***Usefulness***	Develops detailed, realistic work-plan that could be followed to produce successful prototype. Plan provides detailed information on resources needed and team member roles. 4	Develops realistic work-plan that could be followed to produce a successful prototype. Some attempt at detailing needed resources and team member roles. 3	Develops rudimentary work-plan with some awareness of needed resources or team contributions, not necessarily realistic 2	Very limited attempt to develop a work-plan 1
2.2	**Prototype Modeling** ***Quality***	The team works effectively to produce a prototype of sufficient quality to test the key features of the design. Work completed on schedule 8	The team produces a prototype of adequate quality – with some awareness of how it needs to perform 6	A prototype is produced approximately to the original design but with little regard to how it needs to perform 4	Work conducted haphazardly and with little regard to appropriate quality 2

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
3.1	**Devising Tests** ***Appropriateness***	Develops a range of important issues and test procedures are devised to evaluate critical performance characteristics 4	Identifies some important issues and appropriate procedure planned for testing 3	Identifies some issues and designs limited testing procedures 2	Only trivial or inappropriate tests devised 1
3.2	**Testing** ***Effectiveness***	A range of appropriate tests carried out with proper regard to reliability and usefulness, and results effectively presented 4	Some testing is conducted thoroughly and result appropriately presented 3	Some testing carried out but with little regard to appropriate procedure 2	Trivial tests conducted or with ineffective procedures 1
3.3	**Interpretation of Results** ***Usefulness***	Presents a range of carefully developed interpretations of the outcomes from the testing – useful for the next phase of prototype development 4	Results from at least one test carefully interpreted to support to next phase of designing 3	Shallow or unreliable data interpreted for future use 2	Only trivial conclusions derived from tests 1
4.1	**Prototype Refinement** ***Quality***	Design developments are supported, in part, by the results from the testing. The final design is effectively presented with quality drawings and models. 8	Design developments are made from the prototype stage. The final presentation of the design has elements of quality. 6	Some design development from the prototype stage. Limited presentation of a final design, with some evidence of quality 4	Little evidence of design development. 2

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
4.2	**Strengths & weaknesses** ***Thoughtfulness***	Full recognition of the strengths and limitations of the design (technical; aesthetic; user) related back to the design specification. 4	Clear evidence of awareness of strengths and weaknesses 3	Some awareness of the strengths and weaknesses of the design 2	Very limited evidence of awareness of strengths and weaknesses in the final design 1
4.3	**Next Time** ***Redesigns***	Provides clear descriptions of what still remains to be done to improve the current design. Provides explanations of alternative design choices in detail. 4	Provides some evidence of improvements planned for the current design. Describes alternative approaches. 3	Identifies some features that might be modified and shows awareness of the possibility of an alternative approach 2	Very limited evidence that the 'next time' would be any different or any better 1

Source: Goals 2000 MST Performance Assessment Project

Inquiry Scoring Sheet

DRAFT 2/2/1999

Total time = 12 hours

		Minutes	P	S
Introduction to the task (by the teacher)				
a	Present purpose and rules for engaging in the task.	10		
b	Present the task statement and the context of the task	5		
c	Present a provocative activity to raise questions about current understandings.	30		
	Subtotal	**45**		
Phase one: Problem Definition (allow 0.75 hrs)				
1.1	Produce a list of **Possible Questions** that could be answered through a scientific investigation.	10	4	
1.2	Share and revise your questions with suggestions from others. Develop your **Question Revisions** and provide a rationale for them.	25	4	
1.3	Select the **Question to be Studied** and provide the rationale for the selection	10	4	
	Subtotal	**45**	**12**	
Phase two: Problem Investigation (allow 5.5 hrs)				
2.1	Prepare the **Draft Investigation Plan** including specific strategies and general procedures	30	4	
2.2	Share and revise your Draft Investigation Plan with suggestions from others. Prepare the **Final Investigation Plan**	30	8	
2.3	Maintain a detailed **Investigation Log** with an organized record of observations, measurements, and other data.	270	8	
	Subtotal	**330**	**20**	
Phase three: Problem Investigation Results (allow 5 hrs)				
3.1	Conduct **Data Analysis** on the data you have collected. Develop tables, graphs, and statistical analyses as needed	90	8	
3.2	Interpret your analysis and show how they answer your question or test your ideas and lead to your **Conclusions.**	30	4	
3.3	Prepare a **Draft Report** Including: A statement of the problem, question, or idea to be tested, what observations and measurements you made, the data analyses you did, how you interpreted the data and reached conclusions, and what other research might be done next.	90	4	
3.4	Present your draft report with other groups and revise it to include their suggestions that will improve your report. Submit your **Final Report** with your Science Log.	90	8	
	Subtotal	**300**	**24**	
	Grand Total	**720**	**56**	

*Note – P = Total Possible Score
S = Actual Score

Source: Goals 2000 MST Performance Assessment Project

Inquiry Scoring Rubric

Draft 2/2/99

		Accomplished	Proficient	Developing	Beginning
1.1	**Possible Questions for Inquiry** ***Divergent Production***	Produced a variety of diverse and innovative questions that address,the understanding of scientific phenomena (More than 3 ideas) 4	Produced a number of clear questions that address the understanding of scientific phenomena (More than 2 ideas) 3	Produced some questions that address the understanding of scientific phenomena (More than 1 idea) 2	Produced questions that had limited value for scientific inquiry 1
1.2	**Question Revisions and Rationale** ***Discrimination***	A variety of the previous questions revised through discussion. Revised questions seek understanding and is answerable through investigation 4	Some of the previous questions revised through discussion. Revised questions seek understanding and is answerable through scientific investigation 3	One of previous questions revised through discussion. Revised question seeks understanding and is answerable through investigation 2	Very limited and/or poorly developed inquiry questions 1
1.3	**Question to be Studied and Reasons** ***Researchability***	Produced well-stated question that can be answered through investigation. Reasons presented include the potential for increased understanding of the phenomena and practical considerations 4	Produced well-stated question that can be answered through investigation. Reasons presented include only practical considerations 3	Produced well-stated question that can be answered through investigation. Reasons presented do not address potential for understanding or practical considerations 2	Produced poorly stated questions that are unlikely to be answered through investigation. Reasons given do not address potential for understanding or practical considerations 1

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
2.1	Draft Investigation Plan *__Practicality__*	Developed a plan that lays out a general strategy for answering the question including, general procedures to set up conditions, ways of measuring, and analyses, all that focus on the question 4	Developed a plan that lays out a general strategy for answering the question including, general procedures to set up conditions, and ways of measuring that focus on the question 3	Developed a plan that lays out a sketchy strategy for answering the question and that has only procedures to set up conditions, or ways of measuring, or analyses that have a focus on the question 2	Developed a plan that lays out a sketchy strategy for answering the question, that lacks procedures to set up conditions, ways of measuring, and analyses, and that lacks a focus on the question 1
2.2	Final Investigation Plan *__Specificity__*	Produced an improved plan that lays out a more specific strategy for answering the question including, general procedures to set up conditions, ways of measuring, and analyses; all than can focus on the question 8	Produced an improved plan that lays out a more specific strategy for answering the question including, general procedures to set up conditions, and ways of measuring that focus on the question 6	Produced an improved plan that lays out a slightly more specific strategy for answering the question and that has only procedures to set up conditions, or ways of measuring, or analyses that have a focus on the question 4	Produced an unimproved plan that lays out a sketchy strategy for answering the question, that lacks procedures to set up conditions, ways of measuring, and analyses, and that lacks a focus on the question 2
2.3	Investigation Log *__Carefulness__*	Maintained a detailed record of activity describing specific procedures and reasoning. Includes organized set of original observations or measurements and, if appropriate, data tables 8	Maintained a somewhat detailed record of activity describing specific procedures and reasoning. Includes a fairly organized set of original observations or measurements and, if appropriate, data tables 6	Maintained a somewhat detailed record of activity describing the specific procedures. Includes set of original observations or measurements and, if appropriate, data tables 4	Maintained a sketchy record of activity describing only major procedures. contains partial set of original observations or measurements that may be lacking data tables 2

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
3.1	**Data Analysis** ***Thoroughness***	Developed a thorough, well-organized description of how the data was analyzed to answer the question including extensive and appropriate tabulations, calculations, graphs, diagrams, and statistical analysis and tests 8	Developed a description of how the data was analyzed to answer the question including appropriate tabulations, calculations, graphs, diagrams, and statistical analysis 6	Developed a somewhat limited description of how the data was analyzed to answer the question including some appropriate tabulations, calculations, graphs, diagrams, and statistical analysis 4	Developed a sketchy or disorganized description of how the data was analyzed to answer the question including inadequate or inappropriate, tabulations, calculations, graphs, diagrams, and statistical analyses 2
3.2	**Conclusions** ***Persuasiveness***	Presented a well-reasoned and organized presentation of all appropriate conclusions supported by the analysis. Including unplanned but substantiated interpretations 4	Presented a reasoned and organized presentation of appropriate conclusions supported by the analysis 3	Presented an organized presentation of conclusions based on the analysis that are somewhat justified by the analysis 2	Presented a sketchy, incomplete presentation of conclusions with weak connections with the analysis 1

Source: Goals 2000 MST Performance Assessment Project

		Accomplished	Proficient	Developing	Beginning
3.3	**Draft Report** ***Organization***	Developed a draft report with sections all that contain the essential elements for describing the problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research 4	Developed a draft report with sections most of which contain the essential elements for describing the problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research 3	Developed a draft report with sections at least one of which contains the essential elements for describing the problem, methods of investigation, and analysis, interpretations, conclusions, or suggestions for further research 2	Developed a draft report with sections with sketchy descriptions of the problem, methods of investigation and analysis, interpretations, conclusions, or suggestions for further research 1
3.4	**Final Report** ***Completeness***	Developed an improved report with sections (problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research) all of which are well written and have thorough, accurate, descriptions 8	Developed an improved report with sections (problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research) most or which are well written and have thorough, accurate, descriptions 6	Developed an improved report with sections (problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research) most of which are not well written and do not have thorough, accurate, descriptions 4	Developed a report with sections (problem, methods of investigation and analysis, interpretations, conclusions, and suggestions for further research) almost all of which are not well written and do not have thorough, accurate, descriptions 2

Source: Goals 2000 MST Performance Assessment Project

How the MSTe Project Links Mathematics, Science, and Technology Education

Background

The MSTe Project uses a design and construction technology model that involves a commitment to constructivist teaching practices and the use of design portfolios to facilitate this process and for use as an assessment tool. At the heart of this project is the involvement of elementary teachers in design problems that invite construction of products and processes that are connected to science and mathematics concepts. The primary purpose of the MSTe project is to redefine the role of the teacher by helping teachers to discover how to make students "passionate participants" in the instructional process.

