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ABSTRACT

This paper describes a framework for authentic instruction and assessment for the New York state alternative program of integrated mathematics, science, and technology (MST). The paper includes the rationale for the assessment framework, description of tasks, students' work, and suggested evaluation scheme. The MST framework consists of seven defined standards, but at present there is no statewide formal MST program with specific curriculum materials. At this time, the program is composed of extended performance tasks for elementary, middle, and high schools, which include elements of math, science, and technology and require students to solve problems that are connected to the world beyond the classroom. These tasks are authentic, engaging, accessible, readily scorable, and important in that they promote critical thinking and understanding. The MST evaluation system is based on observation of student behavior, student portfolios, and followup assessment. Guidelines have been developed for scoring student portfolios. So far, about 50 teachers have participated in a pilot study of the MST tasks. For the most part, they have found the experience positive and insightful. An appendix presents a high school extended performance task and the assessment rubric. (Contains three tables.) (SLD)

Extended Performance Tasks for Mathematics, Science & Technology

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Paper to be presented at the Annual Meeting of the American Educational Research Association (AERA), New York, NY, April 9,1996.
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Extended Performance Tasks for Mathematics, Science & Technology

Introduction

Education in the United States is currently under a major reform. New ideas from the cognitive, social and political sciences, coupled with changing social and economical realities, call for a new articulation of the goals and practices of public school education. The overriding theme of the current reform efforts is that literacy, including mathematical, scientific and technological literacy, should be acquired by all students, regardless of their current status or future aspirations.

This paper attempts to describe a framework for authentic instruction and assessment for the New York State alternative program of integrated math, science and technology (MST). The paper includes rationale for assessment framework, description of tasks, students work and suggested evaluation scheme.

The MST Program

The New York State Department of Education created an integrated framework for the teaching of mathematics, science and technology (NYSED, 1995). The framework describes discipline-specific knowledge which all students are expected to master, as well as the overarching themes that integrate these three disciplines. A short description of the standards follows:

MST Standard 1: Students use *mathematical analysis, scientific inquiry* and *engineering design*, as appropriate, to pose questions, seek answers and develop solutions.

MST standard 2: Students access, generate, process and transfer information using appropriate technologies.

MST standard 3: Students value mathematics and become confident by reasoning and communicating mathematically, by applying mathematics in real-world setting and by solving problems through the integrated study of number systems, geometry, algebra, data analysis, probability and trigonometry.

MST standard 4: Students understand and apply scientific concepts, principles and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

MST standard 5: Students acquire and apply technological knowledge and skills to design, construct, use and evaluate products and systems to satisfy human and environmental needs.

MST Standard 6: Students understand the relationship and common themes that connect mathematics, science and technology and apply the themes to these and other areas of learning.

MST standard 7: Students apply the knowledge and thinking skills of mathematics, science and technology to address real-life problems and make informed decisions.

Currently there is no state-wide, formal MST program, with specific curriculum materials. Instead, the program is composed of extended performance tasks, for elementary, middle and high school grades, which include elements of math, science and technology and require students to solve problems that are connected to the world beyond the classroom. The MST tasks are based on a disciplined inquiry, which means that they engage students in authentic performances that are valued in the three specific disciplines. In addition, performance of the tasks calls for cooperative problem solving behavior and clear and fluent communication.

Characteristics of MST Extended Performance Tasks

As was described above, the MST program is based on extended performance tasks. These tasks serve two main goals: curriculum and assessment. The tasks are organized around specific practical problems, whose solutions require the application of mathematical, scientific and technological knowledge. While working on the task, students produce daily logs of task-related ideas, observations, measurements, calculations, etc. To complete the task students are asked to produce a final product (e.g., report, model, poster) that summarizes their work. Both forms of materials (daily logs and final product) are used to evaluate the quality of students' performance.

What are the general characteristics of MST tasks?

