DOCUMENT RESUME

ED 439 966 SE 063 490

AUTHOR	Pulis, Lee
TITLE	Construct-a-Glove. Science by Design Series.
INSTITUTION	National Science Teachers Association, Arlington, VA.; TERC, Cambridge, MA.
SPONS AGENCY	National Science Foundation, Arlington, VA.
ISBN	ISBN-0-87355-177-X
PUB DATE	2000-03-00
NOTE	95p.; For other books in the Science by Design Series, see SE 063 488-491.
CONTRACT	ESI-9252894; ESI-9550540
AVAILABLE FROM	NSTA Press, 1840 Wilson Blvd., Arlington, VA 22201-3000. Web site: http://www.nsta.org.
PUB TYPE	Books (010) -- Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Construction (Process); *Design; High Schools; Problem Solving; Research Methodology; Resource Materials; *Science Activities; Teaching Methods; Technology
IDENTIFIERS	*Gloves

ABSTRACT

This book is one of four books in the Science-by-Design Series created by TERC and funded by the National Science Foundation (NSF). It offers high school students a challenging, hands-on opportunity to compare the function and design of many types of handwear from a hockey mitt to a surgical glove, and design and test a glove to their own specifications. Students learn the basic principles of product design while exploring the principles of physics and technology necessary to construct and test an insulated glove. The activities have assessment suggestions and Internet extensions through the National Science Teachers Association's (NSTA) sciLINKS program and are designed to meet the new International Technology Education Standards as well as the National Science Education Standards. Key ideas include: (1) "Homeothermic process [maintaining a constant internal body temperature]"--the measured and perceived warmth of a hand is related to its direct connection to the body's heat engine and the hand's relatively large ratio of surface area to volume. Variables that add complexity to an insulated-glove system design relate to the multiple functions of the hand: an appendage for body cooling, environmental sensing, and manipulating objects; (2) "Heat energy transfer processes, insulation materials, and dexterity"--student teams measure temperature change over time as a gloved hand is exposed to cold. Properties of various materials are explored for their effect on hand warmth and dexterity; (3) "Inquiry"--experiments are designed by students to supplement "fair test" comparisons of several manufactured gloves. Students conduct "hands-in" research to determine combinations of glove materials that balance thermal effectiveness with dexterity for a specific function; and (4) "Design"--students undertake an iterative, multi-disciplinary process that includes research, testing, and evaluation feedback loops as part of the product development cycle. Students work in development teams to design and construct an insulated glove system prototype and present their research and development efforts in a product prospectus. Appendices contain inquiry and design processes, text reconstruction, and various factors and variables to consider during construction. (Contains a glossary and 28 references.) (CCM)

SCIENCE by Design SERIES

construct a glove

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Construct-a-Glove

Developed by TERC
Lead author: Lee Pulis

This curriculum was developed by TERC, Cambridge, Massachusetts. Funded in part by a grant from the National Science Foundation.

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Arlington, VA 22201-3000
http://www.nsta.org/

Science by Design: Construct-a-Glove
Library of Congress Catalog Card Number 00-131683
NSTA Stock Number: PB152X1
ISBN 0-87355-177-X
Printed in the United States of America by Automated Graphic Systems, Inc.
Printed on recycled paper

This book was prepared with the support of the National Science Foundation under Grant Nos. ESI-9252894 and ESI-9550540. However, any opinions, findings, conclusions, and/or recommendations herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

National Science Teachers Association

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Acknowledgments

The creation of the NSTA *Science by Design* series builds on five years of research and development at TERC. This work was funded by two National Science Foundation grants: ESI-9252894 and ESI-9550540 and was directed by John Foster, David Crismond, William Barowy, and Jack Lochhead.

We are especially grateful for the vision, guidance, and prodding of our program officer, Gerhard Salinger, who was our GPS in uncharted territory.

We were helped in innumerable ways by an especially insightful advisory board: Joan Baron, Goery Delacote, Andy DiSessa, Woodie Flowers, John Foster, Mike Hacker, Colleen Hill, Gretchen Kalonji, Robert McCormick, Jim Minstrell, Jim Neujahr, and David Perkins.

The members of the TERC team who contributed to the development and testing of the *Science by Design* units include:

Tim Barclay
William Barowy
Cathy Call
Judith Collison
David Crismond
Brian Drayton
Christine DiPietrantonio
Joni Falk
John Foster
June Foster
Riley Hart
Nathan Kimball
Felicia Lee
Jack Lochhead
Tasha Morris
Tracy Noble
Alison Paddock
Meghan Pfister
Lee Pulis
Jerry Touger
Margaret Vickers
Paul Wagoner
Kelly Wedding
Amy Weinberg

Special mention must be made of the enthusiasm, dedication, and long hours contributed by David Crismond and Earl Carlyon. The following hard-working consultants added greatly to our efforts: Hilton Abbott, Robert B. Angus, Carol Ascher, Warren R. Atkinson, Earl Carlyon, Michael Clarage, Jan Hawkins, Kathy Kittredge, Crispin Miller, James E. LaPorte, Kjell-Jan Rye, Rick Satchwell, Mike Stevens, and Ron Todd.

The authors of the final *Science by Design* units were William Barowy, Felicia Lee, Jack Lochhead, Alison Paddock, and Lee Pulis of TERC.

Science by Design: Construct-a-Glove was produced by NSTA Press: Shirley Watt Ireton, director; Beth Daniels, managing editor; Erin Miller, associate editor; Jessica Green, assistant editor; Michelle Treistman, assistant editor; Anne Early, editorial assistant. Beth Daniels was project editor for the *Science by Design* series. The cover design and book design are by Camden Frost and Vicky Robinson of Graves Fowler Associates.

Field testing of the *Science by Design* series depended on the dedication of dozens of teachers and the helpful cooperation of their school systems:

Jerian Abel, Northwest Regional Education Laboratory
Bruce Andersen, Buker Middle School
Dave Armstrong, Lawrence Middle School
Henry Bachand, Mansfield High School
Hilda Bachrach, Dana Hall School
Ronald Bjorklund, Leicester High School
Marcella Boyd, Manchester Junior High School
Karen Bouffard, Governor Dummer Academy
Althea Brown, Medford High School
Lee Burgess, Lawrence Middle School
David Corbett, Whittier Regional Vocational Technical High School
Steve Cremer, Braintree High School
Deborah Crough, Long Beach High School
Ron Daddario, McCall Middle School
Raymond P. Gaynor, Reid Middle School
Elizabeth George, Westborough High School
Pam Glass, Talbot Middle School
Rick Harwood, Ware High School
Gary Herl, Tantasqua Regional Junior High School
Kate Hibbitt, Lincoln School
Patrick Keleher, Norwood Junior High School
Marty Kibby, Minetron Technology Education Office
Matias Kvaternik, Chelmsford Public Charter School
Jeff Leonard, F.A. Day Middle School
Walter Lewandowsler, Bartlett High School
David R. Littlewood, Agawam Junior High School
John Matthews, Southwick Tolland Regional High School
Eilen McCormack, South Jr. High Brockton
Scott McDonald, Needham High School
Brian McGee, Lexington Middle School
Bob Meltz, Manchester Junior-Senior High School
Charles O'Reilly, Lexington High School
Constance Patten, Lincoln-Sudbury High School
Fred Perrone, East Junior High School
Joe Pignatiello, Somerville High School
Doug Prime, Lancaster Middle School
Michael Rinaldi, Bedford High School
Thomas Rosa, Walsh Middle School
Eugene A. Santoro, Silver Lake Regional High School
John Schott, Smith Academy
Bruce Seiger, Wellesley High School
Douglas Somerville, Woodword Middle School
John Stamp, Manchester High School
Mike Stevens, Maynard High School
Michael Sylvia, Charles E. Brown Middle School
Syd Taylor, Mahar Regional School
Ted Vining, Monument Regional High School
Frank Viscardi, Framingham High School

This project would not have been possible without the help and critique of hundreds of students whom we regretfully cannot mention by name.

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A NOTE FROM THE DEVELOPERS

Integrating Science and Technology

Construct-a-Glove is aligned with the National Science Education Standards for process and content standards in both physical science and biology. This alignment is illustrated on pages four and five. Through inquiry and design, students develop conceptual understanding of heat energy transfer, cell metabolism, and thermal regulation. Because design activities motivate inquiry and inquiry informs design, students engage in the iterative processes of scientific inquiry and technological design through a variety of hands-on activities.