The stated mission of this project is to engage elementary school teachers in scientific inquiry, mathematical analysis and engineering design as a tool for problem solving, while conforming to local state frameworks. In fact, the teachers in this project are creating integrated mathematics, science and technology (MST) experiences for their students that connect to a multi-disciplinary approach to science teaching and learning. The New York State Frameworks for Mathematics, Science and Technology Education are guided by learning standards that inform this project. These standards emphasize:

• engaging students in inquiry, design and problem solving
• accessing and generating data through the use of information technologies
• making connections between mathematics, science and technology
• embedding experiences in a real-world context.

The following scenario situates two elementary school teachers in the context of the MSTe project and addresses the enormous shifts they made in their pedagogy as a result of their experience in this project. These two participants experienced a drastic change in pedagogy from being largely teacher directed to creating an open-ended classroom environment where students' experiences and self-generated challenges direct the flow of the investigations. Both teachers, Diane and Katie, also speak to the influence of design technology and the use of the "Design and Technology Portfolio" as an assessment tool. Diane's experiences are explored in this paper through the analysis of site visits, videotapes of classroom lessons, observations of presentations made at the project mini-conferences, and interviews.

Beginning the Design Process with Soap Bubbles

> "Blow a soap bubble and observe it. You may study it all your life and draw one lesson after another in physics from it."
>
> Lord Kelvin (Ramme, 1995)

Central to the MSTe experience is the integration of design challenges that engage teachers and students in the design process. This process involves identifying the problem to solve, the specifications for the design, the constraints that limit your solution, your own personal research and the plan, construction and test of your product or process. This "T" in MSTe stands for design technology and is an important part of opening up the process of teaching and learning. It is consistent with constructivist teaching practices that encourage students to invent their own theories and test them out.

The participating elementary school teacher teams were immersed in their first summer of introduction to the MSTe project in the mathematics, science and technology of soap bubbles. Using a variety of materials, the teachers were engaged in a range of activities, *none of which had clearly defined steps* and some challenges that had ill-defined problems. Teachers were initially asked to construct ideas around the following challenges:

• What is the relationship of bubble size to bubble solutions?
• How can you derive "pi" using bubble prints?
• How do bubbles form?
• What makes bubbles last?
• Design and construct a bubble maker that conforms to your own set of specifications; in other words, design your "favorite" bubble maker.

The teachers' immersion in soap bubbles became the metaphor for examining problems and solutions from the base of their own lived experiences. The team understood the importance of engaging the teachers in open ended problem solving where the discourse became "How do we design the investigation?" and "What kind of data is this? Is it reliable?" While some teachers struggled without precise directions, many teachers thrived on their own sense of accomplishment and, for some, their new found sense of competence – both as thinkers and builders of theories, products, and processes.

Through their work with bubbles, many teachers began to glimpse the value of engaging students in open ended inquiry, sustained over time, while being provided with materials, reflective guidance and support. Pervading the experience was the expectation that teams of teachers would construct their own meaning from these challenges (Brooks & Brooks, 1993) and that scientific inquiry was an investigative process of "trying to find out" (Koch, 1999a).

Using design challenges as an opportunity to engage teachers in their own thinking, planning and construction is a useful tool for building environments that welcome and foster multiple responses. Bubble maker designs were valued and exciting. There was no hierarchy of "better" or "best" when teachers presented their constructions.

The Classroom Experience

Diane and Katie are veteran teachers. Diane teaches third grade and Katie is the elementary science consultant who team teaches with elementary teachers in their classes. As Diane began her third grade school year, Katie was her support system by actively engaging with Diane to plan classroom experiences and support each other through this change process, i.e., the shift in their pedagogy from a more teacher directed to a more student directed environment.

The outside evaluator who visited Diane's third grade classroom in the first year of the project used both the *NSF Core Evaluation* Classroom Observation Protocol and open ended written responses (Haile, 1998). The Key Indicator Ratings were presented on a Likert type scale with (5) being the highest score. Diane's instruction was rated on her ability to facilitate small group investigations, evaluate the validity of claims or arguments, work on solving real world problems, and assist students in interpreting data. Her scores were high in all categories and she scored a (5) on “Design of instruction is extremely reflective of best practices in science education.” The written comments were telling:

“Diane helped facilitate critical thinking by encouraging students to write about their hypotheses and their ideas. She stimulated the students to write their ideas by beginning with ‘This is what I think...’ Students were asked to write a plan: what my group will do...’ Her tone was encouraging and friendly; students were completely engaged in solving their own problems about ‘What happens to water when it is heated or cooled?’ She made all supplies available and students were responsible for designing the investigations. Students shared roles in the process of investigation; some gave out materials; others wrote the plan, etc. The teacher consistently probed for student’ reasoning and helped to clarify their statements by repeating them back to the students.”

When I watch the videotapes, it is Diane’s respect for the students’ thinking that jumps out at me in the classroom discourse. “I am interested in what you are thinking” she says to the students. The students respond in what appears to be a risk free environment. As students were exploring water in a fish tank and recording their observations, one group noticed that a student’s hand appears bigger when seen through the water. Another student noticed that when you slide your hand on the outside at the corner of the tank, it seems to disappear. Diane encouraged them to design an investigation to explore why the hand disappeared! Honoring the students’ questions is a priority for her. When asked how this differs for her, she explained that, in the past, she felt she always needed to control the events of the lesson. “When I began to do design challenges with them, I noticed that the children are able to take control of their own learning and that they *need* to!” This speaks to the use of design challenges as an important vehicle for helping teachers to shift their pedagogy.

She then related a story to me about planning a detailed lesson about surface area. She wanted the children to understand the concept of surface area and she used little square shapes to pace the children through a planned activity. “The lesson did not go right; the children were really confused; the whole lesson bombed. I asked them, ‘what happened here? What went wrong?’ It seems that the squares they were using had too much depth and it confused them. They got distracted by the depth of the cube and could not focus on the surface. We have to trust the students; they will tell you what they do not understand. Sometimes they will try to please you and play along as if they understand ...you have to observe when they are doing that” For me, the whole issue is about trust and control. I ask myself, what will it take to honor the students as “knowers”? How do I get out of the way so I can really listen to what they are saying” (Interview, 1999).

In a recent presentation to the other participants in the project Diane spoke about how her students have reflected on the process of design challenges and planning investigations. The following list of quotes are representative of her students’ feelings.

Lisa: “I brought this remote control in and took it apart to show everybody the behind-the-scenes of how it worked.

Mike: Checking twice is helpful to your design.

Matt: I noticed that my mouth worked just like a hinge.

Ally: Learning is something different to us now.

Al: The biggest learning tool we can give to others is to tell them to use models to help them with their challenges.”

Implications

Shifts in pedagogy lie at the heart of this project and the process of design and construction facilitates an understanding of student centered learning. It offers an important contrast to traditional "hands-on" elementary science experiences that frequently follow prescribed steps and result in pre-determined outcomes that are judged "right" or "wrong." We have learned in the MSTe project that when students take control of their own learning with supportive teachers reflecting their ideas back to them that the true meaning of inquiry and design is modeled by their investigations.

As we look to the future of science education in the next century, we can explore the role of science education in the MST education framework.

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Mathematical Explorations Using Science and Technology

Sharon Whitton, Ph.D.
Hofstra University

All of us, children and adults alike, can learn a great deal about mathematical relationships by designing and building our own physical structures. The relationships we discover will be more meaningful to us than if we relied on the interpretations of others or studied the same ideas in written form. When we make our own structures, we gain first-hand knowledge about the physical world and how it operates. By building our own structures, we must consider the individual parts that comprise the structure and the physical relationships for connecting them. Once the individual parts are identified, they must then be assembled to create the structure in its entirety. Consequently, the whole enterprise of constructing a physical object is a problem-solving process involving critical analysis, physical dexterity, and creativity. In a very concrete sense, it validates the study of mathematics and is one of the best ways to unify theory and practice.

[Figure 1—Children learn best by constructing their own shapes.]

The study of geometric shape, in particular, is inter-disciplinary. It integrates mathematics, science, technology and art. For instance, scientists use polyhedra to model molecular structures; artists are experts in applying perspective and proportion; architects and engineers rely heavily on the properties of shape and stability; optical devices such as telescopes and lenses are designed using conics; and CAT scan diagnosis requires reconstructing images from pictorial cross sections. Thus, shape is an integral part of our modern world. Moreover, shape is a unifying concept for all of mathematics. The study of shape requires measurement, spacial sense, logic, computation, and many other skills.

More importantly, the study of shape is fun; at least, it ought to be. Students of all ages enjoy making their own shapes. Hands-on geometry in a laboratory setting is highly motivating and less

Source: Dr. Sharon Whitton, Hofstra University

likely to offer the resistance often encountered with traditional approaches.

I have used the following activities successfully with students spanning a wide range of grade levels . The goal of each activity is to engage students in their own discovery of the underlying properties of three-dimensional shapes.

Classifying Shapes

We cannot communicate our thoughts without vocabulary. Therefore, assigning names to things, whether they are people or shapes, is a first step toward classification. Unlike names for human beings, names for geometric shapes are not arbitrary; they help us encode the characterizing properties for classifying them. For example, a *tetrahedron* is a type of polyhedron (a 3-dimensional shape made of polygons); the prefix, tetra, indicates that it has exactly four faces.