- ***The tasks are authentic***

MST tasks are authentic and engage students in activities similar to those done by professionals in their specific field of study. For example, to be authentic to science, MST tasks provide students with opportunities to be engaged in raising questions, formulating hypotheses, exploring solutions, collecting data, validating explanations and presenting work for public critic. To be authentic to mathematics, the tasks ask students to deal with measurement, organization and interpretation of data, search for patterns, development of models and construction of mathematical arguments. The technology aspect is reflected through review of needs and resources, evaluation of costs and risks, design and construction of alternative solution models, technical drawings, testing viability of solutions and presenting convincing cases to concerned consumers.

- ***The tasks are important***

Work on MST tasks promote students' thinking about and understanding of ideas, theories, processes and perspectives which are considered critical within the academic or professional disciplines. The tasks are not trivial pursuit. Their completion requires generative understanding as well as the application of specific knowledge in novel problem solving situations.

- *The tasks are engaging*

MST tasks create opportunities for students to develop, document and publicly present their understanding and the products of their work. Completion of the task is done in small cooperative groups, to encourage discourse and sharing of ideas. The tasks are open-ended and rich enough to allow different groups of students, in the same classroom, to pursue different explorations and solution paths to the same initial task.

- **The tasks are accessible**

MST tasks offer students opportunities to be engaged in meaningful activities that advance the learning of all students. To be accessible to students the task is based on high but reasonable performance expectations. The tasks are flexible enough to allow students with different interests and abilities to be successful.

- **The tasks are scorable**

MST tasks create opportunities for teachers and students to review work, discuss standards of performance and point for potential growth. Scores are based on multiple evidence in the student's performance which are relevant to the desired learning criteria. Therefore the task should require documentation of students' thinking and progress (e.g., daily logs) as well as a final product (e. g., model, poster, simulation, report).

MST Task Administration

Performance of MST task requires combination of inquiry, analysis and design activities, that have the pôtential to engage students in complex learning. The teacher has an essential role during the administration of the task. Although students are expected to take responsibility for their own learning, the teacher has the responsibility to ensure that all students have access to relevant sources of information, to equipment and materials. The teacher has to create opportunities for students to share findings and discuss ideas while they are still working on the task. The teacher has the delicate job of balancing the class activities so that all students are doing their best in an individual, small group and whole class setting. The engineering design model, or the discovery learning cycle, can both serve not only as an heuristic for student task performance, but also as a framework for task administration by the teachers.

Evaluation of Student Work on MST Tasks

MST tasks were designed as episodes of integrated instruction and assessment. To harness assessment to the improvement of student learning and performance there is a need to build an evaluation system that can provide students, teachers and parents with clear understanding of where students are and how far they should progress in their studies. The MST evaluation system is based on three types of informational sources:

A. Observation of student behavior

Classroom observations of student behavior while working on the MST task, is a rich source of information about the students' ability to attend to task's requirements, to collaborate with other students and to be an effective communicator. Teachers are encouraged to observe students, to interview them, to take notes of critical events and to videotape students' presentations of their work. Based on all these information teachers can build personal performance profiles of their individual students. These profiles are not standardized, therefore they can not be used as a basis for state-wide assessment

B. Student portfolios

During the performance of the task students are encouraged to keep a detailed record of ideas, data and findings. At the end of the task, they are asked to summarize their findings in a final scientific report or a letter to some relevant agency, and add it to their portfolio. This collection of tangible documents serves as a rich source of information about students' understanding and their ability to apply their understanding to solve novel problems. The whole portfolio, or a sample work from it, can serve as a basis for student evaluation and formative feedback, done by the school or district teachers. Review, evaluation and scoring of these portfolios provides an excellent opportunity for staff development, but it is too time consuming to serve as a basis for centralized, state-wide assessment.

C. Follow-up Assessment

After student complete their work on the extended task, students are asked to answer a small set of follow-up questions. These questions are directly related to the work students have previously performed (see examples of follow-up items at the end of the sample task). The follow-up assessment can be standardized and students responses can serve as a basis for a state-wide assessment.

