Drying By Design

Using Informed Design to Develop a Food Dehydration System

NYSCATE
NEW YORK STATE CURRICULUM
for Advanced Technology Education

Integrated MST Design Activities for High School and Community College Students

Partners in New York State Curriculum for Advanced Technology Education

Hofstra University
New York State Education Department

Project Co-Principal Investigators

Linda Hobart
Finger Lakes Community College

John E. Jablonski, Vice President and Dean of the College
Fulton-Montgomery Community College

Margarita Mayo, Director of Education, Training and Quality
New York State Business Council

Godfrey I. Nwoke, Ph.D.
New York City College of Technology

Jean Stevens, Assistant Commissioner, Office of Workforce Preparation and Continuing Education
New York State Education Department

Management Team

Project Co-Directors
M. David Burghardt, Ph.D.
Michael Hacker
Hofstra University

Project Coordinator
William Peruzzi, Ph.D.
Hofstra University

Project Administrative Assistant
Lois Miceli
Hofstra University

Project Advisory Council
Stuart Field (Chair), Manager, Saratoga Division
Slack Chemical Company

Dr. James C. Dawson, Member
N.Y.S. Board of Regents

Nancy Bryan, Past President
New York State Technology Education Association

James Cimino, Executive Director
Association of Career and Technical Education Administrators

Dr. Lorraine Hohenforst, Coordinator of Instructional Services
Hamilton-Fulton-Montgomery BOCES

Dr. Elaine A. Johnson, Director
Bio-Link (ATE) Center, City College of San Francisco

Dr. James. V. Masi, Retired Executive Director, Northeast (ATE) Center for Telecommunications Technology
Professor Emeritus, Western New England College

Mr. Bernard McInerney, Statewide Tech Prep Coordinator
New York State Education Department

Mr. Gordon Snyder, Executive Director
National Center for Telecommunications Technology

Project Evaluation Team
Bert Flugman, Ph.D., Director
Deborah Hecht, Ph.D.
Center for Advanced Study in Education
City University of New York

Writers
M. David Burghardt, Ph.D.
Michael Hacker
William Peruzzi, Ph.D.

Copy Editor: Barbara L. Kelly

Publication Designer: Lesa Clark

Format Consultant: Sue Siegel

Pilot Teacher and Photographs: Dr. Stuart Soman

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The State Education Department

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contents

Introduction and Overview

Abstract

This module, the first of 13 NYSCATE modules, features the integration of mathematics, science, and technology (MST) through an emphasis on design in the context of dehydration. In response to a challenge, groups of students consider specifications and work within constraints as they design, construct, and test a dehydrator. The device they construct is expected to dry fruit in as short a time as possible while maintaining the quality of the foodstuff.

Rather than proceed by trial and error, students are expected to make design decisions based on mathematical and scientific principles that they consciously apply. The module features mathematical, scientific, and technological Knowledge and Skill Builder (KSB) activities that groups complete in order to be informed as they design, construct, and test. Topics included in the KSBs are informed design, dehydration techniques, investigations of factors affecting dehydration, linear and curvilinear relationships, data treatments, microbes and spoilage, humidity, and food appearance changes.

Grade Level

This module can serve as an introduction to the process of informed design and is appropriate for use in high schools and community colleges, grades 9-14.

TIME ALLOCATION IN 45-MINUTE PERIODS

23 periods (Some field-test teachers found that their classes needed more time.)

EXISTING COURSES ENHANCED BY THE MODULE

- High school technology education
- Pre-engineering
- Family and Consumer Science

SOURCES

Burghardt, M. David, *Introduction to Engineering Design and Problem Solving*, McGraw-Hill, 1999.

Design Challenge

SETTING THE CONTEXT FOR STUDENTS

Introduction

A local elementary school group is planning a weekend hike during which they must carry everything, including their food and clothing. They are concerned about the heavy load each person will have to carry. Unable to think of ways to substantially reduce the weight of their backpacks, they have turned to your class for advice.

Design Challenge

As part of a group, you will design, construct, and test a dehydrator that dries fruit in as short a time as possible while maintaining the quality of the foodstuff.

Specifications

Dehydrate 250 grams of apple slices to 20% or less of the initial weight.

Constraints

You may use only approved materials and tools. In addition, the drying surface your group uses must have an area no greater than 144 square inches.

Goals and Learning Outcomes

The outcomes promoted by *Drying by Design* are listed here; the order in which they appear is based on the order of the NYS learning standards. (The numbers of the NYS MST learning standards most closely addressed by each outcome are indicated in parentheses.)

In *Drying by Design*, students learn to apply the process of informed design. In order to do so, they acquire the following MST standards-based knowledge and skills:

- how to carry on informed design *(NYS MST Learning Standard 1)*
- how to conduct controlled experiments *(NYS MST Learning Standard 1)*
- graphing techniques and interpretation *(NYS MST Learning Standard 2)*
- linear and nonlinear relationships *(NYS MST Learning Standard 3)*
- surface to volume relationships *(NYS MST Learning Standard 3)*
- factors related to the drying of food products *(NYS MST Learning Standards 3-5)*
- the relationship of microbes to food spoilage *(NYS MST Learning Standard 4)*
- the relationship of dehydration to food decomposition, relative humidity, temperature, and evaporation rate relationships *(NYS MST Learning Standard 4).*

In this module the teacher:

- prompts acquisition of mathematical analysis, scientific inquiry, and informed design processes *(NYS MST Standard 1);*
- fosters cooperative learning as students work in design teams *(NYS MST Standards 1 and 2);*
- provides opportunities for improving communication skills through the use of the Design Journal or Design Activity Folio; Design Report; and group presentation *(NYS MST Standard 2);*
- introduces students to the design process through an engaging design challenge *(NYS MST Standard 1);*
- involves individuals and groups as they compose, construct, test, improve, and present their design solutions *(NYS MST Standard 1);*
- helps students realize what they already know about dehydration and about design *(NYS MST Standards 3-5);* guides students as they identify and investigate factors relevant to design performance *(NYS MST Standards 3-5);* and facilitates acquisition of mathematical, scientific, and technological principles related to dehydration *(NYS MST Standards 3-5).*

In the section Additional Support for Teachers, p. 13, there is a subsection devoted to related learning standards, including standards other than the MST learning standards for New York State.

MATERIALS

Materials and Resources

safety goggles

apples (6, all of one variety)

apple slicer (knife)

wooden strips (4, 60 cm x 1 cm x 1 cm)

wire cutter

wire, bell (5 ft.)

several kinds of wire mesh (including plastic-coated)

3V electric motor

battery holders (2)

C batteries (2)

fan blade

100w -120w floodlight or heating lamp

aluminum foil (10 sq. ft.)

cardboard and/or foam board (10 sq. ft.)

thermometer (100 degrees Celsius)

duct tape

graph paper (10 pieces) or spreadsheets (computer optional)

Provide each student group with materials needed to complete the challenge, such as the materials listed here. (Note: Information provided to the students about materials in the Introductory Packet states: "Your teacher or group may provide materials and tools. Any materials and tools provided by your group must be approved in advance by your teacher.")