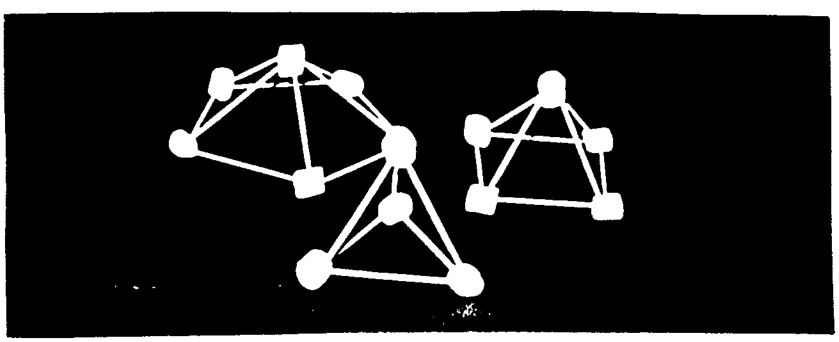
Children love to use tooth picks and marshmallows to create *polyhedra* (plural for polyhedron). When they build cubes, tetrahedra, prisms, or shapes of their own design, children gain more insight into relationships, measurement, and stability than by just examining them. While building these structures, children will discover that certain shapes will collapse easily whereas others always retain their shape. Such discoveries were made by our ancestors thousands of years ago when they began to build bridges and houses.

Activity--Constructing Polyhedra (Grades 3-12)

Pyramids. Invite students to create a triangular pyramid (tetrahedron). Begin by constructing a triangle with three tooth picks used for sides and three marshmallows for the vertices. Then guide students to place a tooth pick sticking straight up from each of the marshmallows. These three tooth picks should then be brought together and stuck into a single marshmallow centered above the triangle. (Younger children may need help with this process).

Explain that a *pyramid* always has a sharp point (vertex) centered above its base and that a pyramid is named according to the shape of its base. So, it is possible to have square pyramids, pentagonal pyramids, hexagonal pyramids, and so on.

1. Invite students to create a square-based pyramid--like the ancient Egyptian pyramids; then challenge them to create a pentagonal pyramid.

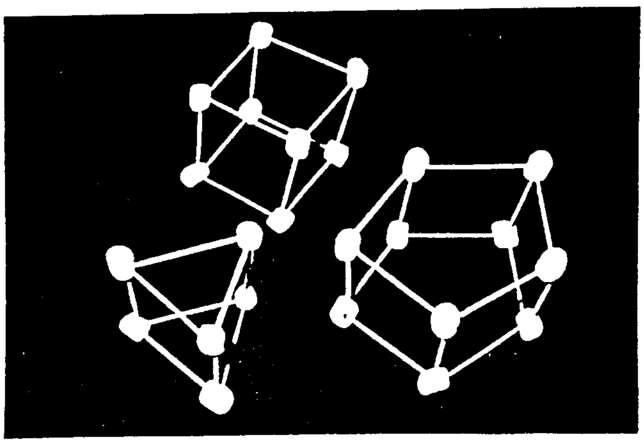


[Figure 2 -- Pyramids made with tooth picks and marshmallows.]

Source: Dr. Sharon Whitton, Hofstra University

Prisms. Explain that a *prism* has two bases that are just alike and parallel to each other. For example, a *triangular prism* has two bases that are triangles. To construct a triangular prism, begin by making two identical triangles. Then, take one of the triangles and place a tooth pick sticking straight up from each of its three vertices (marshmallows). Next, connect the unattached end of each vertical tooth pick to a vertex of the second triangle. Presto! Now we have a triangular prism. Notice that the bases are identical triangles and that they are parallel to each other.

2. Challenge students to create a square prism (cube) and then a pentagonal prism.



[Figure 3 -- Prisms made with tooth picks and marshmallows.]

3. Invite students to create shapes made of combinations of pyramids and prisms.

4. Determine which shapes are more likely to collapse than the others and to record their findings in writing. They will quickly discover that shapes made with triangles are sturdy and those made with squares will collapse.

Older children (grades 5 and up) enjoy discovering the fundamental theorem of convex polyhedra (polyhedra that do not dip inward). This theorem, also known as *Euler's Theorem*, concerns a relationship among the number of vertices, faces and edges of these shapes. The following activity will provide the necessary information for students to discover this relationship on their own.

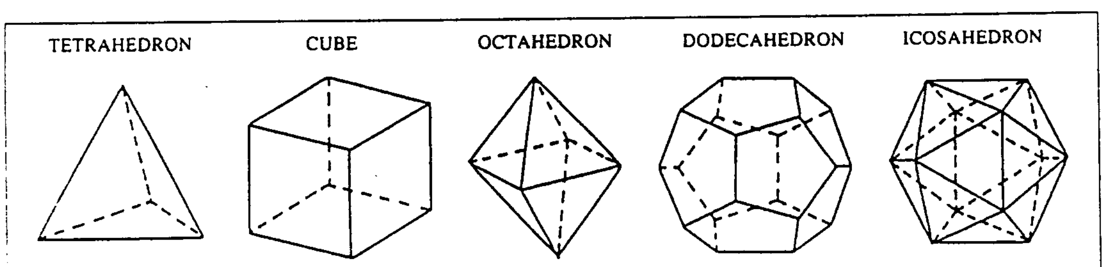
5. Invite children to count and record the number of vertices (marshmallows), faces, and edges (toothpicks) of each of their polyhedral shapes. Encourage them to share their information with others in their class and to compile their information into a single chart, similar to the following:.

	# of Vertices	# of Faces	# of Edges
Cube	8	6	12
Tetrahedron	____	____	____
Sq. Pyramid	____	____	____
Triangular Prism	____	____	____

Guide students to discover the relationship by the following question: For each shape, what can you do to the number of vertices and faces in order to determine the number of edges for that shape?

6. Related research topics for grades 9-12 could be an examination of the shapes of natural crystals (e.g., pyrite, sodium chlorate, chrome alum), the design of kaleidoscopes, the molecular structure of silicon, and the history of Platonic Solids.

With respect to Platonic Solids, a major achievement of the ancient Greeks was the discovery that there exists exactly five *regular polyhedra*. These are defined as convex, three-dimensional shapes composed of congruent regular polygons, having the same number of polygons meeting at each vertex. Plato's academy was so excited by this discovery that they developed a theory of matter based on these shapes. This topic remains a fascinating topic even today.



[Figure 4 -- There are exactly 5 regular polyhedra.]

Source: Dr. Sharon Whitton, Hofstra University

MSTe Challenge: Construct a connected structure, using only tooth picks and marshmallows, that will support the weight of a single volume of an encyclopedia for a period of at least 60 seconds.

Bubble Geometry

Children are tremendously delighted with bubble geometry. Try it yourself! The following recipe makes very strong bubbles that will not pop easily. It can also be re-used for months.

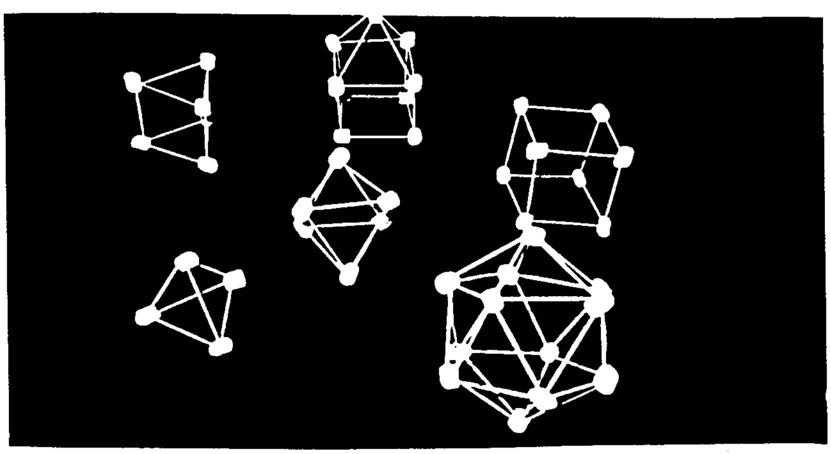
Bubble Brew
1 quart water
4 ounces liquid detergent (ultra concentrated brands work best)
3 tablespoons glycerin (found in your local drug store under skin products)

Most children are already familiar with spherical bubbles and should be encouraged to make them with a variety of blowers they have constructed. Comparisons of bubble sizes will naturally bring about considerations of circle measurement and related geometric properties. Teachers should take this opportunity to teach more about the geometry of circles.

Spherical bubbles are quite fun to play with, but there is an important question we should consider. "Would it ever be possible to create bubbles of different shapes?" In particular, "Is it possible to make cubical or tetrahedral bubbles?" The very idea that bubbles may not always be spherical will probably be unfamiliar to children as well as to adults.

Activity--Polyhedral Bubbles (Grades 5-12)

Building upon their previous experiences with polyhedra, students should be invited to build bubble frames using gum drops and tooth picks. They should use gum drops for these activities because, unlike marshmallows, gum drops remain firm when dipped into bubble solution.



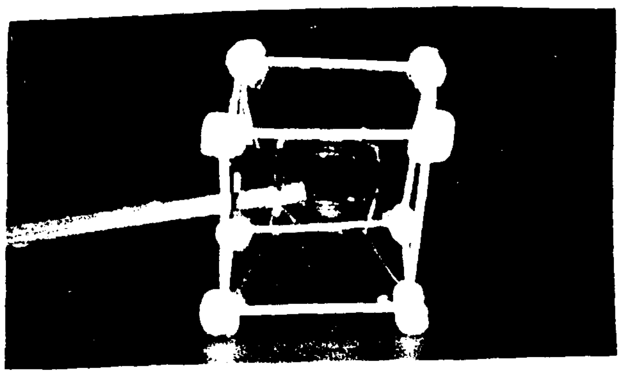
[Figure 5 -- Polyhedra made of tooth picks and gumdrops.]