Scoring of Student MST Portfolios

Scoring is at the heart of any educational evaluation. While the MST tasks provides the means to collect and organize the data for evaluation, the scoring system defines what is important and how to transform various sources of data into evaluative statements.

The following is a set of guidelines that were used for the development of appropriate scoring system for the MST portfolios:

1. Scoring should be organized around a small number of dimensions which reflect the essential features of the MST program.
2. Performance criteria and standards for each dimension, appropriate for the development level of the specific students who perform the task, should be clearly defined and understood by the students, the teachers and the scorers.
3. Scores should be based only on that evidence which is relevant to the specific performance criteria.
4. Scores should be criterion-based, which means that scores are assigned according to an agreed-upon set of performance standards.

Table 1 provides possible dimensions and performance criteria for the evaluation of student MST portfolios. Table 2 shows portfolio data collection and evaluation form and table 3 described performance standards for high level student achievements on a MST task.

Table 1

Dimensions and performance criteria for the evaluation and scoring of students' MST extended task portfolio

Dimension	Performance Criteria
Mathematical analysis	• collect and organize data in an appropriate manner • search for patterns in data • constructs mathematical models and arguments
Scientific inquiry	• raise questions and explore task-related concepts and principles • design experiments, measure and collect relevant data • validate explanations with evidence
Technological design	• analyze problem relative to specific design criteria • build models to examine design specifics • use technical drawings and tools to explore design ideas
Communication	• search for varied information resources • present work and conclusions in a clear and effective way

Table 2
MST data collection and evaluation form

Mathematical Analysis Evidence: Evaluative Statement:
Scientific Inquiry Evidence: Evaluative Statement:
Technological Design Evidence: Evaluative Statement:
Communication Evidence: Evaluative Statement:
Overall Performance:

Table 3

Performance standards for high MST achievements

- **Mathematics**

Student searched for and/or figured out relevant mathematical data. Student used appropriate mathematical operations (measuring, calculating, estimating, etc.) to find patterns and relationships in the data and used the findings to inform and benefit the problem solving process.

- **Science**

Student identified and thoroughly explored the effects of various factors related to the task. Student's records contained all the necessary information to allow others to understand and repeat the scientific investigations that were performed. Student justified the conclusions that were reached by using data and scientific analyses. Student used scientific vocabulary to effectively describe investigations and results.

- **Technology**

Student reviewed needs and resources and evaluated costs and risks of various solutions. Student designed and constructed alternative solution models, included technical drawings, tested the viability of different solutions and presented convincing data to concerned consumers.

- **Communication**

Student searched and effectively integrated different sources of information necessary to solve the given problem. Student clearly communicated the problem, procedures, interpretations and thinking pathways that were followed. The student included high quality presentations of data, charts, graphs, drawings and diagrams, as appropriate.

Summary

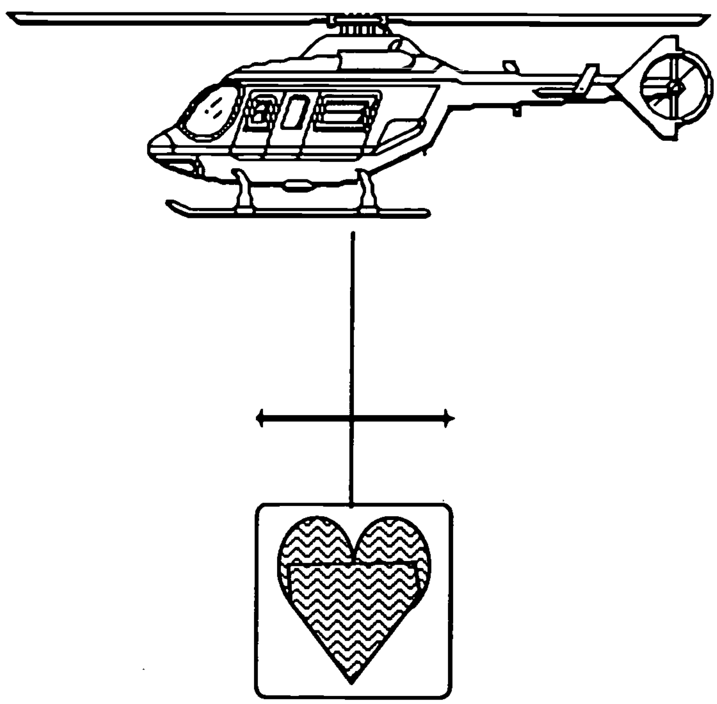
The MST framework inspired math, science and technology educators, at the first time, to work together, to explore the common ideas which are shared by the three disciplines and to start developing learning materials that can engage students and teachers in extended investigations of authentic problems. The initiative has resulted, so far, in a set of content and performance standards for the integrated teaching and learning of mathematics, science and technology (*Learning Standards for Mathematics, Science and Technology*, NYSED, November 1995). In addition, extended MST performance tasks were developed for elementary, middle and high school students. In the current absence of specific MST integrated curriculum and specific learning materials, these tasks can serve as a temporary and partial curriculum.