Additional materials will be necessary to complete the Knowledge and Skill Builders (KSBs) that help prepare students for the design challenge (see NYSCATE *Pedagogical Framework* [p. 6] for more information on KSBs). These materials are listed within the individual KSBs or in the procedural suggestions that further describe the KSBs.

Safety Considerations

Safety goggles must be worn for some of the procedures. In this module heat is applied, apples are sliced, and wire is cut. Take time to emphasize the safe use of the cutting instruments and heat sources you provide. The wire mesh ends resulting from the cutting of the mesh can be sharp enough to break skin. Therefore, make sure that the cut wire mesh is handled carefully. Check the policy in your district for students eating foods involved in classroom activities. NYSCATE recommends that students not eat the dried foods they prepare.

RESOURCES Access to WWW

TIMELINE

Suggested order for completion of KSBs by students:

1. Complete Introductory Packet.
2. Students complete KSBs T1, T2, M1, M2, and S1.
3. The remaining KSBs (S2, S3, and S4) might then be completed in any order, or groups could do different ones and share the information collectively.

Timeline Chart

PERIOD	FOCUS MODEL COMPONENT (for teachers)	INFORMED DESIGN LOOP COMPONENT (for students)	ACTIVITY
1-2	Focus discussion on problem context	Clarify design specifications and constraints	Begin discussion of Introductory Packet (module overview)
3-5	Organize for informed design		Discussion of KSB T1 (Informed Design Cycle); finish packet
6-10	Coordinate student progress	Research and investigation	Conduct KSB T2 (Dehydration Techniques) Conduct KSB M1 (Mathematical Comparison of Relationships) Conduct KSB M2 (Banana Data) Conduct KSB S1 (Factor Investigation) Conduct KSB S2 (Dehydration, Microbes, and Spoilage) Conduct KSB S3 (Humidity) Conduct KSB S4 (Appearance Changes)
11-12	Coordinate student progress	Generate alternative designs	Create sketches and/or models of alternative design solutions
13	Coordinate student progress	Choose and justify optimal design	Select and defend choice of preferred alternative
14-19	Coordinate student progress	Construct a working model and test/evaluate design solutions	Develop plans; Build model and test design solution
20-22	Unite class thinking about accomplishments	Redesign	Class presentations of methods and results
23	Sum up progress on learning goals		Review learning goals; Practice constructive assessment

Procedural Suggestions

Pedagogical Framework Reference

A separate document, the NYSCATE *Pedagogical Framework*, provides an in-depth understanding of the NYSCATE challenge statements, the FOCUS on Informed Design pedagogical model for teachers, student Knowledge and Skill Builders (KSBs), the informed design loop for students, and more.

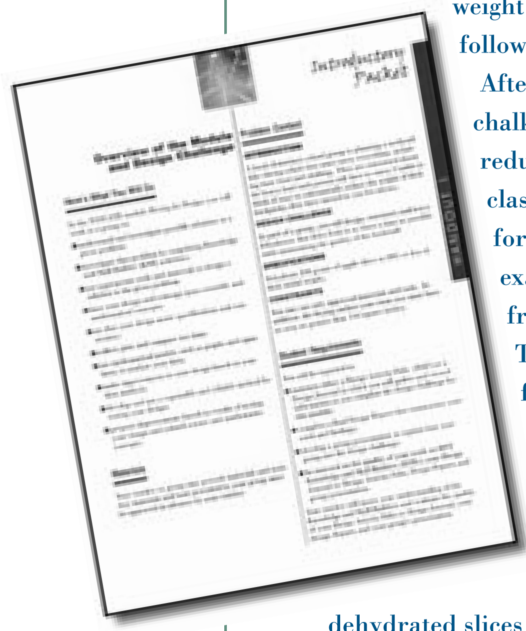
Suggestions

Focus
Organize
Coordinate
Unite
Sum Up

Here suggested strategies are presented within the context of the NYSCATE FOCUS on Informed Design, a pedagogical model for teachers. The FOCUS components are: **Focus** discussion on the problem context, **Organize** for informed design, **Coordinate** student progress, **Unite** the class in thinking about what has been accomplished, and **Sum** up progress on the learning goals (see NYSCATE *Pedagogical Framework*, p. 7, for more on this model).

PERIODS 1 - 2: FOCUSING DISCUSSION ON THE PROBLEM CONTEXT

THE PROBLEM. In order to focus and engage your students, discuss with the class that a group of elementary school children needs their help. The children are planning a weekend hike during which they must carry everything, including their food and clothing. They are concerned about the heavy load each person will have to carry. Unable to think of ways to substantially reduce the weight of their backpacks, they have turned to your class for advice. Ask the following question: "How can the load in the backpacks be reduced?"



After providing "wait time" for the class to think, elicit and record (on chalkboard, flip chart, or overhead projector acetate) a number of weight-reduction ideas and briefly examine the feasibility of each with the class. If the class fails to mention food dehydration, lead them in that direction by asking for examples of the foods astronauts have used. They should respond with examples of dehydrated foodstuffs such as soup, juice, cocoa, chicken dishes, fruits, and vegetables.

Tell the group that they are going to focus on dehydration as a means of food preparation and then describe the design challenge. Distribute Handout #1, the Introductory Packet, and refer students to the design challenge.

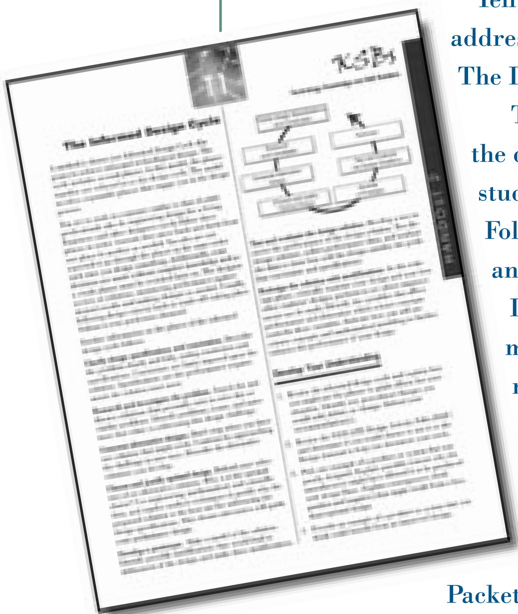
Have students put aside the Introductory Packet until the following period.

Display for the class a plate of fresh apple slices and a plate of dehydrated slices of the same variety and size of apples. Have students compare and contrast the contents of the two plates. Ask "KWL" questions to find out what the students do **know,** what they **want to know,** and what they need to **learn** for the following questions: "How and why do apples become dehydrated under natural conditions?" and "Why and how do humans choose to dehydrate them?" Discover here and elsewhere through such questions the naïve conceptions individual students hold about food preservation and dehydration.

THE CHALLENGE. Redirect students to the Introductory Packet. As you go through the packet's contents together, present the challenge in a manner that will motivate them. Discuss briefly the Here's What You Will Do, Problem Context, and Materials Needed sections.

PERIODS 3 - 5: ORGANIZING FOR INFORMED DESIGN

INFORMED DESIGN. (See the NYSCATE *Pedagogical Framework*, p. 8, for a more detailed discussion on focusing students on the process of informed design.) Elicit from students what they know about good design and who engages in design. Ask for examples of good design and poor design.