Source: Dr. Sharon Whitton, Hofstra University

7. With the given materials, encourage students to create cubes, tetrahedra, prisms, and other types of polyhedra. Demonstrate for them how to do the following:

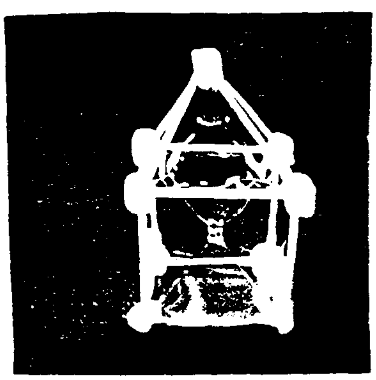
   - Submerge the shapes in the bubble solution so that they are completely covered. For each shape, children should be encouraged to make a list of all of the different plane figures formed by the soap film inside of the frame. These may include triangles, squares, parallelograms, trapezoids, and the like.

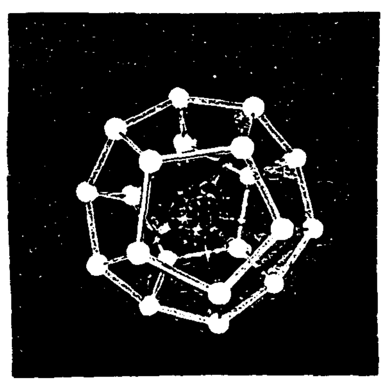
   - Then, wet a drink straw with bubble solution and blow ever so gently into the center of each shape, within the region where the bubble planes intersect. WOW! Now, what do you see?



[Figure 6 -- Blow gently into the center of the intersection of the bubble planes to create a suspended polyhedral bubble.]

Students will discover that some shapes make highly complex, exciting bubbles.





[Figure 7 -- Suspended polyhedral bubbles.]

There is a great deal of mathematics and physics to be found in the study of bubbles. The following are other questions that may be considered in the bubble activities:

- Is it possible to accurately predict the shape of a suspended polyhedral bubble inside of a polyhedral frame?

Source: Dr. Sharon Whitton, Hofstra University

[Anticipated response: Yes, the suspended bubble usually takes the shape of its frame, i.e., a suspended cubic bubble has a cubic frame.]

- How many bubble planes intersect at a single point inside of a polyhedral frame? [Anticipated response: Exactly six planes.]

- How many edges come together at an intersection point of bubble planes within a polyhedral frame?
  [Anticipated response: Exactly four edges come together at an intersection point of bubble planes.]

In conclusion, meaningful study of shapes should be hands-on and exploratory. It crosses the entire curriculum and all grade levels. With imaginative teaching, it can be used as a means for showing the connections of mathematics to nature, art, history, and modern technology. Teachers should seize the opportunity to explore the properties of shapes with their students and become partners in learning.

Helpful resources include:

Bell, J. L. *Soap Science*. New York: Addison-Wesley Publishing Company, 1993.

Isember, Cyril. *The Science of Soap Films and Soap Bubbles*. New York: Dover Publications, 1992.

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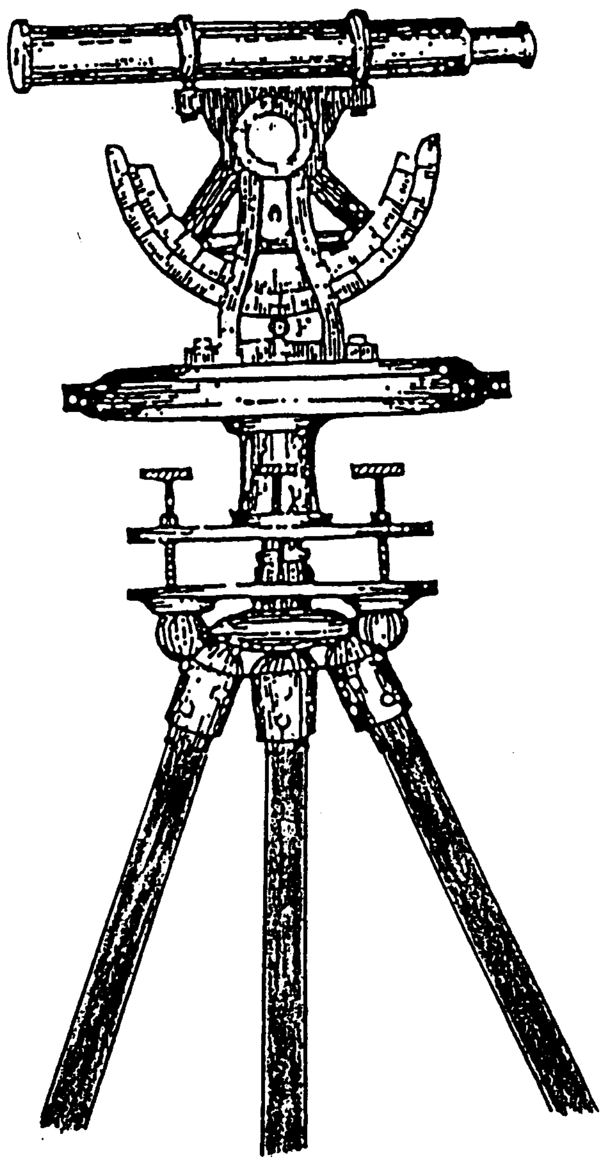
Source: Dr. Sharon Whitton, Hofstra University

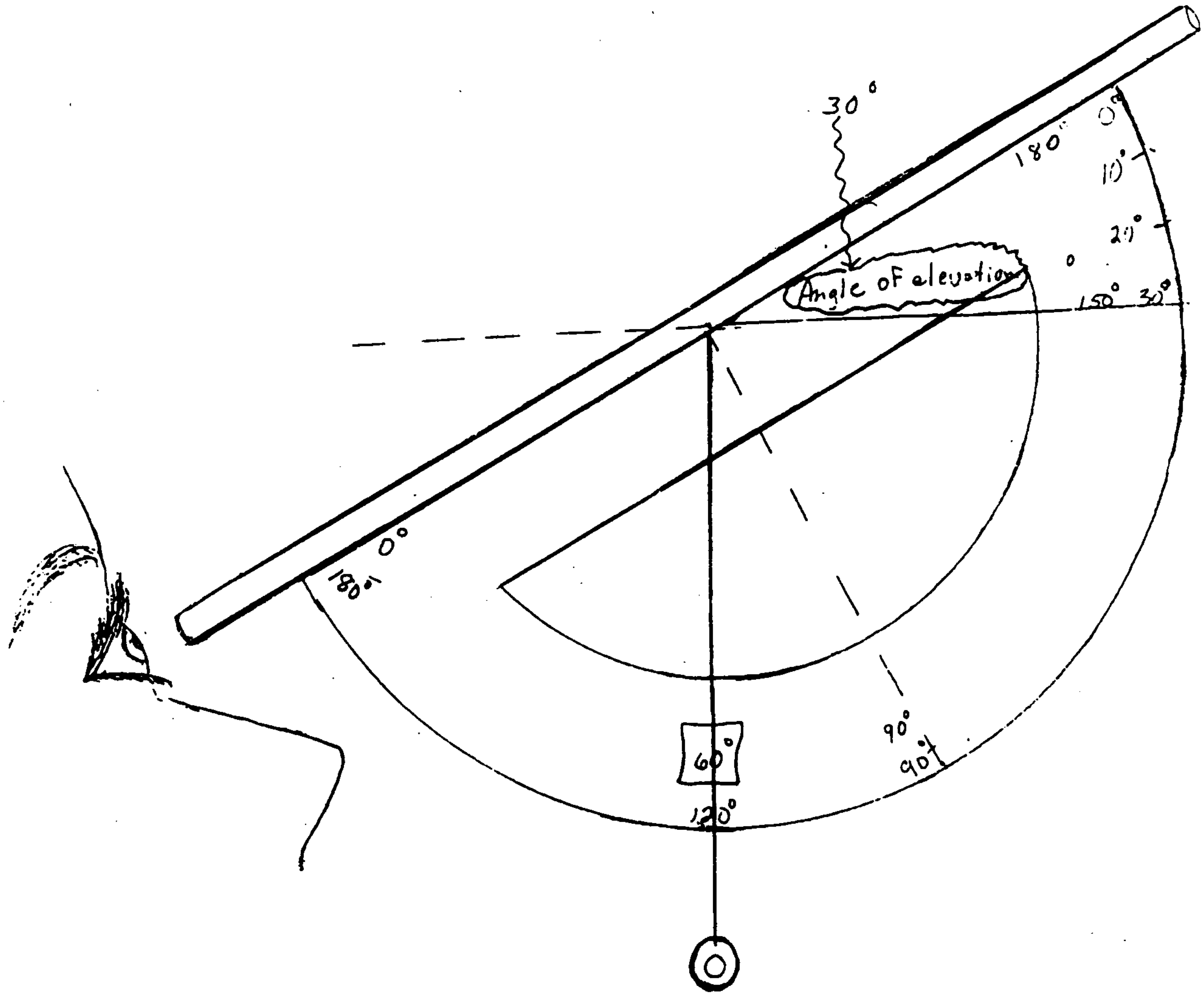
Measurement with Clinometers

During the unit on habitats, students create models of habitats using measurements, ratio and proportion, and scale drawings. They can determine the heights of very tall objects with the clinometers they create, as described on the following pages.