Compare these materials to a highway: if you rush straight through, your students will learn only a little about the territory they have crossed. We provide a number of interesting side roads, which you may or may not choose to investigate. Following these side roads will take more time, but there is no better way to explore the linkage of inquiry and design. For your first trip, you may want to stay close to the highway, but as you gain experience, we hope you will travel further and further from it.

Schedule and Cost

The minimum time needed to complete the core unit is about 12 class sessions. More time will be needed if you choose to include the enrichment activities.

In *Construct-a-Glove*, students are given the Design Brief challenge and instructions for making a Quick-Build insulated glove (about three class sessions). During the Research and Development phases (a minimum of seven class sessions), students identify relevant factors and variables, design and conduct experiments, and contribute to a product development team. They develop a physical model of their design, test, measure, analyze their data, and redesign if necessary. Students search for combinations and configurations of materials that can improve the performance of their prototype glove. Teams critique each other's prototypes and learn to build on the experience and insights of other groups. In the Communication section (one or two class sessions), the team composes a Product Prospectus.

KEY IDEAS

Text Reconstruction

Each key science idea used in the *Construct-a-Glove* unit is covered in a Text Reconstruction (TR) exercise sheet located in Appendix B. The first sheet, "Homeothermic Processes," involves a very simple reconstruction and is intended as an introduction to TR. For more information about the pedagogical benefits of TR, refer to the introductory section in Appendix B.

Homeothermic process (maintaining a constant internal body temperature)

The measured and perceived warmth of a hand is related to its direct connection to the body's heat engine and the hand's relatively large ratio of surface area to volume. Variables that add complexity to an insulated-glove system design relate to the multiple functions of the hand: an appendage for body cooling, environmental sensing, and manipulating objects.

Heat energy transfer processes, insulation materials, and dexterity

Student teams measure temperature change over time as a gloved hand is exposed to cold. Properties of various materials are explored for their effect on hand warmth and dexterity.

Inquiry

Experiments are designed by students to supplement "fair test" comparisons of several manufactured gloves. Students conduct "hands-in" research to determine combinations of glove materials that balance thermal effectiveness with dexterity for a specific function.

Design

Students undertake an iterative, multi-disciplinary process that includes research, testing, and evaluation feedback loops as part of the product development cycle. Students work in development teams to design and construct an insulated glove system prototype and present their research and development effort in a product prospectus.

ASSESSMENT

Student activity sheets may be used for formative or summative assessment. The first *Snapshot of Understanding,* included in the introduction, is intended as a pre-learning index of prior knowledge. It may be compared to similar questions on the final *Snapshot,* given at the end of the last activity, for a self-assessment of learning. Because group work is stressed throughout the unit, group assessment may prove more appropriate than individual scores. If this is not desired, homework assignments may provide the best measure of individual performance.

Portfolio Suggestions

A portfolio can be a useful tool for maintaining individual accountability in a team-work environment, because in a portfolio, students can capture representative samples of their work done over time. Among the many guides to portfolio assessment is:

Portfolio Assessment: A Handbook for Educators by James Barton and Angelo Collins, Addison-Wesley, 1997.

Potential Portfolio Items

The following set of items and products can be accumulated in portfolios for summative assessment. Each corresponds to a core or enrichment activity outlined in the Activities Overview schematic on page 6. They are (with handouts printed in italics):

- Pre-test: *Snapshot of Understanding*
- Initial questions: *Design Brief*
- Individual information search: *Info Search Strings*
- Brainstorming record: *Identifying Factors and Variables*
- Problem statements: *Team Situation Analysis*
- Research and results: *Investigating Heat Transfer and Insulation* and *"Fair Test" Comparison*
- Group process description: *The Inquiry Process*
- Group process description: *The Design Process*
- Physical modeling: *Prototype Construction*
- Prototype performance test notes: *Performance Tests*
- Evaluation of prototype: *Reflections on Your Design*
- Group summary documentation: *Product Prospectus*
- Post-test and self-assessment: *Snapshot of Understanding*

Standards and Benchmarks Connections

TASK	SOURCE
❑ *Students build to specifications, observe and measure thermal performance of a simple insulated glove system*	AAAS 9-12, NSES 9-12, NSES K-12

Standard/Benchmark: Materials and Manufacturing; Systems; Manipulation and Observation; Physical Science Content; Life Science Content; Unifying Concept: Evidence, Models, and Explanation

---

❑ *Students conduct independent information searches in context of contemporary human inventiveness* — AAAS 9-12, ITEA, 9-12, NCSS VIII

Standard/Benchmark: Issues in Technology; Nature and History of Technology Science, Technology, and Society

---

❑ *Students describe variation, and identify variables and corresponding potential controls for improving design to meet performance goals* — AAAS 9-12, ITEA 9-12, NSES K-12

Standard/Benchmark: Systems; Manipulation and Observation; Technological Design; Unifying Concept: Evidence, Models, and Explanation

---

❑ *Students use elements of inquiry, investigating heat transfer and insulation, to inform design* — AAAS 9-12, NSES 9-12, ITEA 9-12

Standard/Benchmark: Scientific Inquiry; Design and Systems; Inquiry; Technological Design; Utilizing and Managing Technological Systems

---

❑ *Students use "fair test" comparisons to quantify relative handwear performance parameters* — AAAS 9-12, NSES 9-12 & K-12, ITEA 9-12

Standard/Benchmark: Critical Response Skills; Physical Science Content Standard; Life Science Content Standard; Unifying Concept: Constancy, Change, and Measurement; Technological Design; Linkages

---

❑ *Students conduct research on human homeothermic regulation and hand function as input to glove system design* — AAAS 9-12, NSES 9-12 & K-12

Standard/Benchmark: Basic Functions; Life Science Content Standard; Unifying Concept: Form and Function

---

❑ *Students communicate orally and in writing their interpretation of this investigation, and what variables to control in design development* — AAAS 9-12, ITEA 9-12, NCTM II

Standard/Benchmark: Scientific Inquiry; Technological Design; Math as Communication; Statistics

---

❑ *Students apply abilities of iterative technological design, including brainstorming, research, ideation, choosing among alternative solutions, development, implementation, and evaluating consequences* — ITEA 9-12, AAAS 9-12, NSES 9-12 & K-12

Standard/Benchmark: Technological Concepts and Principles; Technological Design; Developing and Producing Technological Systems; Systems Operation and Feedback; Abilities of Technological Design; Unifying Concept: Systems, Order, and Organization

TASK	SOURCE
❑ *Students use tools and processes to construct and modify working models* **Standard/Benchmark:** Developing and Producing Technological Systems	ITEA 9–12
❑ *Students collect, represent, and statistically process test data to improve design prototype* **Standard/Benchmark:** Manipulation and Observation; Utilizing and Managing Technological Systems Statistics	AAAS 9–12, ITEA 9–12, NCTM X
❑ *Students create detailed product specifications and manufacturing instructions for their final design* **Standard/Benchmark:** Design and Systems; Manipulation and Observation; Math as Communication	AAAS 9–12, NCTM II
❑ *Students communicate quantitatively the technical construction specifications and performance characteristics for their prototype in a Product Prospectus* **Standard/Benchmark:** Commmunication Skills; Design and Systems; Technological Design; Math as Communication	AAAS 9–12, ITEA 9–12, NCTM II
❑ *Students articulate principles of biological and physical science employed in glove system design* **Standard/Benchmark:** Critical Response Skills; Science and Technology; Technological Design Linkages	AAAS 9–12, NSES 9–12, ITEA 9–12
❑ *Students self-assess their learning by comparing pre- and post-Snapshots of Understanding* **Standard/Benchmark:** Issues in Technology; Science, Technology, and Society	AAAS 9–12, NCSS VIII

SOURCE KEY:

AAAS American Association for the Advancement of Science. 1993. *Project 2061: Benchmarks for Science Literacy*. New York: Oxford University Press.

ITEA International Technology Education Association. 1996. *Technology for All Americans: A Rationale and Structure for the Study of Technology.*

NCSS Task Force on Social Studies Teacher Education Standards. 1997. *National Standards for Social Studies Teachers.* Washington, DC: National Council for the Social Studies.

NCTM National Council for Teachers of Mathematics. 1991. *Professional Standards for Teaching Mathematics.* Reston, VA: NCTM.

NSES National Research Council. 1996. *National Science Education Standards.* Washington DC: National Academy Press.