Tell the class that completing a series of KSBs will help prepare them for addressing the design challenge they face. Then introduce Handout #2, KSB T1: The Informed Design Cycle, and provide time to read it.

The information in KSB T1 should be referred to often as groups work on the design challenge. The informed design loop can be particularly useful to the students as they chart their progress using a Design Journal (or Design Activity Folio). Like professional engineers, they will find themselves using the loop in an iterative way rather than in a linear way.

Discuss the informed design cycle and stress that although design is normally informed by the designer's current knowledge, completion typically requires access to new knowledge. Discuss the need to research what solutions exist to solve this design challenge, and how reaching an optimal design solution requires meeting specifications, working within constraints, and making trade-offs.

STUDENT REQUIREMENTS. Discuss the student requirements (Introductory Packet) after determining whether you will expect the students to use the Design Activity Folio (DAF) or the Design Journal. (These documents are provided in the NYSCATE *Pedagogical Framework* [Appendix 2 and p. 15], along with guidelines for the Design Report and the group presentation [p 26].) Help students see that either of these devices allows them to document progress as they complete literature searches, factor investigations, and Knowledge and Skill Builders (KSBs). Describe the requirement that each student submit a Design Report and each group make a class presentation at the conclusion of the module. Explain that the report and the presentation will be based on information recorded in the Design Journal or DAF. Alert them that the presentations should be multimedia and should detail their design process and results. Help them see that such a presentation summarizes work completed in researching, collecting, and

Students in the beginning stages of developing a prototype.

analyzing data; developing models; improving designs; and making refinements. Describe multiple forms of media (for example, presentation software, color overheads, videos, computer animation) that they might use to enhance their presentations. Assure them that when classmates ask probing questions and challenge group findings at the end of presentations, they are mirroring proceedings that are common at science conferences.

ASSIGNING GROUPS. Talk with some of the students ahead of time to see how experienced they are at working in cooperative groups. Assign small working groups; three is ideal (see "Forming and Facilitating Design Teams" on p. 11 of the *Pedagogical Framework*). Monitor groups throughout the module.

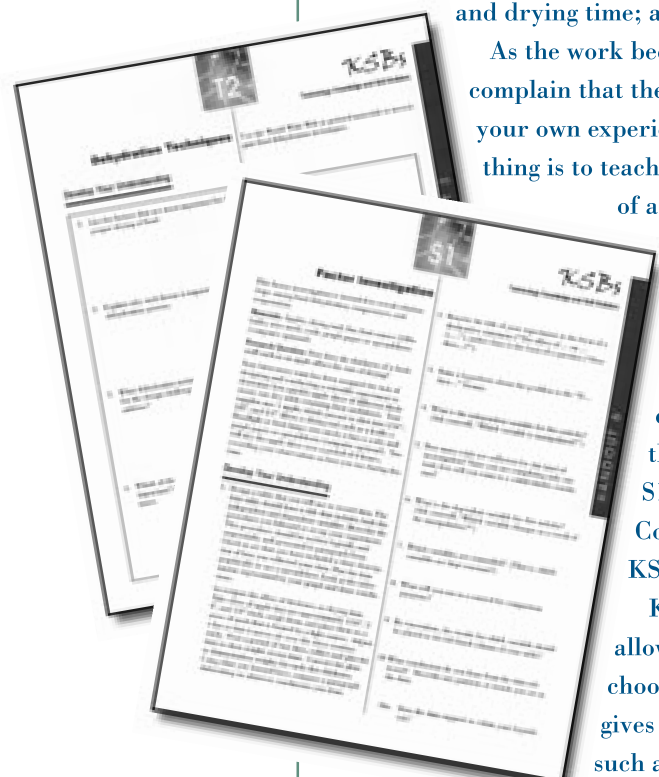
PERIODS 6 - 16: COORDINATING STUDENT PROGRESS

COORDINATE WORK BY INDIVIDUALS. Plan opportunities within this module for students to revisit their initial understandings by providing experiences with new phenomena that contradict their stated perceptions. Unless individuals get to actively process such contradictions, they may fail to grasp the new concepts and then may revert to their naive conceptions.

Help individual students make the connection between carefully documenting information as they proceed and well-written reports and presentations at the end.

Note that a student displaying unacceptable behavior may be doing so because other members of the group do not value what he/she says. Get to know the strengths of such a student and try assigning roles for all members of his or her group. Give the student a role that features a personal strength and inform the group ahead of time that this person is known to do that task well.

Suggest that individual students pursue their own investigations of different topics related to dehydration. Some possible topics include how commercial dehydrators are made; the factors influencing speed of dehydration; microbes and spoilage; the relationship between temperature and drying time; and how to preserve nutrient values.



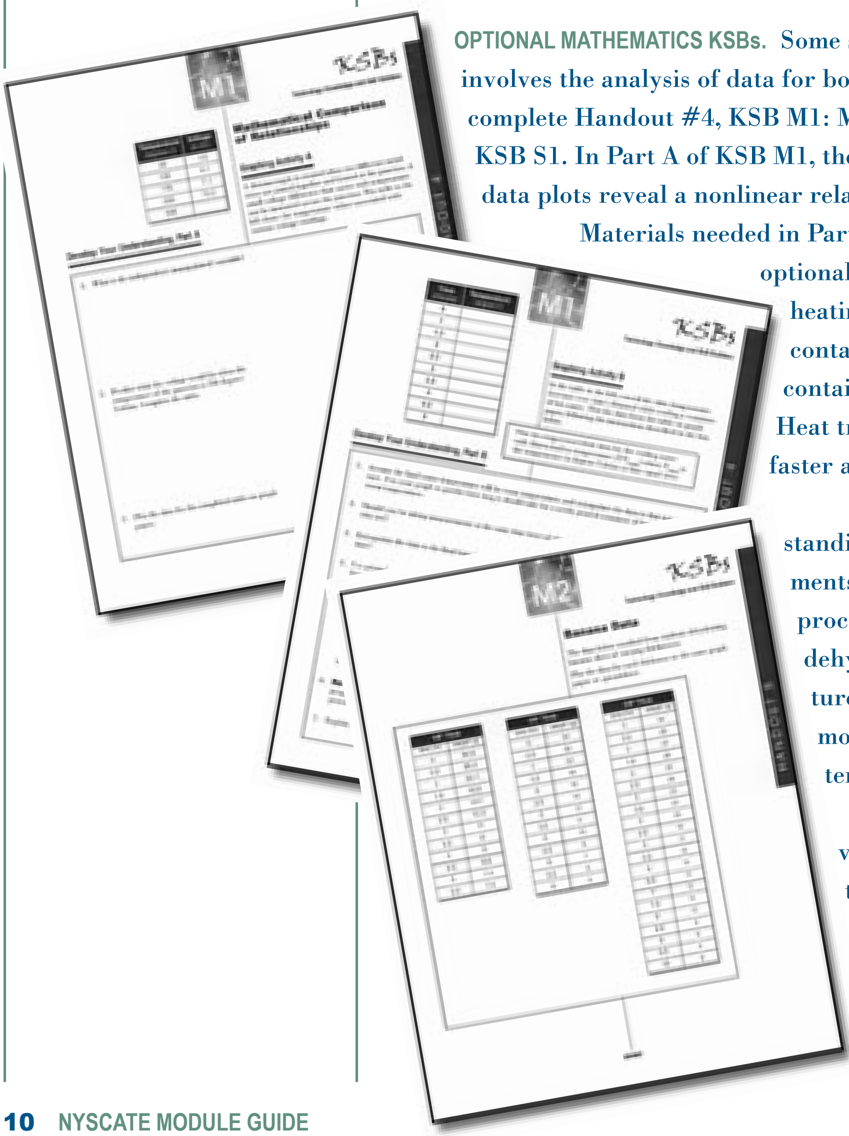
As the work becomes more technical and cerebral, some students will begin to complain that they are doing all the work while others loaf. Citing examples from your own experience, explain to such individuals that the best way to learn something is to teach it to others. Remind the group that it is essential that *all* members of a cooperative group understand all ideas and steps along the way. Conduct frequent oral checks to see that each student has adequate understanding before the group moves on in its work.