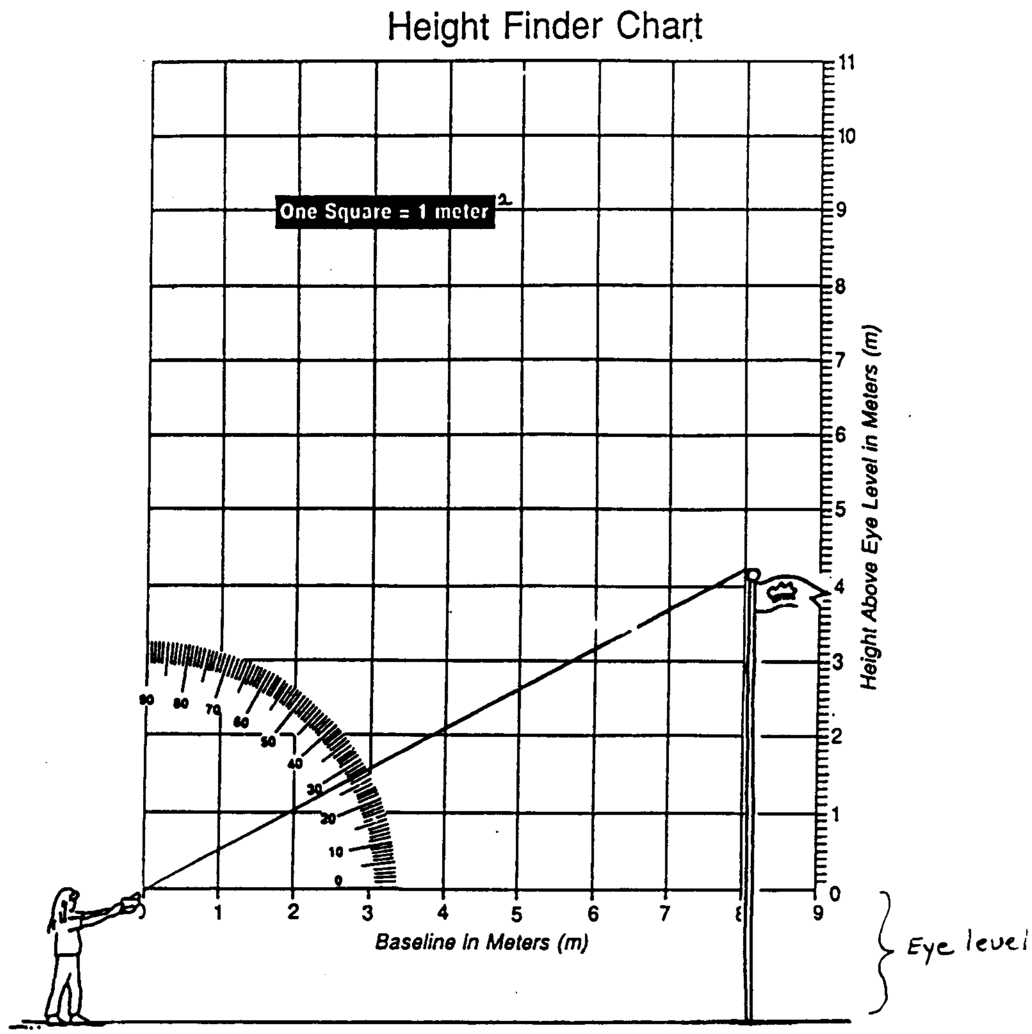
Source: Dr. Sharon Whitton, Hofstra University

Build Your Own Clinometer



Angle of elevation = 90° - 60° = 30°

Source: Dr. Sharon Whitton, Hofstra University



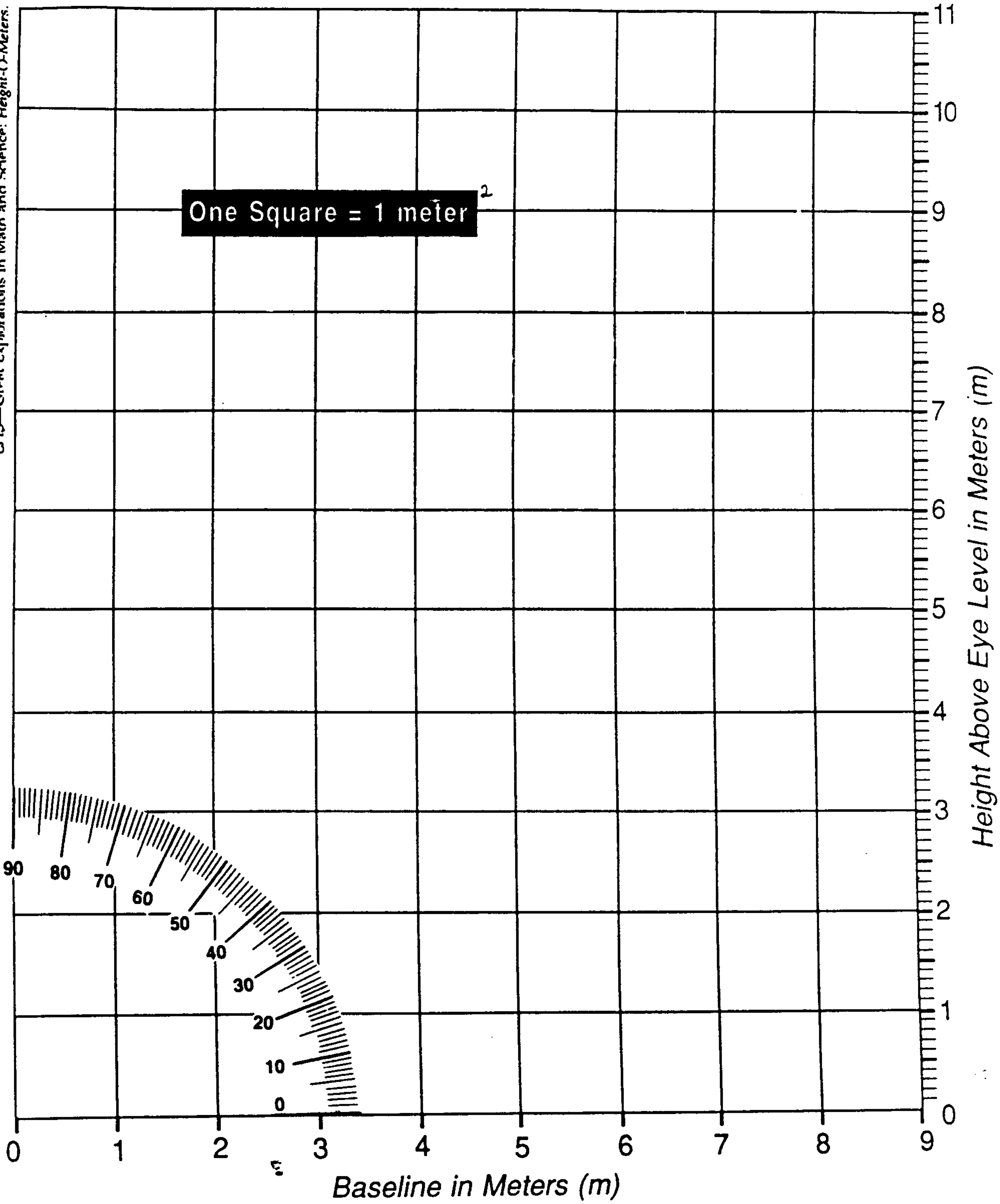
FIND THE HEIGHT OF AN OBJECT WITH A HEIGHT FINDER CHART

Height of object = _____ m *(from chart)* + _____ m *(eye level)* = [   ] m

Source: Dr. Sharon Whitton, Hofstra University

Name ________________

Height Finder Chart



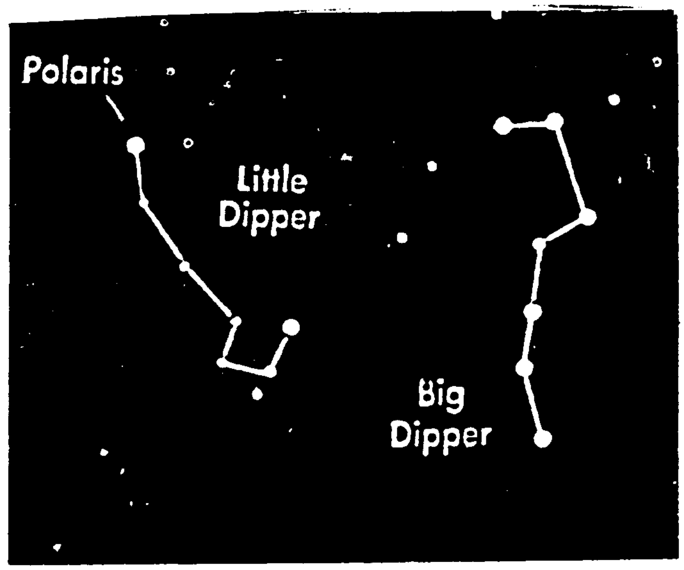
Height of object = _____ m (from chart) + _____ m (eye level) = [   ] m

Source: Dr. Sharon Whitton, Hofstra University

FIND YOUR LATITUDE WITH THE CLINOMETER

Directions:

Locate Polaris in the viewfinder (straw) of the clinometer. Read the angle of inclination.



Results:

1. The North Star will be located.
2. The angle of the North Star will be determined.
3. The latitude of the observer is equal to the elevation of the North Star at that point.

Supplemental Information:

1. The latitude of the North Star at the North Pole is 90° and would be directly overhead.
2. The latitude of the North Star at the equator is 0° and would be directly horizontal if you could see it. The chances are that mountains, trees, houses, etc. would block it from your view.

Source: Dr. Sharon Whitton, Hofstra University

FIND THE HEiGHT OF AN OBJECT USING THE TANGENT OF AN ANGLE

Definition:

$$\text{Tangent}(\theta) = \frac{Y}{X} = \frac{\text{Opposite side}}{\text{Adjacent side}}$$