So far about fifty, risk-taking teachers participated in a pilot study of these tasks. Without a sufficient preparation and a detailed set of administration guidelines, they took their students to a joyful journey of learning and exploration of new uncharted educational territories. Their experience was, for the most part, positive and insightful. As one of the teachers so delicately said: "Watching my students performing the MST task I've realized that all of us, students and teachers alike, can do much more than we currently do in schools". Students' work was collected and teachers started to develop appropriate evaluation schemes to assess the quality of student work, including scoring rubrics, performance standards and benchmarks. This is an important undertake, as there are no theoretical background or concrete examples of integrated MST programs to follow.

This year about a hundred new teachers, from different school districts in New York, will join the project. They will try a new set of performance tasks, as well as the usefulness of various assessment formats. We hope that experiences gained by this project will help administrators and educators make informative decisions about the viability of this and similar innovative educational programs.

Appendix A

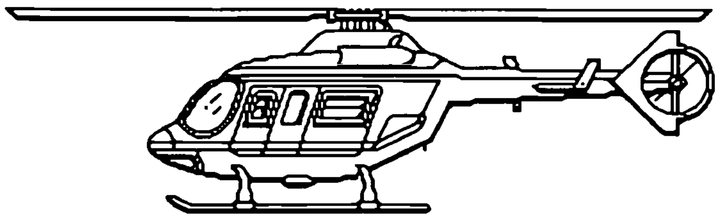
Cool It Down



Extended Performance Task for Mathematics, Science & Technology

(High School Level)

Keep it Cool



Background: Organ transplantation is a medical procedure in which an organ is removed from a donor's body and transplanted into a person who needs it. Kidneys, lungs, heart, cornea, liver, bone marrow and skin grafts are all organs and tissues that have been successfully transferred from donors to recipients. This medical operation requires a physiological match between a donor and recipient and as a result special national data bases have been created to facilitate the quick location of potential matched donors. Many times donated organs have to be shipped over thousands of miles. This requires the construction of special shipping containers that can maintain the viability of the organs by keeping them chilled (not frozen!), immersed in ice for several hours.

Your Task: Design and build an efficient container to transport organs. In this task you will be using model organs. A half-frozen saline solution (about 4 degrees Celsius), stored in a cylinder film container, will serve as a simulation of the organ. The external volume of the container should not exceed two liters (2000 cubic cm). You can build your container from different materials and you can use various methods to control the inner temperature of the container. Remember that estimation of the cost and efficiency of your product should be an integral part of your performance.

Procedure:

- Brainstorm the various factors that might affect the container's ability to keep a controlled temperature environment.
- Brainstorm other factors that should be considered, to make the container practical and appropriate for the shipping of organs.

- <u>Design</u> a series of studies to explore this topic and collect needed information (from experiments, textbooks, electronic data bases or any other information resource).
- <u>Share your initial findings and ideas</u> with the rest of students in the class.
- Decide on the most promising solution from among the various alternatives that your team was investigating.
- <u>Build your optimal model container/s</u>, insert the small container with the cold saline solution and close it up. Find a way to study the internal temperature of your "organ" during a 24 hours period of time.
- <u>Keep a daily log</u> of ideas, procedures and findings. This log will serve you well when you will be asked to produce a final report or present your study before a group of experts.