SCILINKS® THE WORLD'S A CLICK AWAY

Go to: www.scilinks.org

Topic: heat transfer
Code: CAG01

Topic: radiation
Code: CAG02

Topic: conduction/ convection
Code: CAG03

Topic: metabolism
Code: CAG04

Topic: insulation
Code: CAG05

Topic: scientific inquiry
Code: CAG06

Science by Design: Construct-a-Glove brings you *sci*LINKS, a new project that blends the two main delivery systems for curriculum—books and telecommunications—into a dynamic new educational tool for all children, their parents, and their teachers. This effort, called *sci*LINKS, links specific science content with instructionally rich Internet resources. *sci*LINKS represents an enormous opportunity to create new pathways to learners, new opportunities for professional growth among teachers, and new modes of engagement for parents.

In this *sci*LINKed text, you will find an icon near several of the concepts you are studying. Under it, you will find the *sci*LINKS URL (http://www.scilinks.org/) and a code. Go to the *sci*LINKS Web site, sign in, type the code from your text, and you will receive a list of URLs that are selected by science educators. Sites are chosen for accurate and age-appropriate content and good pedagogy. The underlying database changes constantly, eliminating dead or revised sites or simply replacing them with better selections. The ink may dry on the page, but the science it describes will always be fresh. *sci*LINKS also ensures that the online content teachers count on remains available for the life of this text. The *sci*LINKS search team regularly reviews the materials to which this text points—revising the URLs as needed or replacing Web pages that have disappeared with new pages. When you send your students to *sci*LINKS to use a code from this text, you can always count on good content being available.

The selection process involves four review stages:

1. First, a cadre of undergraduate science education majors searches the World Wide Web for interesting science resources. The undergraduates submit about 500 sites a week for consideration.
2. Next, packets of these Web pages are organized and sent to teacher-Webwatchers with expertise in given fields and grade levels. The teacher-Webwatchers can also submit Web pages that they have found on their own. The teachers pick the jewels from this selection and correlate them to the National Science Education Standards. These pages are submitted to the *sci*LINKS database.
3. Then scientists review these correlated sites for accuracy.
4. Finally, NSTA staff approve the Web pages and edit the information provided for accuracy and consistent style.

Course Outline

Introduction

Design Brief
Snapshot of Understanding

Quick Build

A Quick-Build Insulated Glove
Identifying Factors and Variables
Team Situation Analysis

Research

Overview
Individual Research Reports
Research Protocols for Investigating Heat Transfer and Insulation
"Fair Test" Comparison

Development

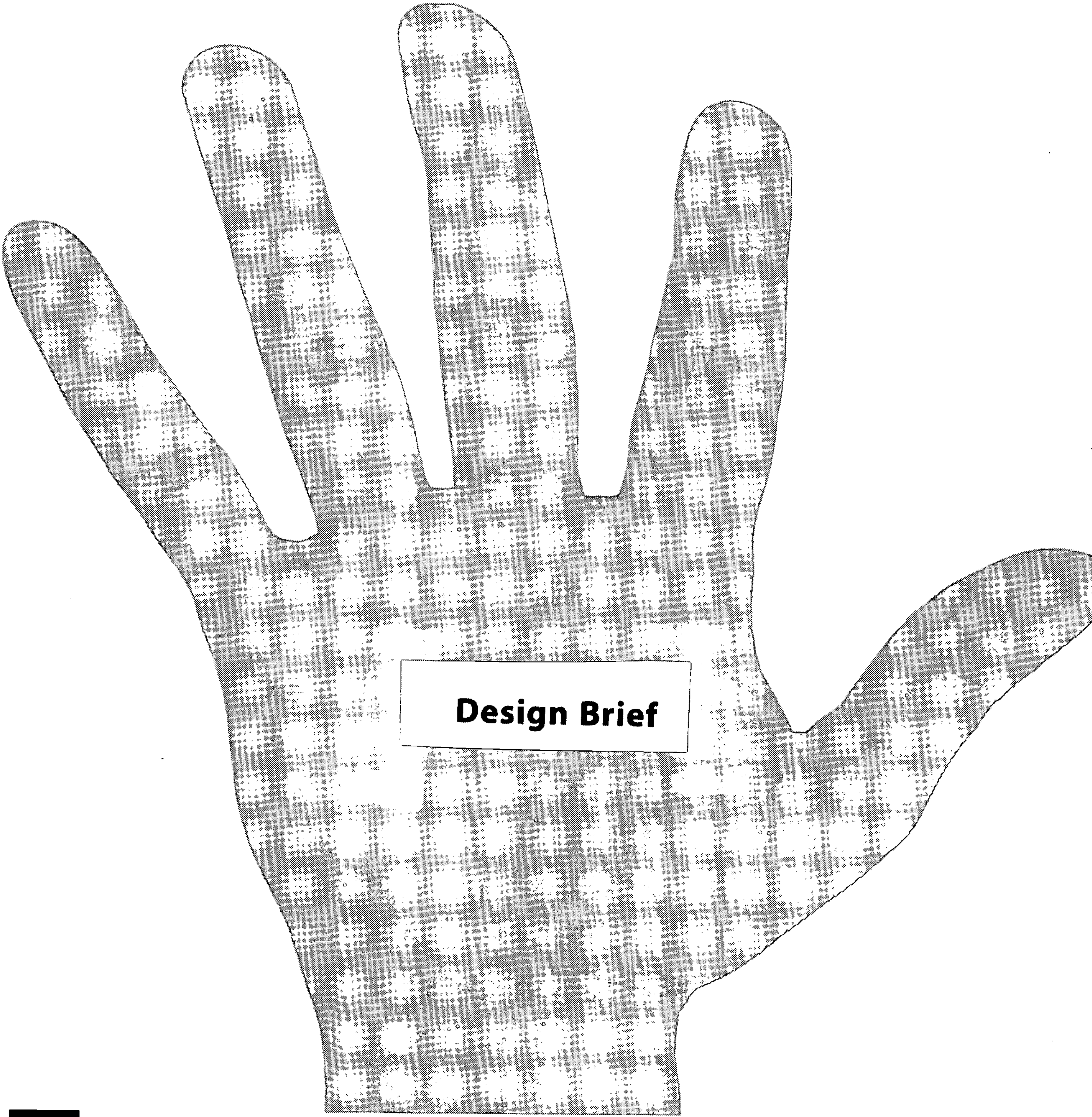
Overview
Development Assignment
Feedback
Reflections on Design

Communication

Overview
Creating a Product Prospectus
Snapshot of Understanding
Next Steps

Side Roads

Sample Industry Handwear Description
Thermal Factoids
Information Search Strings
Inquiry Process
Homeothermic Regulation
Design Process
Text Reconstruction Exercises:
Homeothermic Processes
Heat Energy Transfer


Design Brief

INSULATED GLOVE DESIGN BRIEF

In this activity, you will be researching, designing, building, and improving an insulated glove system. You will use both technological design and scientific inquiry as processes to investigate and improve the performance of your prototype.

Your Design Challenge

As a member of a product research and development team, design an insulated glove system that keeps the tip of your index finger as warm as possible in uncomfortably cold surroundings, while maintaining dexterity for a specific function.

Scope of Work

- **Quick-Build:** Build and test an initial glove design according to instructions.
- **Research:** Investigate heat transfer and insulation and identify variables you can control to create an improved insulated glove.
- **Development:** Specify function, redesign, build, and test; collect data and analyze patterns of results; then finalize your prototype for critical review.
- **Communication:** Present a product prospectus that summarizes your team's final design, including documentation such as sketches, data, specifications, and limitations.

SNAPSHOT *of Understanding:*

What I already know about Homeothermy, Heat Transfer, and Research and Development.

The unit of study you are about to begin will challenge you to design, build, and performance-test a prototype model of an insulated glove. To meet the performance specifications, you will have to investigate heat transfer physics, biological temperature regulation, and insulative effectiveness of materials and configurations. Before you begin, record a sample of what you already know by answering the questions below. This is not a test; rather it is a series of questions that ask about your current knowledge of key ideas in this unit. At the end of the unit, you will answer similar questions, and compare what you have learned.

1. What are the parts of the hand?

   (a) What are the functions of a hand (e.g., sensing, temperature regulation, manipulation, etc.)?

   (b) Make a sketch of a hand and label the important parts and functions.

2. List as many special purpose kinds of gloves as you can. Place a "T" by those specifically designed to provide thermal protection.

Example	*Welding - T*

SCILINKS® THE WORLD'S A CLICK AWAY

Topic: heat transfer
Go to: www.scilinks.org
Code: CAG01

Topic: radiation
Go to: www.scilinks.org
Code: CAG02

Topic: conduction/ convection
Go to: www.scilinks.org
Code: CAG03

3. Think of a time when your hands were really cold. What were you trying to do?

   How did you warm them?