$$X \cdot [\text{Tangent}(\theta)] = \cancel{X} \cdot \frac{Y}{\cancel{X}}$$

$$X\,[\text{Tangent}(\theta)] = Y$$

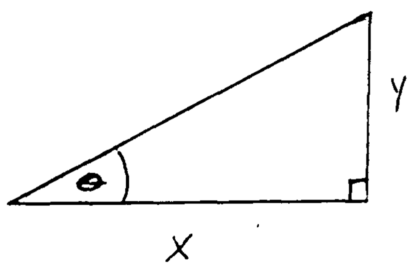


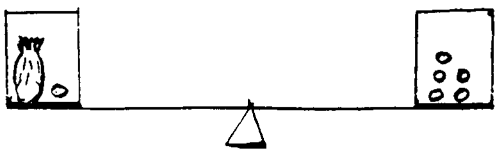
Table of Tangents, Cosines, and Sines

∠	TANGENT (opp./adj.)	COSINE (adj./hyp.)	SINE (opp./hyp.)	∠	TANGENT (opp./adj.)	COSINE (adj./hyp.)	SINE (opp./hyp.)
0°	.0000	1.0000	.0000	45°	1.0000	.7071	.7071
1	.0175	.9998	.0175	46	1.0355	.6947	.7193
2	.0349	.9994	.0349	47	1.0724	.6820	.7314
3	.0524	.9986	.0523	48	1.1106	.6691	.7431
4	.0699	.9976	.0698	49	1.1504	.6561	.7547
5	.0875	.9962	.0872	50	1.1918	.6428	.7660
6	.1051	.9945	.1045	51	1.2349	.6293	.7771
7	.1228	.9925	.1219	52	1.2799	.6157	.7880
8	.1405	.9903	.1392	53	1.3270	.6018	.7986
9	.1584	.9877	.1564	54	1.3764	.5878	.8090
10	.1763	.9848	.1736	55	1.4281	.5736	.8192
11	.1944	.9816	.1908	56	1.4826	.5592	.8290
12	.2126	.9781	.2079	57	1.5399	.5446	.8387
13	.2309	.9744	.2250	58	1.6003	.5299	.8480
14	.2493	.9703	.2419	59	1.6643	.5150	.8572
15	.2679	.9659	.2588	60	1.7321	.5000	.8660
16	.2867	.9613	.2756	61	1.8040	.4848	.8746
17	.3057	.9563	.2924	62	1.8807	.4695	.8829
18	.3249	.9511	.3090	63	1.9626	.4540	.8910
19	.3443	.9455	.3256	64	2.0503	.4384	.8988
20	.3640	.9397	.3420	65	2.1445	.4226	.9063
21	.3839	.9336	.3584	66	2.2460	.4067	.9135
22	.4040	.9272	.3746	67	2.3559	.3907	.9205
23	.4245	.9205	.3907	68	2.4751	.3746	.9272
24	.4452	.9135	.4067	69	2.6051	.3584	.9336
25	.4663	.9063	.4226	70	2.7475	.3420	.9397
26	.4877	.8988	.4384	71	2.9042	.3256	.9455
27	.5095	.8910	.4540	72	3.0777	.3090	.9511
28	.5317	.8829	.4695	73	3.2709	.2924	.9563
29	.5543	.8746	.4848	74	3.4874	.2756	.9613
30	.5774	.8660	.5000	75	3.7321	.2588	.9659
31	.6009	.8572	.5150	76	4.0108	.2419	.9703
32	.6249	.8480	.5299	77	4.3315	.2250	.9744
33	.6494	.8387	.5446	78	4.7046	.2079	.9781
34	.6745	.8290	.5592	79	5.1446	.1908	.9816
35	.7002	.8192	.5736	80	5.6713	.1736	.9848
36	.7265	.8090	.5878	81	6.3138	.1564	.9877
37	.7536	.7986	.6018	82	7.1154	.1392	.9903
38	.7813	.7880	.6157	83	8.1443	.1219	.9925
39	.8098	.7771	.6293	84	9.5144	.1045	.9945
40	.8391	.7660	.6428	85	11.4301	.0872	.9962
41	.8693	.7547	.6561	86	14.3007	.0698	.9976
42	.9004	.7431	.6691	87	19.0811	.0523	.9986
43	.9325	.7314	.6820	88	28.6363	.0349	.9994
44	.9657	.7193	.6947	89	57.2900	.0175	.9998
45	1.0000	.7071	.7071	90		.0000	1.0000

Source: Dr. Sharon Whitton, Hofstra University

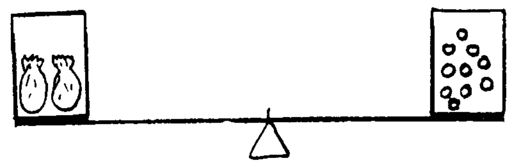
How Many Candies Are In Each Bag?

1.



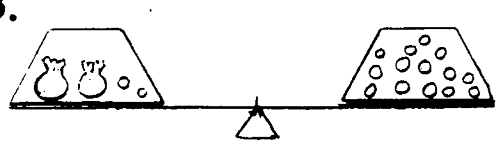
B + 1 = 5

2.



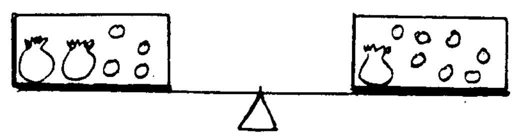
2 B = 10

3.



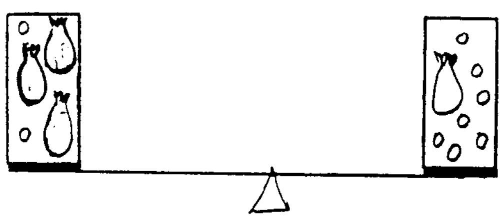
2 B + 2 = 14

4.



2 B + 4 = B + 7

5.



3 B + 2 = B + 7

6. B + 4 = 7

7. 2 B = 18

8. 3 B + 1 = 2 B + 9

9. 4 B = 20

10. 4 B + 3 = 2 B + 9

During the Pulley and Level Unit, students create balance beams. These are used as physical models for solving equations.

Source: Dr. Sharon Whitton, Hofstra University

Barriers to MSTe Implementation

MSTe represents a certain departure from more traditional approaches to teaching mathematics and science at the elementary school level. It also introduces an additional element – technology – which is often not explicitly addressed in existing curricula. The MST learning model asks the teacher to serve as a facilitator of inquiry-based learning activities in each of these disciplines. Such activities reflect the processes by which new knowledge is generated in the actual practice of mathematics, science, and technology. They also illustrate the synergistic relationship between these disciplines in such a way that learning in each area is re-enforced. Finally they provide sufficient latitude for exploration that students have a significant role in developing their own knowledge bases.

Since MSTe is non-traditional in a very real sense, it represents change. New requirements and conditions must be met if the MST approach is to be effectively implemented in the classroom, school, or district. Almost certainly, barriers will also be encountered in attempting to meet these requirements or achieve these conditions. Some of the significant barriers that may arise in the process of implementing an elementary MST program are discussed below:

Need to Build Administrative Awareness and Support

Generally, what goes on in the MST classroom will not look like a the "standard model" class, with students sitting at their desks in rows, busily writing in workbooks. At least initially, administrators who are used to the standard model might think that the MSTe classroom simply does not provide an effective learning environment. Teachers' evaluations, of course, depend upon observations made by such people. They are also responsible for allocation of resources, preparation/release time, building parent/school board support, etc. vital to the development of an effective MSTe program. Perhaps the most vital step in overcoming all barriers to MSTe implementation is to offer an explicit convincing demonstration to senior administrators that (1) learning does indeed occur in the MSTe classroom; and (2) it is a rich environment in which students are learning how to think, as well as derive and master content, and are using these skills in individually rewarding activities.

Perceived Disconnects with Standards and Testing

To a great extent, what goes on in classrooms is driven by State learning standards, and more importantly, exactly what is asked for in tests to demonstrate how well a particular school is meeting these standards. Traditionally, State and local tests have stressed explicit content knowledge – more or less standard definitions and calculations were asked for in problems, and answers were either right or wrong. There is now a growing trend, particularly at the primary level, toward asking students to perform tasks using their own methodologies.

Still, the question of how much classroom effort should be devoted to covering "hard" content and how much to process is far from resolved in the mind of educators or the public. There are also questions about how content should be taught. There is less recourse to drill but elements of it still remain – such as asking students to memorize definitions of long lists of scientific vocabulary words, taken largely out of context. Thus, the question of how rigorously the MST approach can address State standards and provide requisite content knowledge – while encouraging children to develop their own knowledge bases – may be a real barrier to implementation. This might be addressed by first demonstrating that the overall MSTe approach specifically addresses virtually all of the State MST Learning Standards. Second, it should be made clear that, while students will be expected to discover a good deal of content in their own explorations or projects, sufficient background will be provided *a priori* and during the activity to support a meaningful course of investigation. Lastly, it should be pointed out that a group debriefing will be held at the end of each activity in which both the key content elements as well as the process steps encountered in the activity will be explicitly identified, reviewed, and summarized.

Need to Recruit and Prepare Teachers

MSTe requires teachers to act increasingly as facilitators of student learning rather than as instructors. Teachers must first develop scientific questions, engineering problems, and lines of mathematical inquiry to lay before their students. As much as possible, an activity should involve elements of more than one discipline. Within the activities the teachers should allow the students to work as independently as possible, while providing guidance – preferably as leading questions rather than statements – to maintain a focus on educational objectives. The teacher must then effectively extract and summarize what has been learned as a whole in the course of the activity, and finally determine how well the educational objectives have been met by the individual students.

This is a very different role from that in which the teacher tells students things, makes explicit homework or lab assignments or conducts discussion sessions to reinforce what has been said, and then gives exams to see how well they got it. In a real sense, the MSTe teacher is being asked to put more trust in his or her students as self-learners. Thus, if the activity does not provide an environment where students can learn in this manner, the exercise fails. Teachers must have real confidence that such activities can in fact be designed and that it is worth the trouble, or they simply will not try MSTe. The fact that many teachers may lack this trust and confidence, absent any experience to the contrary, can be a major barrier to MSTe implementation. Probably the best, if not the only, way to begin to address this issue is to provide opportunities for candidate teachers to see MSTe in action – with students. Support for this at the administrative level is essential.

If, as described above, we ask that MSTe teachers facilitate the students' extraction of process and content principles from their MSTe activities, the teachers themselves must be able to recognize the presence of these principles in the activities. This may require background at a deeper level than that provided by kit vendors. A teacher using an activity where his or her knowledge base does not extend beyond what is to be expected of the students will require access to consultants or additional resources to be a really effective facilitator. Having to provide this assistance can also present a barrier to MSTe implementation. The extent to which it does so will depend on teachers' backgrounds and activities chosen and should be a key consideration in planning the curriculum.

Additional Resource Requirements – Physical and Human

MSTe is based on hands-on inquiry, often by students working in teams, and involving projects which may run for some time. Implementation will require that materials be on hand –

either as purchased kits or individual items – as well as adequate classroom work space. Moreover, since MSTe activities may call on students to develop their own information resources, some level of access to both hard copy reference material and the Internet should be available.

Any MSTe implementation program will make special demands on key people - in developing pilot activities, in conducting awareness programs for administrators, school boards, parents and the general public, in recruiting and helping to prepare other teachers, etc. Effective communication between teachers involved in the implementation process at different schools is also essential, so that both resources and lessons learned can be shared as the process proceeds.