<u>Directions for team evaluation:</u>

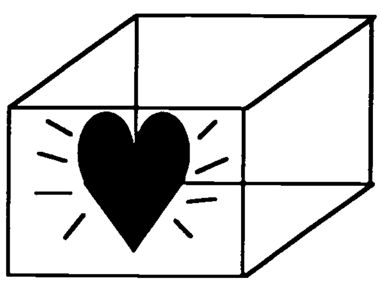
- Prepare a multi-media presentation of your project.

(Multi-media presentation means that you use more than one mode of presentation. For example, you can add visuals to your oral presentation, to clarify procedures and/or demonstrate final product. Or you can choose to be a real high-tech presenter, using video clips, computer simulations and edited sound to augment your presentation).

<u>Directions for individual evaluation:</u>

- Write a final report to the local hospital's purchasing agency, describing your product.

The report should include all steps you took to investigate, design, build and test your product. Add any information that in your opinion will persuade the hospital to purchase the design of your container for future use. The report should not exceed 3 pages, including any graphs or charts.



Notes to the Teacher

In the "Keep It Cool" task students have to use their knowledge of math, science and technology to complete the task of designing a container to transfer human organs for surgical transplantation. Students are expected to gather relevant information, as well as design, draw, build and test different models of containers. They are expected to measure and calculate the surface area, volume and heat transfer of containers of different shapes and materials. In addition students have to analyze the cost-benefit-risk aspects of different models. A class discussion of the medical procedure and the ethical aspects of this issue is expected as part of this project. At the end of the project, the quality of student performance will be evaluated either by a class presentation or a final individual report.

During the project let students be creative and do not limit them to specific designs. On the other hand, require students to adhere to design constrains, such as size, safety and cost. To complete the task students will need different materials to build models and explore the effect of container size, shape and materials on its effectiveness as a cooler. Provide all students with the basic materials that are on the list and encourage them to bring more materials and scraps from home.

Project organization

There are many different ways to work on projects like the "Keep it Cool" in class. One way that promotes inquiry-based learning, is to use the BSCS's (Biological Sciences Curriculum Studies) 5E's learning cycle which includes the following elements:

Engage ----> Explore -----> Explain ----> Elaborate -----> Evaluate

How can you use the 5-E model with the "Wet Sliding" task?

Start with **engaging** the students in the task. Introduce the task, create interest in the task, raise questions and attempt to uncover what students know and think about various concepts that are related to performance of this task. Make sure that students read and understand what they have to do to accomplish the task and how their work will be assessed and evaluated during and at the end of the project.

Without detailed explanations, let the students **explore** the task. Don't tell them what to do, don't feel pressured to direct their activities. Instead provide students with the opportunity to freely explore the various aspects of the task. Encourage students to work collaboratively on initial discussion, experimentation and articulation of possible solutions to the task. Observes the students while they work in groups, listen, ask probing questions and give students ample of time to think and wonder through the problem. Do not provide formal explanations of scientific concepts at this stage, but rather wait until students feel the need for knowledge and begin to articulate specific questions. The engage and explore phase will take at least two class periods.

After students completed the initial investigation of the task, gather them all together and let them describe their current progress. Let them share **ideas** and **explanations** with each other. Students should explain their own thinking about the problem, listen critically to each other and ask questions that can lead to focused investigations and data collection. For example, if students wonder what is the best shape, encourage them to explore the relationship of volume to surface area for different objects (e.g.,,. cylinder, box, sphere, etc.). Facilitate the integration of concepts such as *heat, temperature, heat transfer, convection, insulation, models, experiments*, etc., into class discussion. If students are not familiar with these concepts and the way they can be measured and/or calculated, offer them specific activities to get the necessary skills. This phase might take several days, depend on the previous knowledge of students in your class.