GROUP RESEARCH AND INVESTIGATION THROUGH KSBs. Have students complete Handout #3, KSB T2: Dehydration Techniques. If your class has prior knowledge of the mathematics in KSB M1 and M2, then you can save time by proceeding directly to Handout #6, KSB S1: Factor Investigation. Otherwise, complete KSB M1: Mathematical Comparison of Relationships and/or KSB M2: Banana Data prior to KSB S1.

KSB S1 has students explore factors that affect dehydration and allows them to practice using some of the equipment/materials they may choose to use later in completing the design challenge. This activity gives students concrete evidence that there are design factors to consider such as thickness of apple slices. KSB S1 calls for the use of materials (apples, slicing tool, fan, heat source [such as a 120w bulb], wire mesh, scale, and graph paper or spreadsheets (computer optional) to address a research question ("How does the thickness of a foodstuff such as an apple affect the rate of drying?").

Here are acceptable responses to the Develop Your Understanding section of KSB S1:

1. A new title might be "The effect of thickness on drying time."
2. One possibility is: "**If** the thickness increases, **then** the drying time will increase proportionately."
3. The variable that is purposefully changed by the experimenter is "the apple thickness."
4. Each test should be conducted at least three times. The way around this is to pool data from several experimenters using the same conditions.
5. The variable that responds is "the drying time of the apple slices."
6. All other factors should remain the same and have a fixed value, e.g., the amount of heat from the lamp, or the fan speed. All variables should be kept constant except the independent and dependent variables.
7. The control is the standard for comparing effects, e.g., an apple slice that is purposely prevented from drying by heat or airflow.
8. The independent variable (apple thickness), by convention, is placed in the left-hand column of the table, the dependent variable in the right-hand column.
9. Answers will vary. Some will notice the nonlinear relationship; others will express ideas for optimizing the design.
10. Answers will vary.

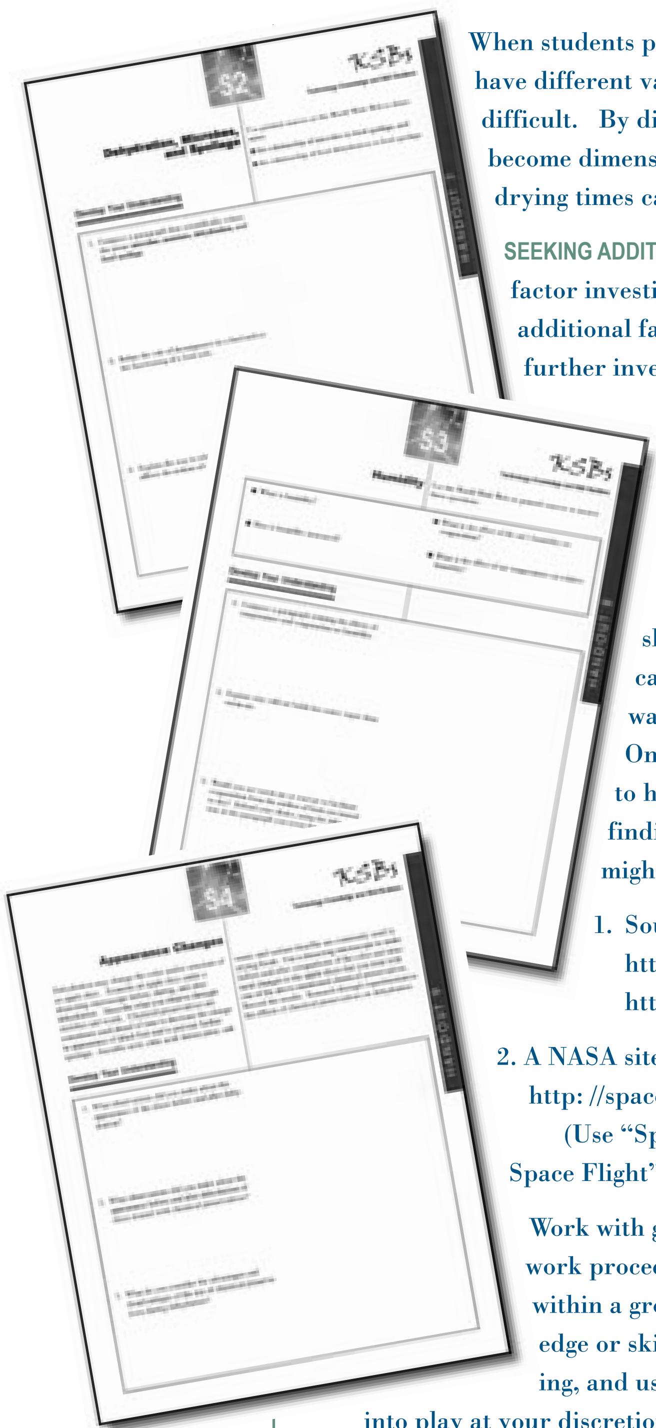


OPTIONAL MATHEMATICS KSBs. Some student groups would benefit from an activity that involves the analysis of data for both linear and nonlinear relationships; if so, they should complete Handout #4, KSB M1: Mathematical Comparison of Relationships, prior to KSB S1. In Part A of KSB M1, the data plots reveal a linear relationship. In Part B, the data plots reveal a nonlinear relationship.

Materials needed in Part B include graph paper or spreadsheets (computer optional), safety goggles, +100 degrees Celsius thermometer, a heating source, a water source, and a poorly insulated container. Be aware that it would save time in Part B if the container chosen (cup, beaker, etc.) were not well insulated. Heat transfer from the container to the environment will be faster and the overall cooling time will be reduced.

The desired response to the Develop Your Understanding item in Part B ("Should you be taking measurements at the same time interval throughout the cooling process?") is: "Since the form of the data is similar to dehydration, $Y = Y_{final} + Y_{initial}e^{-xt}$, the more rapid temperature change in the beginning of the cooling process suggests more frequent readings than toward the end, when the temperature change is slower."