   Which heat transfer process did you use? (e.g., radiation, conduction, convection)

4. What test(s) could you perform to determine if an animal is "warm-blooded" (homeothermic) or "cold-blooded" (poikilothermic)?

5. To maintain your relatively constant body temperature of 36°C, what does your body do automatically?

   What are some things you do purposefully to make yourself warmer or cooler?

6. What are **temperature** and **heat**, and how are they related?

MATERIALS

Student Activity Sheets

- Course Outline
- Insulated Glove Design Brief
- Snapshot of Understanding

Ring, Pocket, or Folio Binder

- *(student supplied) for keeping student activity sheets, notes, and drawings for reference and portfolio assessment*

PREPARATION

- *Read and become familiar with the entire unit.*
- *Prepare an introduction to motivate student interest.*
- *Define your assessment system with a clear, simple description.*

DAY 1

OVERVIEW—DESIGN BRIEF

Give students the *Insulated Glove Design Brief* and the *Snapshot of Understanding*. Initiate class discussion and highlight important design issues.

Construct-a-Glove Challenge to Students

Each student, as a member of a product research and development team, is to design an insulated glove system that keeps the tip of the index finger as warm as possible in uncomfortably cold surroundings while maintaining dexterity for a specific function.

SNAPSHOT *of Understanding:*

Students write short answers to questions about their prior knowledge of heat transfer, body temperature regulation, and research and design processes. (20 minutes suggested.)

TEACHING SUGGESTIONS

Introduction

Hand out the *Insulated Glove Design Brief* student activity sheet. Ask students to keep these and future sheets together in one place and to bring them to the classroom with other notes to serve as a record and reference for daily activity (and assessment) in the unit. Advise students that they will work in teams, use processes of technological design and scientific inquiry together, and that other teams will critique their prototype with respect to the challenge criteria. Students are also required to document their activity in order to both contribute effectively to the final team presentation and to enhance their individual portfolios. Be clear on your rubrics for assessing their work and share them with students. Indicate which activities will be individually graded and which will be given a team score. Be prepared to justify team scoring if some students (or parents) are not used to the idea.

Issuing the Construct-a-Glove Challenge

We encourage you to expand the challenge to accomplish additional learning objectives but be careful to think through what will be involved.

For example, a criterion of dexterity (such as the ability to pick up a marble with the insulated glove system) might be added to enrich the challenge if robotics or finger function is pertinent to your course objectives. But this addition will demand more sophisticated technical materials, involve greater construction difficulties, and require more student time.

Other Possible Criteria

- Let students specify the dexterity they have achieved after-the-fact, in their product prospectus.

- Let teams choose to design for one of several simulated bid invitations. You will need to prepare the bid request document (be sure to include dexterity task specifications).

- Set one uniform standard for all teams to achieve with the gloved hand immediately following a standardized immersion time in ice water. Example tasks might be picking up a pencil off a flat surface, operating a camera, using pliers, holding a nail for hammering, tuning a radio, opening a keyed lock, placing a nut on a bolt, etc.

- Set a theme such as survival in snow country; orient toward natural insulation materials such as leaves and grasses that can be gathered outdoors; and specify necessary hand functions such as gathering firewood and signaling for help. (Define or supply the range of options so as not to damage the local environment.)

Pre-Assessment

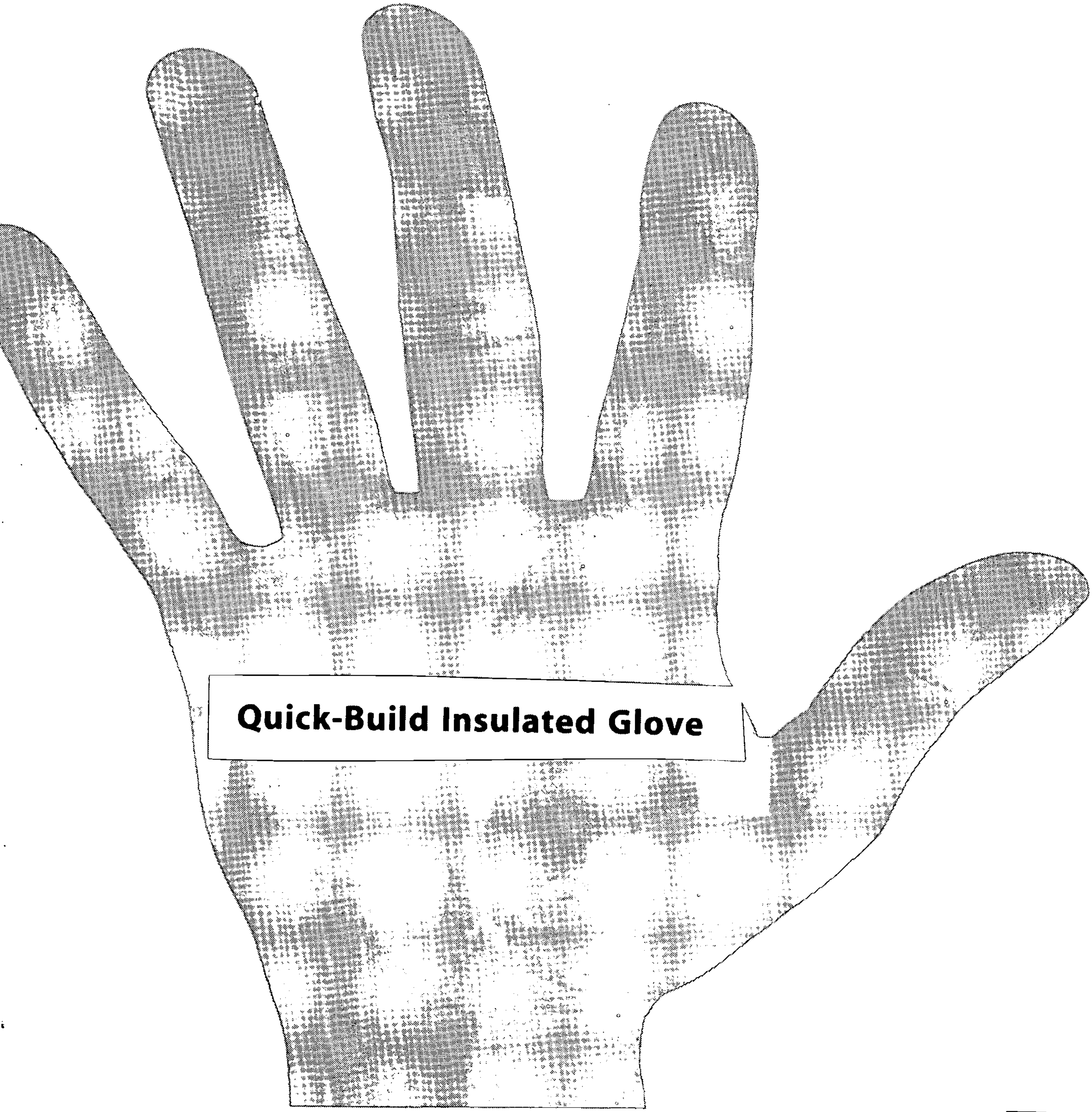
Hand out the *Snapshot of Understanding*. Emphasize that this is not a test, and they will not be graded on this activity. Its purpose is self-diagnostic, to find out what they know initially about the unit's key science and technology learning objectives. Making an inventory of their prior knowledge is an important learning tool. Not only can the inventory help to guide their learning toward the areas where students need to learn the most, but it also prepares their minds to accept new information in a manner that ties it meaningfully to what they already know. At the end of *Construct-a-Glove,* students will be able to compare answers to Snapshot questions given at the beginning of the unit to those they will answer at the end of the unit.

Allow about 20 minutes for students to complete the Snapshot, then collect and retain.

In the *Snapshot of Understanding,* students list as many special-purpose gloves as they can, given one example (welding). Some additional examples are:

- staining/painting/waxing
- food handling
- gardening
- dish washing
- skiing
- driving
- diving
- golfing
- meat cutting
- boxing
- baseball
- hockey
- fashion
- surgical
- wood cutting
- mountain biking
- cattle roping
- chemicals handling
- fire fighting
- traffic directing
- electrical line working
- space walking
- hunting
- archery
- ice fishing
- mountain climbing

Encourage a class discussion of differences among special purpose gloves; this can help students better relate form to function.