Absent creative ways of meeting these resource, a real barrier to MSTe implementation will exist. The question of physical resources is perhaps best addressed by first ensuring that the greatest possible use is made of materials, etc. already on hand, but used in different ways. The human recourse issue is primarily one of finding time – for key people work cooperatively to carry out the elements of the MSTe implementation process mentioned above. If these people are themselves classroom teachers and sufficient reallocation of their time to MSTe implementation is not possible, a virtually insurmountable barrier to effective MSTe implementation will exist.

Need for New Testing and Evaluation Protocols

Like other learning activities, the well-designed MSTe "lesson" will have well-defined learning objectives. However, teachers may find themselves dealing with activities that do not lead to unique "right" answers. Instead, both the student's grasp of process and content may be embedded in the outcome of a group activity. Here judgment will be required on the part of the teacher to assess what a student knows or is able to do. This, in turn, will require a critical perspective not too different from what is involved in judging student science fair projects**.** One looks for certain things, some of which can be easily identified (e.g., which bridge held the most weight) and others which are more subtle (e.g., what if anything did the students learn about the basic math and science principles which apply to the problem and was any attempt made to apply these in a rational way). Thus, to a certain extent, implementing MSTe will call for changes in teachers' approaches to grading and a recalibration in terms of what to look for. Administrators will have to buy into the notion that such performance-based approaches can indeed provide a meaningful measure of what has been learned. Clearly, both requirements can present barriers to implementation.

Classroom Management Issues

In the MSTe classroom, different students will be doing different things, or the same thing in different ways, singly or in groups. This can present problems in classroom management which, if not anticipated and planned for, will be a major barrier to effective MSTe implementation. Again, space should be adequate and workstations, materials, etc. efficiently organized. This should not present an insurmountable obstacle; art and technology teachers have been working this way for years. Moreover, if MSTe is to be implemented on a large scale, both team teaching and the services of an MSTe resource person would be helpful in overcoming this barrier.

Never, ever…

…call on a student if their hand is not raised.
…call on a student who you know does not know the answer.
…call on the same child all the time.
…compare students.
…have "favorites".
…make students copy on the board when it is just tedious.
…give repetitive writing.
…call out students' grades.
…make student do 50 problems when 5 is enough.
…give homework over the weekend or vacation.
…restrict students movements.
…restrict creativity.
…be afraid of messiness.
…prohibit questioning.
…prohibit students from reading ahead or by themselves.
…punish a whole class for a few students who break the rules.
…discount student opinions or emotions.
…ignore students questions or comments.
…deny curiosity.
…"knock" or criticize a student for his/her approach.
…make a student feel small or insignificant.
…forget to mark and return student's work in a timely fashion.
…embarrass, verbally abuse, or degrade a student.
…speak sarcastically or condescendingly.
…frustrate a student.
…make a student feel unworthy.
…be unprepared.
…be negative.
…be routine.
…tell boring stories.
…talk too much.
…chalk and talk.
…yell.
…lose your temper.
…give unannounced tests.
…use materials that students can't touch.
…teach by book ("turn to page…").
…give busy work.
…give answers (allow discovery).
…be inconsistent.
…consider limits on potential.
…lose the excitement for teaching.
…say "never, ever."

Structuring Learning Environments for Collaboration

A learning environment needs to meet the needs of all involved. Learning styles vary from student to student and from subject to subject. How can we meet all these variables? To meet individual learning needs, the student needs to be an active participant in his or her learning. In order for the student to be an active learner, therefore, you need to consider the student's needs. This is simple to do for one student, but when you have 30 students in a classroom, the task becomes a bit more formidable. Still, if you provide many ways of learning a single concept, then each child will come across the learning style that best meets his or her needs for that particular concept.

Learning Centers

To match students' learning styles and still manage a large class, you can set up learning centers. Learning centers are described in different ways. I am referring to learning centers that all have a common thread. If you are teaching fractions, then fractions is the common thread at each learning center. If you are working on a particular theme, such as weather, then weather is the common thread at each learning center.

The learning centers should also have certain essential elements. Each center should address your curriculum objectives. They should provide a cooperative element for the students. They should provide practice and reinforcement time. They should offer a valid assessment for you and self-evaluation for students. They should address all learning styles (tactile, visual, auditory, etc.).

Managing the Centers

How can you manage all of this? Students can use a progress chart. Progress charts come in many different formats. They can be general to fit any lesson; or you can create one specific to the lesson or theme; or you could set language arts progress charts, math progress charts, etc.

Another good management tool is a rubric. At each center or certain centers there could be a task that needs to be completed and handed in for a grade. You need to set basic classroom rules for work at the centers, such as "three before me," that is, ask three other students for help before you ask the teacher.

Setting learner-paced centers that flow in a clockwise rotation allows you to easily see how each child is progressing. Always explain each center's directions and expectations before rotation begins. Have examples of desired outcomes at each center when appropriate. The purpose of this is not to have children copy the model but to set a good example. If you are teaching a certain style of writing, for example, you will need to give students both a teacher example and a professional example.

Encourage cooperative behavior that is constructive to center activities. Discuss proper center behavior (noise level, movement in classroom, etc.).

An Extension Center

If you were to restructure a whole grade level, you could efficiently use the resources in your entire school. An example of this is called an extension center. For the

Source: Kathy Haack, Westhampton Beach School District extension center approach, you block out time in the day to provide each student the opportunity to study what is most important to that child's success. All the teachers and staff involved with your grade level (resource room teachers, speech teachers, music teachers, art teachers, librarians, etc.) work with those students then, which allows you and each special area teacher to work with small groups of students. The students are not taken from the classroom at all different times in the day. They are only taken at the designated block of time called extension center. We have implemented this in our school district and it allows the enrichment teacher the opportunity to work on very large MSTe projects; everyone on the grade level can participate.

Doing MSTe Projects

I found that the best way to implement MSTe projects is to take a close look at the curriculum for the particular grade level. It is very important not to add another subject but to change the instructional strategies. You may need to do away with a project or two or maybe even some whole group lessons for a particular unit to provide the necessary time to implement another project. As long as you are still meeting your curriculum objectives, everything should be fine. Although MSTe focuses on math, science and technology in the elementary school, it is a good idea to look at the language arts and social studies curricula. There are many ways to build MST into these areas. You could build a very small MST project around a story from the language arts literature, such as building a town after reading the story, *Roxaboxen.* You could create a very large MST project around a curriculum objective, such as a social studies unit on communities or ancient history.

Conclusion

In any case, MSTe and learning center environments provide students with the opportunity to understand fully the objectives being taught. In light of research such as the constructivist theory and the learning pyramid, students need time and a variety of opportunities to process information to develop higher order thinking skills.

Modifying Classroom Environments for MST Instruction at the Primary Level

Most primary classrooms of grades kindergarten through second already implement the idea of centers, or stations. Centers allow teachers to integrate different subject areas with a focus on one theme in different areas of the classroom. Because of these centers, it is very easy to implement MST. We need to remember that MST stands for math, science, and technology. Through the themes each can be achieved.

The themes are usually based on a broad science and social studies topic designed by the New York State Standards and the school district. After the theme is chosen then center areas are designed. Centers can include activities in language arts, math, writing, reading, art, discovery, kinesthetic, fine motor, listening, computers, and technology. Through these activities the children are challenged, can explore, and can develop their own ideas and questions. One thing to remember is that not all of these areas need to be covered. If one of these activities does not fit the theme then leave it out. By leaving it out the true meaning of what your teaching will be apparent. Throwing in extra activities weakens the valuable activities. Eventually somewhere in the theme all of the activities will be covered in a meaningful way.

Many school districts have an abundant amount of activities that each primary grade needs to teach. One valuable lesson we have learned is that “less is more.” What does that mean? It means that spending every week or two on a different theme is not always valuable to the children you are teaching. Many of them need a longer time to grasp certain concepts. Focusing on one theme for a longer period of time and tying in other relevant activities will be more valuable. For example: In first grade animal homes is a science theme designated by the district. By focusing on animal homes the children learn about the desert, the arctic, the meadow, the rain forest, and the woods. Through these areas we branch out into different animals, incorporate the designs of their homes, the measurement of the homes, temperature, word problems, stories, and more. The easiest way to see how much you can get out of a theme is by creating a web.

One of the most confusing activities for the primary grades is technology and design. Often people think technology has to do mostly with computers. It does and it doesn’t. There are many school districts that do not have daily computer access in the classroom. Many students go to a computer lab. Those that have computers in their classroom can use computer programs to help foster the themes. For others the use of scissors, rulers, tracers, glue, hole punchers, crayons, and markers are other forms of technology. They are tools that allow children to create and develop fine motor skills, just as a keyboard and a mouse do on the computer.

Design is the other confusing area. During playtime or activity time, many children construct buildings, puzzles, and pictures. The idea of design is to get the children to make a plan of what they are going to do, do it, and then reflect on their final project. Most teachers do this orally but with MST we want the children to do it on paper first as part of a “Design Portfolio.” The portfolio can easily be done with any primary grade using copy paper. Use two sheets of paper and give the students the idea and parameters of the project. On the first side have them draw a picture of what their project will look like. Remind them it does not have to be perfect. For the more advanced children, have them write a sentence or two explaining their illustration. On the next side have them list the materials they need. Explain it as a recipe. If a cook forgets something the item probably won’t taste right. Then allow them to get their materials and begin construction. When construction is finished have them reflect back on the next page by drawing what their finished project looked like. Many will draw the same thing, but as the children get use to the activity their reflection will be better. Lastly, have the students rate the activity. Draw one star if they didn't like it, two stars if it was okay, and three stars if they would like to do it again. This gives the children ownership of the activity and also allows the teacher to see if the project was beneficial.

The design portfolio process does not work overnight. It takes time and patience but the outcomes are incredible. As the design aspect becomes more comfortable the portfolio can take the shape of the project. For example: The students were exploring a sunflower. They took it apart and counted the seeds and did many other activities with the seeds. The design portfolio was in the shape and color of a sunflower.