Most student groups are likely to need help seeing the value of using dimensionless data during analyses and therefore would benefit from completing Handout #5, KSB M2: Banana Data, prior to attempting KSB S1 but after KSB M1. KSB M2: Banana Data helps students see how converting to dimensionless data enhances data analysis. The effect of the drying of fruit is nonlinear and follows a process of $y = A + Be^{-xt}$.



When students plot the data, the *y* ordinates for the different banana thicknesses have different values, making comparison between and among the thicknesses difficult. By dividing the weight at any time by the initial weight, the *y* ordinates become dimensionless numbers between 1 and 0 for all thicknesses and the slice drying times can be more readily compared.

SEEKING ADDITIONAL FACTORS AFFECTING DEHYDRATION. After debriefing on the factor investigations (KSB S1), conduct some small group discussions on additional factors that might affect fruit dehydration. Prompt the students to further investigate the process of dehydration through the use of experts, print sources, the World Wide Web, and/or additional factor investigations. Present students with Handouts #7 - #9, KSBs S2: Dehydration, Microbes, and Spoilage; S3: Humidity; and S4: Appearance Changes; and help them decide the type and extent of their investigations.

Materials needed for KSB S4: Appearance Changes include apple slices, dissecting microscope (3-D scope), and one or more chemical preservatives such as ascorbic acid, citric acid, lemon juice, salt water, and sodium bisulfite.

One efficient way for a class to investigate dehydration extensively is to have different groups cover different investigations and share findings later on. Here are samples of Internet sources that students might locate:

1. Sources on drying foodstuffs:
   http://www.ag.uiuc.edu/vista/html_pubs/DRYING/dryfood.html
   http://www.isd.net/stobin/Cooking/drying2.html

2. A NASA site with an alternative dehydration activity:
   http: //spacelink.msfc.nasa.gov
   (Use "Space Food and Nutrition" link and then "Dehydrating Food for Space Flight" link.)

Work with groups of students, monitor overall progress, and see that student work proceeds in an orderly and timely way. If things are not going well within a group, help group members find another way to obtain the knowledge or skills they need. Individual tutoring, peer teaching, teacher lecturing, and using outside resources and/or instructional technology might come into play at your discretion.

SHARING. Convene the large group one or more times to share results of individual and group investigations. Invite students to listen critically to one another and facilitate a discussion of how this knowledge can be used to inform their design of a dehydration system. Continue to work as a facilitator as students work in their groups to create alternative designs. Check to see that each group understands that its solution must address the specifications and constraints and the conditions needed to dehydrate apples. Remind each group to make decisions and select design components based upon their investigations and their understanding and application of MST principles. You might want the groups to develop a rating system to determine which alternative design is preferred.

PLANNING AND CONSTRUCTING. Continue to work as a facilitator as groups select their preferred alternative and develop plans for construction. Facilitate a discussion of trade-offs that are made in the search for an optimal design solution. Encourage groups to identify and model functional design elements and construct their working prototype.

TESTING. Bring students together as a large group and discuss ways in which each group might test their design. Facilitate small group development of testing and evaluation procedures.

Bring the entire group together to compare results. Encourage student groups to carefully review the work of other groups to glean ideas that might inform a redesign. When redesign is discussed, continue to direct students' attention to how the understanding and application of MST concepts can guide improvements.

PERIODS 17 - 22: UNITE THE CLASS IN THINKING ABOUT WHAT HAS BEEN ACCOMPLISHED

DESIGN REPORT. The reports are one of the major opportunities for you to determine whether individuals have attained your goals for this module. Continue to work as a facilitator as groups document their progress and share results. Explain that each student must submit a Design Report. Assist individuals in structuring and writing their Design Reports. The Design Report should include a discussion of redesign with justifications for the redesign decisions. Remind students that the report should include a response to the hiking club issue described in the Introductory Packet. Provide students with the Design Report guidelines from the NYSCATE *Pedagogical Framework* (p. 26). As you introduced this mod you told students that careful documentation in the Design Journal leads to a well-written final report later on. For individuals who have trouble writing, check their documentation frequently along the way to ensure that they will have a source of information adequate to generate a report.

GROUP PRESENTATIONS. Discuss with the class what is considered proper and expected deportment during group presentations. Address the need to use a variety of media to support the presentation. Review and distribute the presentation guidelines from the NYSCATE *Pedagogical Framework* (p. 27).

During the group presentations to the class, encourage students (through example) to ask appropriate questions and provide constructive feedback to the presenters.

PERIOD 23: SUM UP PROGRESS ON THE LEARNING GOALS

INDIVIDUAL STUDENTS. Keeping in mind that the design challenge is a means of accomplishing the learning goals, review the module's learning goals periodically to stay on track during the module and during its assessment. Seek to ascertain improvement not only in design abilities, but also for conceptual understandings in technology, mathematics, science, language arts, and general problem solving. Be constructive in assessment, emphasizing student progress and identifying specific areas for improvement. The NYSCATE *Pedagogical Framework* suggests tools for this assessment including process-rating forms, content tests, and preliminary product-scoring rubrics. In particular, you should strive to combine methods of assessment to arrive at a grade that is consistent with the methods of grading you presented to students during the organizing phase of this module.

MODULE EFFECTIVENESS. You will find it helpful to keep teaching notes on the module itself or in a journal. These notes can be reworked as students' assessment results are garnered to provide you with information to guide improvement in instruction and in the module itself for the next time you use it.

OVERVIEW OF DEHYDRATION

General Food Problems

Humans have always had to be concerned about storing food in ways that maintain its quality. Typically, other living things — rodents, insects, and microbes — are the greatest threat to our ability to store food. We counter these food deterioration threats by engineering the environment to increase the shelf life of foodstuffs: storage in secure facilities and packaging in pest-proof containers limit food contamination caused by rodents and insects.

Microbes and Food

Lessening the effects of microbes on food requires other strategies. Environmental factors that we typically optimize to control the effects of microbes are temperature (refrigeration slows down both microbial growth and the chemical reactions that increased populations of microbes initiate), chemical additives (some chemicals inhibit the growth of microbes), and dehydration (lack of moisture inhibits the growth of microbes).

Dehydration

Dehydration (drying), the oldest method of preserving food, is a very effective way to preserve food. Early American settlers dried foods such as corn, apple slices, currants, grapes, and meat to survive times when it was difficult to hunt, grow, or gather food.

During dehydration, the liquid in food, primarily water, is evaporated at the surface. The reason water evaporates is that the water's liquid vapor pressure at the surface is higher than the vapor pressure in the air next to the food's surface. Accordingly, water molecules become vapor particles more often than they become liquid particles. Since it's true that the lower the relative humidity, the greater the force driving evaporation, evaporation rate is greater if the air is moved away and new air continually moved in as evaporation takes place.

Humidity, Evaporation, Solar Energy

Relative humidity is defined as the mass of water vapor a given mass of air contains compared to the maximum amount (mass) of water vapor it could contain at a particular temperature and pressure. The absolute amount of water vapor that air can hold is greater at higher temperatures than at lower ones. For instance, in the winter the outside air at 0 degrees Celsius might have a relative humidity of 80%, but when that air enters a house and is warmed (heat transfer) to 25 degrees Celsius, the relative humidity drops to 15%. The absolute amount of moisture in the air did not change, but the air's carrying capacity for water vapor did change.