Quick-Build Insulated Glove

2 DAYS

QUICK-BUILD INSULATED GLOVE

Your body, like a home in cold climates, has a complex heating system optimized to maintain an internal temperature typically well above that of its surroundings. Chemical digestion of food can be compared to combustion of fuel in a furnace. Your circulatory system pipes heat to all parts of your body, just as air ducts or pipe loops do in the home. Just as some parts of your home feel warmer or cooler than others, temperatures at different locations in and on your body can vary within a range of comfort or concern. Your body's many biological sensors can reduce and redirect heat, and even activate evaporative cooling (sweating). Similarly, zoned thermostats control home heating and cooling by on/off switching or speed control of fans and dampers, or pumps and valves. Rooms, or hands, that are too cool can be warmed by either adding heat or reducing heat loss with insulation.

Work in teams of three to do the following experiments concerning thermal energy, heating, cooling, and insulation. Each individual should record independent notes and answers as well as the shared team data. These will be used later for portfolio assessment.

1. Decide which one of your team's available hands will be gloved and tested. Record in your lab book the factors you took into consideration when deciding which team member's hand you chose (for example volume to surface ratio, warmth to touch, rings, nail length, etc.) and the reasoning you used.

    a. Trace the chosen team member's hand on a sheet of paper.

    b. Mark points 1, 2, and 3 (as in the diagram on page 17) and select two additional points 4 and 5.

2. Predict where you think the coolest and warmest temperatures will occur. Label these points C and W.

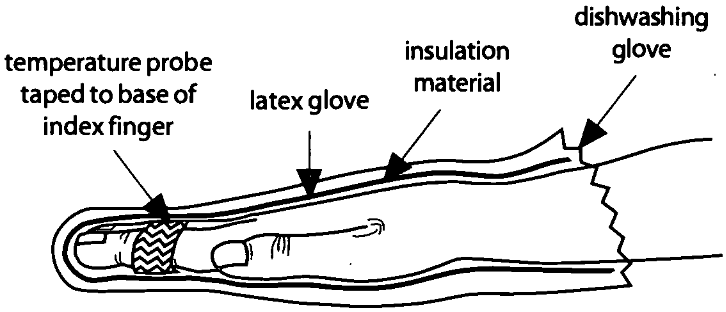
3. Measure and record the temperature of each of the five numbered points. Take or express your readings in degrees Celsius. Describe in your lab book any difficulties you had in measuring or uncertainties you have about your data.

4. Lightly tape the temperature sensor to the test hand at a location relevant to the design challenge, and insert the test hand into one of the smaller, tightest fitting, disposable gloves provided. Immerse the gloved hand in ice water, being careful not to allow water inside the glove. Record temperature changes over a four-minute period.

   Summary of baseline findings:

5. Remove the gloved hand from the water and towel-dry the outside of the glove. Apply a layer of insulation and/or spacer materials (your choice) to the outside of the gloved hand and carefully insert into a second, larger glove. Be sure to consider the issue of dexterity and the need to remove the inner glove intact.

6. Immerse the double-gloved hand in ice water, again being careful not to allow water inside the glove. Take new temperature readings over time and compare to your baseline data. Remove your Quick-Build glove carefully.



IDENTIFYING FACTORS AND VARIABLES

Reflect on the Quick-Build experience and identify the factors and variables that you think are important to meeting the design challenge. Classify the variables into two categories: those related to the glove system itself, and those more associated with the user. Indicate the range of variation expected, quantitatively (numerically) or qualitatively (characteristically). Then list the corresponding design factors, constraints, or concerns you can anticipate. Be prepared to contribute your ideas as input to your class or team for the next research and development stage of your work.

Glove System Variables	Range of Variation
Example: *convection seal at wrist*	*no seal* ← *loose* → *tight*
User-Related Variables	**Range of Variation**
Example: *starting state of user's hands*	*Chilled* ← *normal* → *hot & sweaty*
Design Factors	**Constraints**
Example: *wrist seal pressure*	*prevent convection without constricting blood circulation*

TEAM SITUATION ANALYSIS

Reflection on Your Quick-Build

From a compilation of design factors and system variables, work as a team to select the key parameters you and other members agree to research. Assign each parameter to a team member who will be responsible for that aspect of the improved performance of your insulated glove. Record your selected variables, along with corresponding notes for modifying the Quick-Build, in the table below.

Most Significant Variables	Suggested Modifications
Example: Direct heat loss through conduction	Slow heat flow with more layers of insulation

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PREPARATION

- *Obtain Quick-Build construction and testing materials.*
- *Tailor Quick-Build instructions or assembly drawing to materials obtained. Reproduce, if desired.*
- *Preview library and Internet resource information (URLs that are current at time of publication are listed in the References).*
- *Consider noise, safety, access to water, and clean-up in choice of location for the hands-on Quick-Build exercise.*
- *Designate and arrange assembly and testing areas for the Quick-Build.*
- *Organize materials for orderly access.*
- *Determine student team size (groups of three work well) and formation strategy.*
- *Contact related workplace career representatives: science, manufacturing, history, social science, fashion, sports, etc., for establishing context and relevance.*

OVERVIEW—QUICK BUILD

In a single, fast-paced class session students work in groups of three, following instructions to construct a "Quick-Build" insulated glove. They use an ice water bath to create a temperature gradient for rapid baseline and Quick-Build testing. They record data on hand temperature change over time, and make notes for improved experimental as well as product design. Homework and class discussion following the Quick-Build should stress identification of key variables.

Quick-Build

The activity is divided into six steps:

1. Selecting location of data points on the hand;
2. Predicting relative outcomes of temperature readings at the selected points;
3. Measuring the temperature of the index finger under normal, room-temperature conditions;
4. Taking a baseline temperature measurement of the index finger immersed in an ice water bath;
5. Design and construction of Quick-Build glove; and
6. Measuring the temperature of the index finger immersed in ice water but protected by a Quick-Build glove.

Identifying Variables

As homework, students individually reflect on their Quick-Build experience and create a list of factors and variables to be considered. In the following class, these ideas are compiled into one list and then pared down to a key set via a class discussion. In support of this assignment, you may add context reading (as homework) where students read one or more sample illustrated industry handwear product descriptions from clothing or equipment catalogs. This will quickly broaden their awareness of design considerations and help them acquire a common vocabulary for discussions and further research.

(Guidance on conducting an optional structured class Internet information search is provided on page 61.) Additional resource pages of several detailed commercial glove descriptions are provided in Appendix A. Potential contexts may span a full range of specialized student interests from synthetic textile manufacturing to Arctic exploration, to ski slope fashion.

Team Situation Analysis

Student product development teams analyze the class compilation, reflect upon the factors and variables deemed most significant to meeting the challenge, and select agreed-upon areas to research.

TEACHING SUGGESTIONS

DAY 1
Building, Testing, and Sketching the Quick-Build

This needs to be a fast paced action class—a dramatic break from the reflective mood of the introduction.

Allow students one class session to work in teams to build and test a Quick-Build insulated glove. Customize directions to the specific materials you are providing.

Arrange the common tools and supplies, such as scissors, staplers, adhesives, and tape, so that all students have easy access to them. Students may need reminders or demonstration of safe and effective use. Intervention by you at critical junctures may also be required to ensure safety throughout the exercise.

Miscellaneous Suggestions

Students should start with the small gloves (and possibly the smallest hand), so that the larger glove(s) can be pulled on as outer layer(s) over any applied spacing and insulation materials.

Each student team should resolve how to deal with rings and long fingernails, and present their rationale in answer to the question about hand selection on the *Quick-Build* activity sheet.

Special Notes

Taping the temperature probe to the pad of the index finger before hand insertion in the glove is recommended to assure consistent skin contact; care must be taken not to use a tight wrap that constricts circulation, or an amount or type of tape that provides significant insulation.

Most thermal gloves are not designed to be waterproof; the use of the ice water bath is, however, the most convenient situation for rapid testing. A very thin disposable glove can be used as the outer waterproof layer to keep inner layers dry.

A few students who maintain careful and continuous temperature change observations may see homeothermic feedback response (cold-induced vasodilatation). In this case, hand temperature rises after initial cooling.

When a hand or foot is cooled to 15 °C, blood vessels constrict and blood flow decreases. If cooling continues to 10 °C, constriction is interrupted by periods of dilation with an increase in blood and heat flow. This "hunting" response recurs in five- or ten-minute cycles to provide extremities minimal protection from the cold.