In the **elaborate** phase students should resume their active exploration of the task. They will propose solutions, perform experiments, collect and record data and model an optimal solution. Your role is to provide guidance when students need it, to help students gather materials and needed equipment, to monitor students' progress and to encourage them to be critical and creative in completion of the task. This is the time to introduce students to Computer Assisted Drawing (CAD) programs, if you have them in school. If not, encourage student to produce scaled drawing of their various models. Make sure that all students are actively participating in the project and they understand its components, but allow them to actually perform different parts of the task (e.g., one student can make the drawings while the second is building the model and the third is calculating heat transfer). Students will probably need three to five days to complete this phase of their work.

After all teams completed the design, construction and testing of an optimal prototype model, let each group organize their materials in a multimedia presentation. The presentation should include at least two forms of communication (e.g., talk, posters). Encourage students to use other media of communication (e.g., color overheads, slow motion videos, computer animations) to augment their presentation. Make sure that students treat the media as secondary to the substance of their presentation. If you plan to evaluate the work of the team (in contrast to the work of each individual students) let each team present its work before the whole class. At the end of the presentation let students ask probing questions and challenge each other. Using the *MST - Performance Assessment Rubric*, (a copy of suggested rubric is attached) ask students to **evaluate** the quality of the work of their team and other teams. Collect these evaluations, summarize them and add your own evaluation to form a final written formative feedback to each team. You can change the team evaluation to individual evaluation, by changing the nature of the final presentation. Replace the multimedia team presentation by a final individual written report to the local hospital, that will include description of the project and specific recommendations for the organ transfer procedures. Through this final report students will be expected to show their individual understanding of the various concepts and processes involved in the task performance. Again, finish the project by providing students with a formative, written feedback, that points to strengths and weaknesses in their work.

Materials & Equipment

- Materials to build models of container, including various insulators and thermoelectric components, as required by students.

- Film containers, filled with half-frozen saline solution (15% NaCl in water)

- Working tools (e.g., scissors, cutters, hammers, screw drivers, glues, paints, etc.)

- Measuring instruments (e.g., thermometers, watch clocks, rulers, compasses)

- Drawing tools (e.g., pencils, drawing paper, rulers, CAD software).

MST - Performance Assessment Rubric

Student/Team name: _________________________ Grade: _________
School: _________________________ Course: ___________________
Teacher Name: ____________________________

Evaluate the quality of each performance criterion and use the following scale to grade each performance:

A = Excellent performance
B = Proficient performance, needs minor revisions
C = Acceptable performance, needs major revisions
D = Unacceptable performance

Scored Dimension	Grade
Scientific inquiry	
Student/team:	
Identified and thoroughly explored the effects of various factors related to the task.	_______
Described activities in a clear way, allowing others to repeat the scientific investigations that were performed.	_______
Justified the conclusions that were reached by using data and scientific analyses.	_______
Mathematical analyses	
Student/team:	
• Used appropriate mathematical operations (measuring, calculating, estimating, etc.) to find patterns and relationships in the data.	_______
• Described data in a relevant manner (tables, charts, graphs, equations, etc.).	_______
• Used the mathematical findings to inform and benefit the problem solving process.	_______

MST - Performance Assessment Rubric (cont.)

Technological design	
Student/Team:	
• Designed and constructed alternative solution models, illustrated by technical drawings.	_______
• Reviewed needs and resources and evaluated costs and risks of various solutions.	_______
• Tested the viability of different solutions and presented convincing data to concerned consumers.	_______
• Used equipment & materials skillfully.	_______
Contribution to team work	
Student/Team:	
• Shared ideas and helped each other in the team.	_______
• Shared ideas and helped the rest of the class.	_______
• Performed the work in a responsible, logical and organized way.	_______
Communication	
Student/Team:	
• Searched for and effectively integrated information from different sources.	_______
• Presented the problem, procedures, data and solutions in a clear and organized way.	_______
• Used media to raise interest and augment presentation.	_______

AERA April 8-12, 1996

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