Historically, solar energy has been the most common heat source used for dehydration and it is typically used in two different ways:

1. to warm the air before it flows over the food, thus increasing the capacity of the air to contain water vapor (this incorporates the process of mass transfer);
2. to warm the surfaces of the food, thus increasing the rate of evaporation from the surfaces (this incorporates the process of heat transfer).

As the liquid on the surface evaporates, more liquid from the interior of the food flows to the surface by mechanisms such as capillary action and diffusion. These processes are comparatively slow, which explains why the dehydration process may take days to complete. In this module, floodlights or heating lamps are made available for students to use in simulating the sun's energy.

BUILDING KNOWLEDGE AND SKILL

The challenge your students face involves designing a dehydrator. Many will want to proceed by trial and error. To prevent this, you must convince them that they need to find out what they now know as a group and what they will need to know about the process of design, and about dehydration, in order to complete the challenge properly. The Knowledge and Skill Builders (KSBs) are meant to help students become more informed in both of these areas. Refer to the NYSCATE *Pedagogical Framework* for additional information on the informed design process (p. 7).

RELATED LEARNING STANDARDS

Drying by Design places major emphasis on the following learning standards.

Learning Standards for Mathematics, Science, and Technology

The University of the State of New York, The State Education Department

STANDARD 1B - ANALYSIS, INQUIRY, AND DESIGN

Observations made while testing provide new insights into phenomena.

- Represent and organize observations and interpret data.
- Develop a written report that describes proposed explanations.

Engineering design is an iterative process involving modeling and optimization, and used to develop technological solutions to problems within given constraints.

- Carry out a thorough investigation and identify needs for technological innovation.
- Use a wide range of information resources and document findings.
- Generate a variety of solutions and choose the optimal solution based upon specifications and constraints.
- Develop working plans.
- Devise and perform a test of the solution.

STANDARD 3 - MATHEMATICS

Students use mathematical modeling/multiple representation to provide a means of presenting, interpreting, communicating, and connecting mathematical information and relationships.

- Represent problem situations symbolically by using algebraic expressions and graphs.
- Model real-world problems with equations.

STANDARD 4 - SCIENCE

Energy exists in many forms, and when these forms change, energy is conserved.

- Observe and describe transmission of various forms of energy.

STANDARD 5 - TECHNOLOGY

Technological tools, materials, and other resources should be selected on the basis of safety, cost, availability, appropriateness, and environmental impact; technological processes change energy, information, and material resources into more useful forms.

- Select appropriate tools, instruments, and equipment and use them correctly to process materials, energy, and information.
- Explain trade-offs made in selecting alternatives.
- Describe and model methods to control system processes and monitor system outputs.

STANDARD 6 - INTERCONNECTEDNESS: COMMON THEMES

Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

- Collect information about the behavior of a system and use modeling tools to represent the operation of the system.

STANDARD 7 - INTERDISCIPLINARY PROBLEM SOLVING

The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena.

- Design solutions to real-world problems, using a technological design process that integrates scientific investigation and rigorous mathematical analysis of the problem and the solution.
- Explain and evaluate phenomena mathematically and scientifically.

Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

- Students participate in an extended mathematics, science, and technology project in which they work effectively; gather and process information; generate, analyze, and implement ideas; and present results.

Learning Standards for Career Development and Occupational Studies

The University of the State of New York, The State Education Department

STANDARD 2 - INTEGRATED LEARNING

Integrated learning encourages students to use essential academic concepts, facts, and procedures in applications related to life skills and the world of work. This approach allows students to see the usefulness of the concepts they are being asked to learn and to understand their potential application in the world of work.

- Demonstrate the integration and application of academic and occupational skills in their school learning, work, and personal lives.
- Use academic knowledge and skills in an occupational context, and demonstrate the application of these skills by using a variety of communication techniques (e.g., sign language, pictures, videos, reports, and technology).
- Research, interpret, analyze, and evaluate information and experiences as related to academic knowledge.

STANDARD 3A - UNIVERSAL FOUNDATION SKILLS

Basic skills include the ability to read, write, listen, and speak as well as perform arithmetical and mathematical functions.

- Use a combination of techniques to read or listen to complex information and analyze what they hear or read.
- Convey information confidently and coherently in written or oral form.
- Analyze and solve mathematical problems requiring use of multiple computational skills.

Thinking skills lead to problem solving, experimenting, and focused observation and allow the application of knowledge to new and unfamiliar situations.

- Demonstrate the ability to organize and process information and apply skills in new ways.

National Standards for Technological Literacy

STANDARD 2

Students will develop an understanding of the core concepts of technology.

- Z: Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
- AA: Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

Student participating in group presentation.

ASSESSMENT STRATEGIES FOR *DRYING BY DESIGN*

Assessment of student design work should consider many factors and focus on the design process as well as the finished product (design solution).

Each component of design-related student activity is represented in preliminary rubrics (scoring guides) found in the NYSCATE *Pedagogical Framework* (p. 30). That set of rubrics is generic to all NYSCATE design activities. However, the rubrics can be tailored to a particular assignment and should be discussed with students in advance so that they are aware of the evaluation criteria.

A sample from the set of rubrics is presented here for the design solution.

The Design Solution

A. AN ACCURATE SKETCH OF YOUR FINAL DESIGN, AS BUILT, WAS DRAWN.

4. Drawing was on graph paper to scale with all elements included. Isometric view or multiple views (top, side, and front) were shown.
3. Drawing was on graph paper to scale with all elements included. Drawing showed the design in two dimensions (a flat view).
2. Drawing was on graph paper approximately to scale with most elements included.
1. Drawing was not to scale and important elements were missing.

B. MATERIALS AND TOOLS WERE PLANNED AND USED APPROPRIATELY IN CONSTRUCTING PROJECT.

4. Listed materials and tools are present, as well as a description of how they should be used.
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.

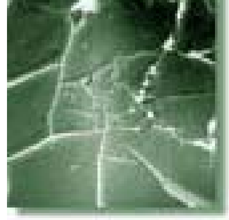
4. The solution solved the problem statement; this was explained in the write-up along with how the specifications and constraints were addressed and/or how the design was modified to assure their being met.
3. The solution solved the problem statement and the constraints and specifications were met.
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. THE DESIGN WAS CREATIVE.

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 someone else's solution.
1. The solution appears to have been copied from someone else's work.

In addition to your assessment of student design process and products, you should assess the quality of students' Design Journals (or DAFs), Design Reports, and group presentations to the class. You might include multiple choice, short answer, or extended response questions that provide assessment of design understandings, content knowledge, and technical skill.

Handout Section



Overview of the Module and Design Challenge

Here's What You Will Do

In the NYSCATE module *Drying by Design*, you will work in a group to:

- understand and investigate possible solutions to a given problem;
- investigate that problem by completing Knowledge and Skill Builder (KSB) activities;
- use appropriate tools and materials to design a solution to the given problem;
- base your design and redesign upon scientific and mathematical concepts;
- see that your design meets specifications and constraints;
- collect, plot, and compare test data;
- use mathematical models, such as graphs and equations, to analyze your data;
- make improvements to your design based on your data analysis;
- develop and use a repeatable and reliable method for testing your design;
- propose improvements based on results of testing your design and related science and mathematics concepts.