MATERIALS

FOR EACH STUDENT

Student Activity Sheets
- Quick-Build Insulated Glove
- Identifying Factors and Variables
- Team Situation Analysis

From Previous Activity
- Design Brief
- Snapshot of Understanding

Optional
- Information Search Strings
- Sample Industry Handwear Description
- Thermal Factoids

FOR EACH TEAM
- *Quick-Build construction and testing materials*
- *digital thermometer, computer-linked temperature probe or indoor/ outdoor cable thermometer*
- *three to five disposable painter's, food service, cleaning, or surgical-type gloves in a range of sizes*
- *one cotton and one wool glove (or similar assortment) for layering*
- *scraps of fabrics and materials (cotton, wool, papers, foils, bubble wrap, foam sheet, yarn, straw vermiculite, drinking straws, etc.) for extra insulation*
- *ice water*
- *containers*
- *sponges*
- *towels*
- *camera (recyclable, instant, digital) or video for recording team processes and design evolution*

If your course objectives or students' interests include bioregulation, you may wish to encourage further research on topics such as wind chill, hypothermia, and other cold weather injuries such as frostbite, trench foot, and chilblains.

Before the end of class, each student should make a rough sketch of his/her group's Quick-Build, then, as homework, fully label each part. If appropriate for your class, you might recommend that manual drafting, CAD, anatomical sketching, or other technical illustration process be used for later inclusion in the team report and individual portfolios.

Homework

Identifying Factors and Variables

After the fast-paced Quick-Build class, homework provides a welcome time to reflect and determine next steps. Set the stage for design improvement analysis with the *Identifying Factors and Variables* activity sheet. On the sheet, students list key variables they observed as they built and tested their Quick-Builds, and specify a range of possible variation. Stress the importance of completing this homework overnight so that it informs the next day's discussion. Students classify the variables into two categories: those that are part of the device itself and those more associated with the user. An example of each kind of variable is included on the student activity sheet. Some variables you might expect students to identify include:

Glove System Variables

- the kind of covering material
- tightness of elastic or cuff seal
- the amount of trapped air
- amount and kind of insulation material
- finger fit
- seam integrity

User Variables

- user metabolism
- recent caloric intake
- hydration position
- contact of thermometer
- consistency of operator positioning for measurements
- user circulatory characteristics
- previous cold injuries
- user installed insulation (body fat, hat on head, etc.)
- presence of caffeine (diuretic), alcohol (vasodilator), or nicotine (vasoconstrictor) in bloodstream

Key factors to be considered will vary with the specifics of the challenge, but might include some from the following:

Glove System Design Factors

- comfort
- static charge
- durability
- chemical resistance
- dexterity
- pressure on hand
- flexibility
- softness
- bulk
- stiffness
- warmth-to-weight ratio
- fit—form and size
- insulation loft
- venting
- cushioning protection
- cut resistance
- abrasion protection
- stretch
- permeability
- drying time
- color and visibility

DAY 2

Class Discussion of Variables

Start a class discussion of the homework just completed. Compile a class list of the variables and ranges of variation students can identify. You may want to make a large chart on the board and jot down students' ideas so that all students have access to the complete list.

Use the discussion to set the stage and level the playing field for the next activity where the student design teams plan modifications to improve their design.

Quick-Build Quick Changes

If time allows, students can experiment with some quick trial-and-error modifications to their Quick-Build to devise and conduct "fair test" hands-on experiments on the characteristics and configurations of insulation materials.

Stay alert for opportunities that may deviate from parts of the preplanned activities—especially those proposed by the students themselves. Pursuing students' promising alternative outcomes warrants careful consideration; not only does such a detour accommodate student interest, it also serves as a valuable source of motivation.

SIDE ROADS

Sample Industry Handware

The Sample Industry Handware reading in Appendix A can be used at any time to provide students with one example of the kinds of design considerations that real glove manufacturers use. In addition to the reading provided, similar materials have appeared in various outdoor clothing catalogues.

ALERT!

SAFETY ALERT!

Be alert to safety during all tool and adhesive use sessions. In addition, if using latex gloves, provide the opportunity for any student to avoid exposure if they have a known latex allergy, and inform others of symptoms to watch for. These symptoms are: local swelling, hives, or rash. Severe reactions are rare and are almost always preceded by repeated minor reactions of gradually increased severity.

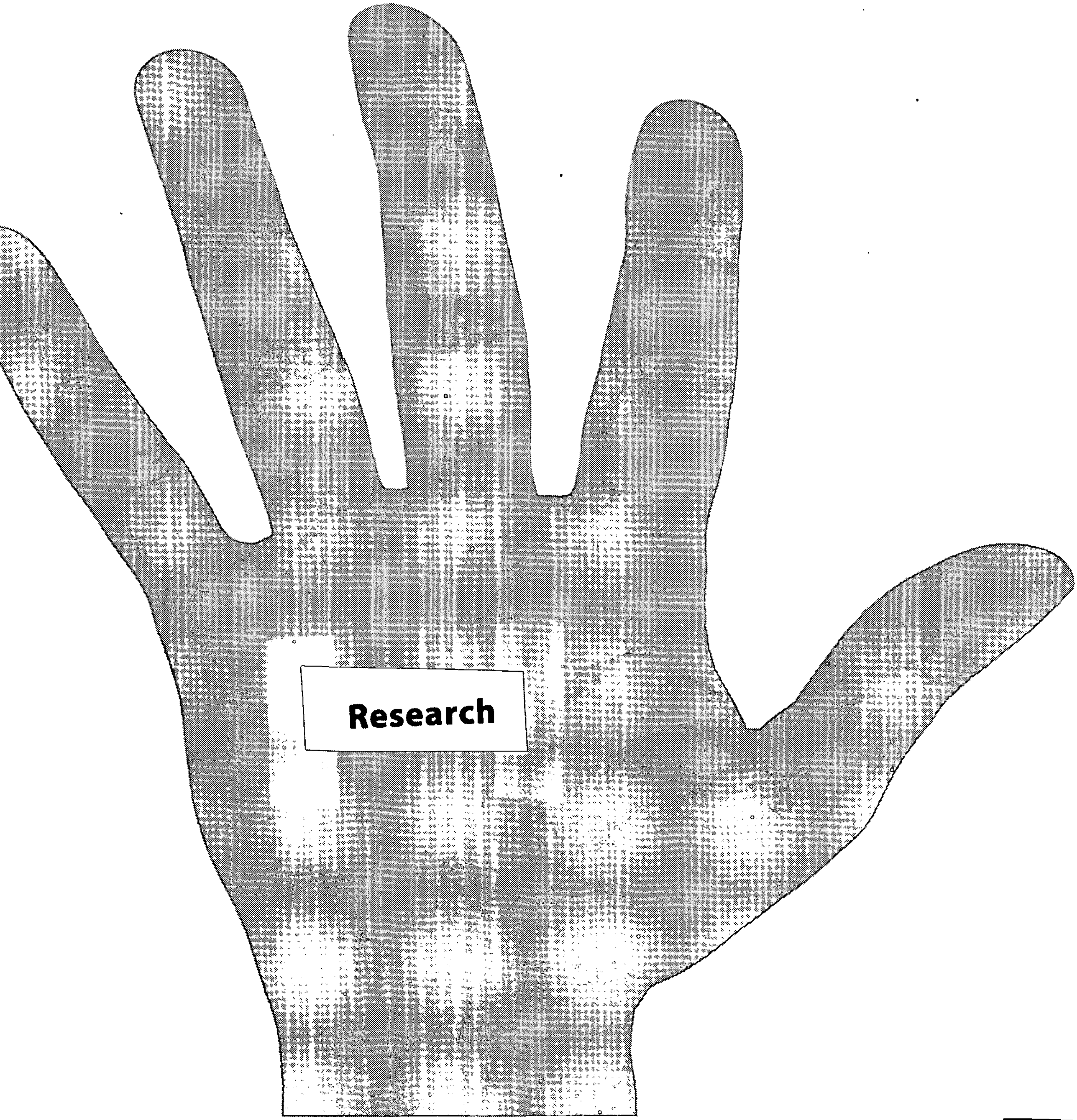
Students who have had previous cold injuries such as frostbite on their hands may have damaged capillary fields, which could both affect thermal reaction and cause return of discomfort to the student.

Thermal Factoids

The *Thermal Factoids* section of Appendix A consists of a collection of short statements about thermal science that are designed to puzzle and provoke—hopefully to stimulate interest. In section A the short statements should be identified as true or false. All are true. Section B provides an excellent take-home lab that can easily involve the entire family. It can also be conducted as an in-class demonstration, perhaps with a blindfolded student determining which container is hotter. Section C contains important scientific definitions and conventions that students may need to know to complete their designs.