By teaching this way it allows all children to participate. These activities are done in small group, mixed grade level groups, and also individually. The children help each other and work at their own pace. It is hard to pick out those children who have difficulties because somewhere one of their strengths is met in these activities. Modifications can be made for students who need it, however, no child ever says I can't, they always want to try and do the best they can do. As teachers, what more can we ask for?

Implementing MST in the classroom can be challenging for those that don't like change. But when students go home talking about solids, liquids, and gases and then come in the next day with a project or a report they are did at home, that really shows the activities were meaningful and real.

As teachers our role is to foster the growth of our students. As the environment changes we too need to change our teaching styles. This MSTe style of teaching is exciting and beneficial to all.

Modifying Classroom Environments for MST Instruction at the Intermediate Level

Oh, what a teacher could do with unlimited storage for tools and materials and plentiful space for students to work both individually and in small groups! But this is the real world, and we must all make creative use of the classroom space at our disposal. Modification and flexibility are the keys.

Designing a classroom environment to facilitate MST instruction on the intermediate level should take into consideration space and safety factors, ease of access to materials and equipment, and student-to-student interaction concerns.

The first issue I tackled as a MSTe teacher was to secure a workstation in which to store tools and valuable equipment. Such workstations can be purchased but I asked a colleague to build me two to suit my needs. The first wheeled workstation is six feet long and has sliding doors front and back. This workstation houses all of my Lego kits and the magnetic levitation track. It also contains numbered plastic shoeboxes for storage of students' "works-in-progress," an essential part of any technology classroom. The second wheeled station is smaller and contains all the tools that students should use only with adult supervision. Also, I am fortunate in having one corner of a supply closet at the end of the hallway for extra storage.

A bank of five computers lines one wall of my classroom, and a hydroponics center has a permanent site in the back of the room. There are the usual wardrobes, bookcases, and 30 desks and chairs. As the workstations are the only table space we have, I ask the children to move the desks and chairs together when we work on projects requiring more space.

At times our work spills out into the hallway, and I must ask for administrative help in bringing in tables from another building. This is necessary only when we are engaged in an activity like constructing our maglev vehicles and parent volunteers are working with individual children.

Having had training in cooperative learning, I am comfortable with students working together and the activity level that accompanies it. Cooperative learning can be a powerful tool for student learning, but takes much thought and preparation if the teacher's instructional goals are to be realized.

I have found it best to begin with students working in pairs. When this is found to be a comfortable arrangement, students can graduate to groups of three. The composition of the groups must be carefully thought out so that each student has an opportunity for hands-on experiences and feels his/her contributions are valued.

Sometimes I select the students who will work together; at other times they self-select. My goals for the activity are the deciding factor. The teacher must realize that all children will not make the transition to groups of three at the same time. Also, I have not found it productive for my fourth graders to work in groups larger than three because there is too much idle time for some students. Throughout the year I make sure that my students have the opportunity to work with many of their classmates.

When doing cooperative learning, it is essential that students realize the goals for the activity and their roles and responsibilities in achieving them. Some activity should be provided for those groups of students who finish early, even if it is the completion of seatwork.

Tidying the room after an activity is a consideration as well. The time constraints, clean-up procedures and expectations for storage of "works-in-progress" should be clearly spelled out in advance. I've found most youngsters highly cooperative because they look forward to similar fun activities in the future!

Design is the MVP (Most Valuable Process) in MST! Design activities give students the opportunity to work together and they stimulate the inquiry process by giving students something visual to work with and on which to make modifications later. Most young children will not see the value of the design process at first. In many cases they have been used to just diving into the materials and creating something haphazardly. "If it doesn't work, rip it apart and start over" has been the theory. Analyzing *why* something does not work is an alien notion to many children.

Students should be allowed to handle samples of the materials they will be using to see what they can do. They then design their project with pencil and paper, gather the materials they need from the workstation, and construct it. This procedure saves valuable time and materials, and I have found that students approach their projects with more thoughtfulness and care.

Early in the year I introduce the children to the design process by having them investigate insects as examples of animal populations. To stimulate interest in the topic I gather books and magazines and place them around the room. I also borrow student insect collections made by upper grade level students. Then my students are challenged to discover: "What makes an insect an insect?" Working in pairs they investigate the resources and design and label their own insect. I do not allow them to proceed to the construction stage until they have demonstrated that an insect has three body parts (head, thorax, and abdomen) and six legs attached to the thorax. This constructivist method of teaching promotes retention of knowledge because students have discovered it themselves.

The insect model they create is truly an authentic means of assessing student knowledge. The design portfolio provides yet another means of evaluating their work. It is also something "on paper" to share with parents and administrators who may be more familiar with those kinds of assessments.

Elementary technology education, with its integration of the other disciplines, solves the problem of the student who just can't seem to sit still. These students are in their element when doing a hands-on project and often the most creative ideas come from their boundless energy! I like the fact that in most of our projects there are many "correct" answers to the problems I pose for students and those they pose for themselves. I am amazed at the many ingenious ways they find for solving them.

The elementary MST teacher will find many rewards in the classroom, the most important being the many students willing and eager to learn. Thus far I have not found any MST activity that was gender specific. The teacher's attitude, approach, and expectations in this area are all-important. Preparing students for a future where they will change jobs many times means we must be about the business of helping children learn to work with others, think creatively to solve problems, and reach their potential!

Designing Classroom Environments

Physical Environment

Basics for all Classrooms

- Math manipulatives, such as pattern blocks, color tiles ,cm rulers, cm cubes, etc.
- Science materials for hands-on investigations
- MST logs, D 7 T Portfolios, and journals
- Charts: - student-developed rubrics that are posted in the classroom
- diagrams of tools
- materials price list
- Overhead projector
- Computers

- Junior size tools (safety goggles, 3 hammers, 2 vices, 3 C-clamps, 24 lynx jointers, 3 screwdrivers, 3 saws, 3 miter boxes, 2 hot glue guns, scissors, hand drill and bits, wooden hole punch, hole punch, wire stripper, etc.)

- Materials for construction (cm wood dowels, nails, glue, string, hot glue sticks, Elmer's glue, paper towel dowels, batteries, battery holders, motors, construction paper, cm paper, aluminum foil, plastic wrap, pieces of plywood, staplers, wire, straws, tongue depressors, ice cream sticks, newspaper, masking tape, double sided tape, scotch tape, pulleys, wheels, cm graph paper, cm card stock. screws, screw eyes, cardboard, cotton, gears, syringes, buzzers, light bulbs, rubber bands, paper clips, eye hooks, wire strippers, brass fasteners, etc.)

Be prepared to rearrange classroom configuration

- desk arranged in groups (tables preferred)
- separate centers for working with tools, hot glue
- meeting place for student reflections
- counter space available for students' work-in-progress
- storage space for materials and tools

Make project dimensions no larger than students' desk size

Establish structured clean-up rules: student designated head custodians to oversee general clean-up

Present a variety of models found in everyday life to help springboard student ideas for design

Source: Kathryn Chapman and Donna Migdol, Oceanside UFSD

Safety Issues

- Parental permission slips to use tools
- Demonstrate safe use of equipment and tools
- Use gloves and protective clothing when necessary
- Ventilate areas when gluing
- Enlist extra adults for tasks needing closer supervision
- Ensure students have enough space to work

Human Resources

- parents - to donate materials, to participate at centers during construction (set-up a schedule), to share expertise related to project (e.g., architect, construction worker)
- building custodian - to share job description
- administration - to provide financial support and extended planning time
- teachers - to participate in team teaching, project integration working with specialty teachers (art, music)

Approaches to Organization

Time allocation to make best use of time:

- Teach math concepts coupled, e.g., area and multiplication
- Block time into one to two hour segments integrating two or more subjects
- Set aside time for student reflection

Source: Kathryn Chapman and Donna Migdol, Oceanside UFSD

The following list represents a minimum set of materials necessary to implement design and technology in the elementary classroom.

TTS STARTER KITS FOR MSTe sites - 1999

MSTe 1999 Tools Kit

Product Code	Product Description	Unit Price	Quantity in Kit
TTDS	Small double-sided mitrebox	$ 4.54	4
TTH	Hacksaw	$ 2.95	4
TTHB	Hacksaw blades (pack 10)	$ 3.00	1
TJOB-S	Corner jointer (single)	$ 1.40	8
TTSS	Snips	$ 10.95	1
THP	Hole punch for lolly sticks	$ 11.67	1
TTRIMP	Metal safety rule (imperial)	$ 3.00	2
TGC	C-Clamps	$ 2.95	4
TGJM	Multi-gear jig	$ 8.75	1
DRDRILL	!-land drill (pistol-grip with bits)	$ 18.95	1
TTSK	Standard cutting knife	$ 1.95	1
GLUEGNTRG	Low-temp glue gun with trigger	$ 5.75	3

TOOLSKIT-NY **Price $100**

MSTe 1999 Materials Kit:

Product Code	Product Description	Unit Price	Quantity in Kit
TWBB	Basswood strips (100, 2ft X 3/8")	$ 38.00	1
TFS	Spatulas (100)	$ 6.50	1
SEYE732-100	Axle holder-screw eyes (100)	$ 2.80	1
TMDF-M	Wheels (mixed pack of 100)	$ 22.95	1
TGJ-RES	Card discs (mixed for jig and wheels)	$ 39.95	0.5
GGO-PULL-C	Pulleys (mixed pack of 60)	$ 13.00	1
TRB#16	Elastic bands (#16, 200)	$ 1.80	1
TRB#18	Elastic bands (#18, 200)	$ 1.80	1
TFAST34	Fastners for levers (pack 100)	$ 1.00	1
TWD	Dowel for wheels and pulleys (40ft)	$ 7.95	1
GLUE125	Wood glue (small bottle)	$ 2.50	1
GLUESTLT	Low-temp glue sticks (pack 12)	$ 1.33	5

MTLSKIT -NY **Price $100**

To order:
Phone: 1-800-206-6604
Fax: 1-800-679-0802
Email: tts@tts-group.com
Mail: TTS Inc.
39 Everett Drive (Building D)
PRINCETON JUNCTION NJ 08550-5307