Materials Needed

Your teacher or group may provide materials and tools. Any materials and tools provided by your group must be approved in advance by your teacher.

Problem Context

INTRODUCTION

A local elementary school group is planning a weekend hike during which they must carry everything, including their food and clothing. They are concerned about the heavy load each person will have to carry. Unable to think of ways to substantially reduce the weight of their backpacks, they have turned to you for advice.

DESIGN CHALLENGE

As part of a group, you will design, construct, and test a dehydrator that dries fruit in as short a time as possible while maintaining the quality of the foodstuff.

SPECIFICATIONS

Dehydrate 250 grams of apple slices to 20% or less of their initial weight.

CONSTRAINTS

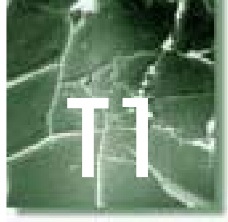
You may use only approved materials and tools. In addition, the drying surface your team uses must have an area no greater than 144 square inches.

Student Requirements

You will be expected to:

- maintain either a Design Activity Folio (DAF) or a Design Journal in which you will gather and record information as you complete the design challenge for this module;
- complete a final Design Report that summarizes your work and findings;
- develop a group presentation to explain how your group met the design challenge;
- be assessed on the quality of your work on MST Knowledge and Skill Builders (KSBs), your Design Journal or Design Activity Folio, Design Report, and group presentation.

Your teacher will assess your understanding of the Knowledge and Skill Builders and evaluate the quality of your Design Activity Folio or Design Journal, your Design Report, and your group's presentation.



The Informed Design Cycle

A method is shown (see informed design cycle diagram) to achieve informed technological design. The cycle includes several phases. In this model, the phases together are referred to as the design cycle. The model involves repeatable phases that engage you in the design process.

You are to work in a manner similar to that of adult professionals who do engineering design for a living. Engineers and other designers rarely follow these phases in order. Instead, they move back and forth from one phase to another as needed. You also are not expected to go through the phases in the same order each time you design something. Additionally, some decisions are made without complete knowledge and as a result phases must be revisited later on. The designer arrives at solutions, monitoring performance against desired results and making changes as needed. Usually, following design criteria leads to trade-offs taking place. Seldom is true perfection obtained.

Further information on the phases of the informed design cycle follows:

Clarify design specifications and constraints. Describe the problem clearly and fully, noting constraints and specifications. Constraints are limits imposed upon the solution. Specifications are the performance requirements the solution must meet.

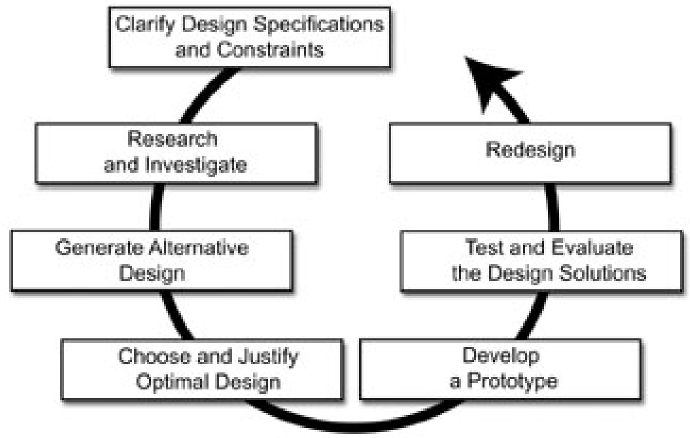
Research and investigate the problem. Search for and discuss solutions that presently exist to solve this or similar problems. Identify problems, issues, and questions that relate to addressing this design challenge.

Generate alternative designs. Don't stop when you have one solution that might work. Continue by approaching the challenge in new ways. Describe the alternative solutions you develop.

Choose and justify optimal design. Defend your selection of an alternative solution. Why is it the optimal choice? Use engineering, mathematical, and scientific data, and employ analysis techniques to justify why the proposed solution is the best one for addressing the design specifications. This chosen alternative will guide your preliminary design.

Develop a prototype. Make a model of the solution. Identify possible modifications that would lead to refinement of the design, and make these modifications.

Test and evaluate the design solution. Develop a test to assess the performance of the design solution. Test the design



solution, collect performance data, and analyze the data to show how well the design satisfies the problem constraints and specifications.

Redesign the solution with modifications. In the redesign phase, critically examine your design and note how other students' designs perform to see where improvements can be made. Identify the variables that affect performance and determine which science concepts underlie these variables. Indicate how you will use science concepts and mathematical modeling to further enhance the performance of your design.

Develop Your Understanding

1. Review the informed design cycle and explain how you might use the phases to guide efforts for your situation. Identify any procedural changes you would add, delete, or change. Defend your recommendation(s).
2. Review the NYSCATE Design Activity Folio (DAF) and determine if you would choose to use it or the Design Journal to help you document your work.
3. Pick one example of a product or system that was poorly designed. Explain possible reasons why the manufacturer might have allowed it to be produced with design flaws. Explain consequences (both positive and negative) that might result from a less-than-optimal design.
4. Provide an example of a product or system that you think could benefit from an improved design.

Dehydration Techniques

Use the World Wide Web or printed materials to investigate food dehydration techniques.

Develop Your Understanding

1. List the factors that are most important for the proper drying of food.

2. Explain why each factor is important in the dehydration process.

3. What dehydration techniques seem appropriate for the design challenge you have been asked to address?

4. Which of the appropriate techniques seems most important? Make a claim that explains its importance.

Mathematical Comparison of Relationships

Graphing Activity A

A thermocouple is created when two different metal wires are joined together and heated at the junction. A small voltage difference that varies with temperature can be measured across the junction. The table to the left shows the temperature values associated with various voltage readings.

Temperature (degrees C)	Voltage (in mV)
25	1.0
100	4.1
175	7.1
250	10.2
330	

Develop Your Understanding, Part A

1. What is the independent (manipulated) variable?

2. Predict what the voltage would be when the temperature of the junction is 330 degrees Celsius. Complete the table.

3. Plot the data for the completed table on graph paper.

Time (minutes)	Temperature (degrees C)
0	
1	
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	

Graphing Activity B

In the table to the left, record the data (temperature decrease over time) obtained while cooling a container of hot water. Plot the data from the table on graph paper, following the instructions described in the box below.

> Plot the temperature/time data for the cooling water with dimensionless temperature ($T/T_{initial}$) where $T_{initial}$ is the temperature in degrees Celsius at time equal zero.

Develop Your Understanding, Part B

1. Assume the final water temperature will be room temperature, and extrapolate the data to that temperature. Use your graph to predict how long it should take for a newly poured container of hot water to reach room temperature.

2. Should you be taking measurements at the same time interval throughout the cooling process? Why or why not?

3. Extrapolate the data to the final temperature. How long do you estimate it will take to reach this temperature?

4. Use printed sources or the World Wide Web to search for the meaning of mathematical terms such as *linear* and *nonlinear*. Use the terms in a sentence to describe the relationships present in the two graphs you constructed.