Information Search Strings

One way students can learn more about design options for their thermal glove challenge is to research information about handwear on the Internet. This activity provides steps on how to show students basic Internet search techniques and lists a number of World Wide Web sites for students to investigate.


Research

OVERVIEW—RESEARCH

You have completed the Quick-Build insulated glove and observed some effects of limiting heat loss by decreasing conduction and convection. To improve your insulated glove system for practical use, you need to learn more about interactions between the thermodynamic and the bio-regulatory systems involved. You will also need to search out information on various materials and configurations.

There are different ways to approach and conduct research. You could use trial and error—simply try a lot of combinations of materials and see what works best or is acceptable. This could take a lot of time, and require a good deal of materials gathering and data collection. A sounder investment of time, effort, and cost can be made if you conduct an initial information search.

For your initial research, you will probably use a library, the Internet, textbooks, and personal queries. Then you will need to identify some questions and then design experiments to answer them. Refer to the *Inquiry Process* resource sheet in Appendix A for more guidance. Realize that one question often leads to another, so you might need to repeat the inquiry cycle several times. You may even need to return for further research after you have otherwise moved on to developing and building a prototype physical model.

Team Assignment

Using the list you made of significant factors, divide up tasks among your group so that each factor will be fully researched. Make sure that each group member understands the key information needed. Working within the parameters given by your teacher, establish a schedule for individual reports that allows your team to review each report before your teacher asks to see it.

INDIVIDUAL RESEARCH REPORT

For homework, you will research the topics that your team assigned to you. The rest of your team must learn about what you found out, therefore, you must present them with a written report that will detail the most important things you discovered. But there is really no way to know now which parts of what you researched will prove most useful when the team begins work on the prototype. For this reason, an important part of your research report is the identification of sources. A good report shows clearly where to look for the best information.

SCILINKS THE WORLD'S A CLICK AWAY

Topic: metabolism
Go to: www.scilinks.org
Code: CAG04

Topic: insulation
Go to: www.scilinks.org
Code: CAG05

INVESTIGATING HEAT TRANSFER AND INSULATION

The research experiments you design for this activity should help you determine the best of available insulation materials and application systems to use in your insulated glove prototype. To arrive at a suitable experimental design, you might try listing anticipated problems in procedure or interpretation, and posing solutions. A couple of sample considerations are offered to stimulate thought:

Problem: Metabolic and circulatory feedback effects vary among and within human hands, thus the temperature inside a glove depends on the hand as well as the glove.

Solution: *Replace a radiating human hand with a water-filled glove at known initial temperature. Measure heat loss over time. How does this control of variables affect interpretation of your results?*

Problem: Immersion in ice water provides fast experimental results, but requires that outer materials be waterproof, unduly limiting material choices.

Solution: *Adapt the experimental set-up to use a source of constant cold air temperature, such as a refrigerator or an air conditioner. Or, use a thin waterproof disposable film glove as an outer layer and devise a correction factor for the insulating effect.*

1. Write down your research protocol for evaluating gloves.

2. Sketch your experimental set-up and label it so that another researcher would be able to duplicate your experiment(s).

"FAIR TEST" COMPARISON

A "fair test" comparison is a comparison among two or more designs in which no design is given an advantage.

Product Comparisons

1. Observe differences between your Quick-Build insulated glove and a commercial glove that has been designed to be worn in cold weather.

Quick-Build Glove	Commercial Glove

2. Using your research protocol, compare the insulation effectiveness of the commercial glove to your Quick-Build product.

3. Do the results of your research protocol fit with your understanding of how the two gloves compare?

4. Decide whether changes need to be made in your protocol.
   Is it a fair test?

MATERIALS

FOR EACH STUDENT

Student Activity Sheets

- Overview of Research
- Individual Research Report
- Research Protocols
- "Fair Test" Comparison

Optional Sheets

- Inquiry Process
- Homeothermic Regulation

FOR EACH TEAM

- *clamps and stands (or duct tape) for stabilizing each glove in vertical position for testing and measuring (if using water filled gloves to control for homeothermic feedback effects)*
- *thermometers (digital indoor/outdoor with waterproof flex cables)*
- *ice, water, and buckets (three-pound coffee cans serve well)*
- *timing devices*
- *towels*
- *graph paper*
- *assortment of commercial insulated gloves provided by students*

FOR CLASS

- *A diverse selection of potential insulating, reflective, spacer, and encasing materials*

3 DAYS

OVERVIEW—RESEARCH

Students work in their product research and development teams to investigate significant variables in heat transfer and insulation. They divide the tasks of researching and preparing *Individual Research Reports*.

Students use controlled exposure tests (with an ice water bath) for experiments they design. To control for homeothermic feedback and other user variables, they can use a water-filled glove instead of a human hand, measuring temperature change of the water in the glove with different insulation, layering, and spacing configurations. Results should be presented in a data table and a graph to compare the amount of temperature change as a function of time for each of the different test configurations.

Each design team creates a research protocol for testing gloves. The teams validate this protocol with "hands-in," "fair test" comparisons of commercial insulated gloves. They consider their lab findings in the contexts of human thermal regulation, materials science, insulation technology, and handwear design.

This is a good time for an optional teacher presentation on heat capacity and specific heat, as well as composite insulation factors for different combinations of materials.

Insulating and Encasing Materials

- a range of sizes and types of disposable gloves
- styrofoam peanuts
- newspaper
- soilless potting mix
- bean bag chair fill
- cotton bat
- bubble wrap
- aluminum foil
- plastic wrap
- drinking straws
- straw, excelsior
- Easter grass
- coin tubes
- clothes drier lint
- Cheerios™, etc.

Students may also be encouraged to add to the collection with various adhesives such as double-sided cellophane tape, glue stick, rubber cement, duct tape, foam adhesive pads, silicon sealant, etc.

TEACHING SUGGESTIONS

DAY 1

Group students into product research and development teams of three to five. Review their assignment: investigate different insulators and design a uniform method for measuring the thermal insulation of gloves.

Each team of students will likely test different factors and reach different conclusions, but if given the opportunity to share their experimental designs and findings, all will benefit by the diversity of multiple team approaches. Comparing findings across the class should reinforce appreciation of the numerous variables (and possible solutions) involved. You may choose to eliminate the need for each team to test all key variables by assigning certain key variables to specific teams.

Using the Quick-Build glove as a starting point for the experimental set-up makes the data collected earlier directly relevant as a baseline for assessing improvement through redesign. If possible, students should complete their data collection and organize their results in a table during this class session. Use your judgment to decide whether to extend, curtail, or defer research activity beyond this time allotment. Additional time for research and experimentation may fit in better during the development activities in the next activity.

Outside of class, students should construct a graph for each set of data in their table and answer the series of homework questions on the activity sheet.

DAY 2

For the first part of the session, facilitate the previous homework review by choosing several groups to sketch or project their graphs on the board for use as a basis of discussion. Ask students to detail the experimental set-up and glove configuration associated with each graph. In order to assess the level of class understanding, pose questions and elicit responses from a range of students.

Sample questions might include:

Which graphs tell us about layering as an insulation factor?

Why are the graphs different?
[relate to observed properties of each configuration or material, such as amount, thickness, thermal conductivity, entrapped air, etc.]

PREPARATION

- *Devise ways of fixing gloves to hang vertically for the water-filled experimental set-ups.*
- *Predetermine suitable type, quantity, and variety of test materials for safe and manageable team use of class time.*
- *Consider allergies, safety, cost, time, mess, and cleanup.*
- *Locate and obtain materials in quantities sufficient for both the research and development activities.*
- *Encourage students to provide additional materials, but prepare guidelines and implement a process or practice of approval before use.*

ALERT!

SAFETY ALERT!

Most adhesive materials present some hazard from fumes or skin contact. Avoid the worst—such as super glues and spray adhesives—entirely.

Read labels and have specified solvents and cleanup materials available.

Instruct and caution students regarding proper and careful use.

How are the relative thermal properties of different materials shown in these graphs?

For the remainder of the session, guide the class in choosing a common research protocol so that the work of different teams can be fairly compared.

DAY 3

In this session students integrate the idea of feedback into the way they have been thinking about homeothermic regulation. Include a discussion about heat flow as the cause of the sensation of coldness. If you touch a metal object and a wooden object both at room temperature, the more conductive metal object feels colder because heat flows away from your finger faster.