5. **Return to this later on.** When you collect data in KSB S1, determine the following:

   5a. Examine the graph you constructed for dehydration of apple slices. Extrapolate beyond the data provided to predict the weight (for the next time interval) of your apple slices. In other words, what would have happened had you continued to dehydrate your apples beyond what you accomplished?

   5b. Does your graph represent a linear or a nonlinear relationship?

6. **Return to this later on.** When you have constructed your dehydrator and used it to gather data on progress for your apples, plot the data from your dehydrator on a graph and describe whether this drying process is linear or nonlinear.

7. Explain your reasoning based on the thermocouple and water-cooling graphs you previously completed.

Banana Data

The data below resulted from students dehydrating banana slices of varying thicknesses.

Plot the data for each thickness on the same graph paper or spreadsheet.

1/8" Thick	
time (hr)	weight (g)
0	36.9
0.5	28.3
1	22.1
1.5	18.5
2	14.7
2.5	12.3
3	11
3.5	9
4	8
4.5	8.6
5	7.4
5.5	7.4

1/4" Thick	
time (hr)	weight (g)
0	30
0.5	26
1	22
1.5	19
2	16
2.5	14
3	12
3.5	11
4	10
4.5	8
5	7
5.5	6
6	6

3/8" Thick	
time (hr)	weight (g)
0	30
0.5	28
1	27
1.5	26
2	25
2.5	24
3	23
3.5	21
4	20
4.5	18
5	17
5.5	16
6	15
6.5	13
7	12
7.5	11
8	10
8.5	9
9	8
9.5	8
10	8

Comparison of the resulting curves is difficult because they have different weights for the various times. Finish the new table below, in which the data is dimensionless. Divide the weight readings by their initial values for each thickness. Plot the new data on the same graph paper or spreadsheet. The units for the different slices are the same.

1/8" Thick	
time (hr)	weight (g)
0	1
0.5	0.767
1	0.599
1.5	0.501
2	0.398
2.5	0.333
3	0.298
3.5	0.244
4	0.217
4.5	0.233
5	0.2
5.5	0.2

1/4" Thick	
time (hr)	weight (g)
0	1
0.5	0867
1	0.733
1.5	0.633
2	0.533
2.5	0.466
3	0.4
3.5	0.366
4	0.333
4.5	0.267
5	0.233
5.5	0.2

3/8" Thick	
time (hr)	weight (g)
0	1
0.5	0.933
1	0.9
1.5	0.867
2	0.833
2.5	0.8
3	0.767
3.5	0.7
4	0.667
4.5	0.6
5	0.567
5.5	0.533
6	0.5
6.5	0.433
7	0.4
7.5	0.366
8	0.333
8.5	0.3
9	0.267
9.5	0.267
10	0.267

Develop Your Understanding

1. Note the form of the curves for the first plots; are they linear or nonlinear?

2. Considering the last graph, what would be the best thickness for drying the greatest mass of bananas in the least amount of time?

Factor Investigation

This factor investigation is intended to reveal relationships among food dehydration, temperature, and evaporation.

Materials: Apples, slicing tool, fan, heat source (120w bulb), wire mesh, scale, graph paper or spreadsheets (computer optional)

Research Question: How does the thickness of a foodstuff such as an apple affect the rate of drying?

Your laboratory team has been assigned the task of designing and conducting a scientific experiment to determine how quickly apple slices of different thicknesses can dry while retaining their usefulness. Your supplies are: 1 apple, which you are to slice into 1/16", 1/8", and 1/4" slices; a slicing tool such as a knife; a floodlight or heat lamp; wire mesh; a fan; a scale; and graph paper or spreadsheets (computer optional). You will dry the apple slices over a period of 6 hours, recording your observations as best you can during this time.

Develop Your Understanding

1. Design a table that you will use to record data. The data table should have a title that includes both the independent and dependent variables. Describe the procedure you followed to set up your experiment. This procedure should be written logically and sequentially and presented in paragraph form. Check to see that you have included a clear description of how you collected your data. Plot the data graphically or use a spreadsheet. Look at the information represented by your graph and draw conclusions.

   Investigate the effect of thickness on drying time. Take slices of apple that are approximately 1/16", 1/8", and 1/4" thick, weigh them, and place them on a piece of mesh that is heated by a light source. Adjust a fan so that it moves air over the slices continuously. Over a period of two days, collect and plot the data to show weight versus time. Convert the plots to dimensionless weights for each slice thickness. Using what you learned here, compose a paragraph elaborating on whatever conclusions you draw.

2. Rewrite the title of your experiment in the form of a declarative statement ("The effect of … on … is…."), rather than in the form of a question ("How does…?").

3. Make a hypothesis about the problem in the "If… then…" format.

4. What is the independent variable for this activity? (Ask yourself, "Which variable is manipulated?")

5. How many trials are sufficient for this kind of investigation? Since you are completing only one trial, how will you come to a valid/reliable conclusion?

6. What is the dependent variable for this activity? (Ask yourself, "Which variable changes as a result of the manipulation?")

7. Which variables are controlled? (That is, which variables are kept constant?)

8. What will you use as a control for comparison purposes?

9. By convention, the results for which variable should be placed in the left-hand column of your table?

10. What conclusions do you draw from the data collected? Describe any patterns or trends you see in the data.

    10a. Does the data support or refute your hypothesis?

S2

KSBs

Science Knowledge and Skill Builders

Dehydration, Microbes, and Spoilage

Use printed sources or the World Wide Web to determine:

- the relationship of microbes to food spoilage, and
- the relationship of food dehydration to food spoilage.

Develop Your Understanding

1. Compose a paragraph that scientifically relates the terms *microbes*, *moisture*, *dehydration*, and *food spoilage*.

2. Relate the role of decomposers in a food web to the functioning of a food web.

3. Explain the way in which the drying of foodstuff affects the actions of decomposers.

Humidity

Use the World Wide Web or printed sources to answer these questions:

- What is humidity?
- How is humidity measured?
- What is the effect of the air's humidity on evaporation?
- What is the effect of air temperature on relative humidity?

Develop Your Understanding

1. Compose a paragraph relating the effects of temperature and evaporation on humidity.

2. Explain why cold air holds less water vapor than warm air.

3. Would you use warm air or cool air to facilitate evaporation from the surface of fruit you intend to dry? Defend your choice, using the information in the paragraph you wrote for number 1.

Appearance Changes

Dehydration may change the color and/or structure of an apple slice. Examine an apple slice under a dissecting microscope before, during, and after dehydration. Describe what you observe through sketches and words. Chemical preservatives are sometimes used ahead of time to decrease the change in appearance of dried fruit and to prevent further spoilage. Ascorbic acid, citric acid, lemon juice, salt water, and sodium bisulfite are commonly used in drying foods. Use a dissecting microscope to make before-and-after comparisons of the color and structural changes to the apple slices that you treat with one of the above-mentioned chemical preservatives. Record the results. Research through experimentation the effects of chemical preservatives on dehydration.

Develop Your Understanding

1. What observations did you make about the appearance of the slices before and after dehydration?

2. What observations did you make about the appearance before and after dehydration of slices treated with chemical preservatives?

3. What do you consider the advantages and disadvantages of the use of chemical preservatives during dehydration?