The main activity for this session is to allow students to compare insulative qualities of various commercial gloves and describe the design effectiveness of each.

Because most gloves are not waterproof, students may use a disposable glove as an outer sheathing to enable the use of the ice water bath. They should test with the same team member's hand inserted in each glove and record thermal and other sensory data to compare with the earlier Quick-Build data set.

Assessment

Assessment may be based on whether students state testable hypotheses, follow through and document a controlled variable experiment, graph and write interpretations of results, record reflections on areas for improvement, and contribute to their team effectively.

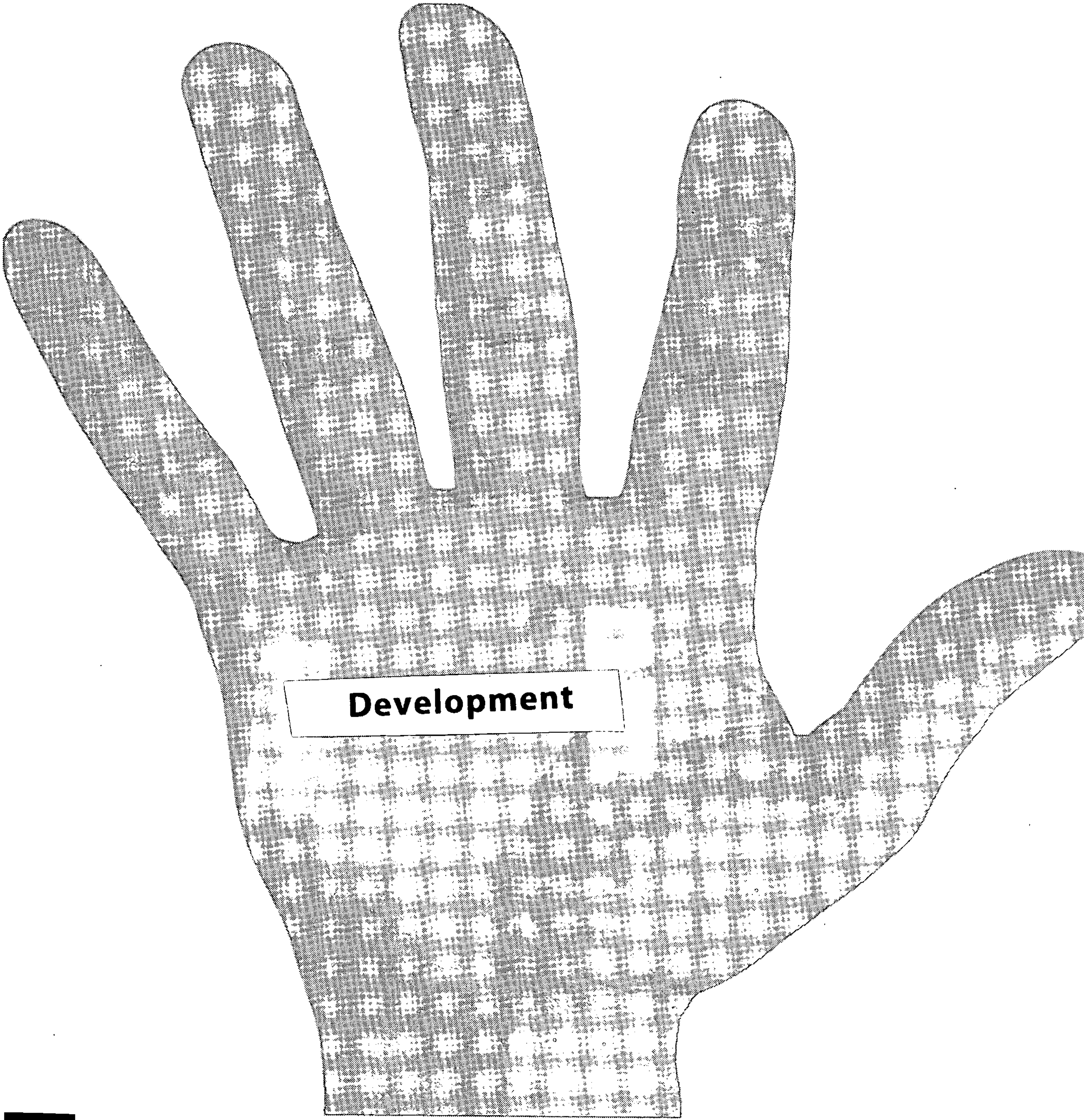
SIDE ROADS

Inquiry Process

The *Inquiry Process* sheet in Appendix A provides one possible way to think of the inquiry process and may be used either as an example or as the template for all your students to follow. If you use it as a template be sure to indicate that this is your choice and not the only possible way to view inquiry. Point out to students that there are many situations where it is useful to have everyone follow a common system even though many other systems would be equally good.

Homeothermic Regulation

The reading entitled *Homeothermic Regulation* in Appendix A provides a more detailed account of the same process described in key ideas. You will find this reading particularly useful if principles of biological science are important course objectives.


Development

OVERVIEW—DEVELOPMENT

You have completed activities investigating insulation and conservation of heat with various materials in different configurations. You have also researched and observed the human thermal bioregulatory system response to cold. To meet the *Construct-a-Glove* Design Challenge, you will next develop an insulated glove prototype that minimizes heat loss while maintaining dexterity for a specific function.

Scope of Work

- Redesign your glove system for improved performance within specifications.
- Build your prototype and test its performance using your research protocol.
- Measure and record prototype test conditions.
- Compare your prototype with that of other teams.

Good planning is essential to good design. Look again at your research where you identified variables and key directions for further investigation. Think about how best to combine physical design options with biological considerations. Be creative within your objectives and constraints. Review the *Inquiry Process* and *Design Process* resource sheets for ideas on next steps. Evaluate your prototype critically and make modifications until you are satisfied with improved performance or run out of time. Remember to reflect on your process and record your reflections in your notebooks; how you go about your design and what you learn are key elements in the communication and assessment activities to follow.

DEVELOPMENT ASSIGNMENT

Design prototype

- Make a sketch or blueprint (use standard format)
- List all materials
- Write assembly instructions

Fabrication

- Collect or construct parts
- Assemble prototype

Test prototype

- Apply research protocol

Evaluate prototype

- Collect user reviews and other "informal" evaluation (see *Team Feedback* and *Reflections On Design* forms).
- Using all available information, list strengths and weaknesses of your prototype, and compile a list of possible improvements.

Return to "Design prototype" step if there is time.

TEAM FEEDBACK

Identify those factors that are interfering with the ideal performance of the prototype glove. Make suggestions about modifications that could improve performance. Record the problem factors and suggested modifications in the table below:

Factors	Suggested Modifications

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REFLECTIONS ON DESIGN

- What is the one feature of your insulated glove system about which you are most proud?

- Describe the concerns you have with the present design.

- Describe in a paragraph or two the approach your team took in the designing and building of your prototype. Include a problem your team encountered with the performance tests and how you went about solving it.

4 DAYS

OVERVIEW—DEVELOPMENT

As homework, students can read a brief description of the *Design Process* in Appendix A (optional). They determine where in the activity loop they've been, where they are now, and where to go next.

On the Quick-Build glove diagram provided, students individually superimpose, label, and note additional planned performance enhancement features (such as wrist airseal, heat reflective lining, solar absorptive covering, etc.) determined from their research, then compare with team members to move toward consensus on selection of design elements.

Students construct a prototype of their improved design and document with a drawing in a format appropriate for the illustration technology used.

Students do a second pass on identifying variables that impact performance, this time for their redesigned glove, and record their suggested modifications. They consider changes required for mass production and record steps for replication efficiency.

Each team pairs with another for *Feedback*. They compare glove features, and make and receive suggestions for modifications.

Students performance test their prototype using a classwide common test protocol (agreed to ahead of time). They measure temperature change, describe patterns, and record all other relevant factors.

Students fill out the *Reflection on Design* sheet, describing strengths and concerns as well as their approach and team process.

Time Requirement

Four class sessions

Students should be encouraged throughout this sequence to continue their team collaboration and to do additional work outside of class. Indicate that completing the task on schedule requires considerable discipline.

MATERIALS

FOR EACH STUDENT

Student Activity Sheets

- Overview—Development
- Development Assignment
- Reflections on Design
- Feedback

Review

- Indentifying Factors and Variables

Optional

- The Design Process
- Sample Industry Handwear Description
- Team Situation Analysis

FOR EACH TEAM

- *clamps and stands*
- *disposable vinyl, latex, or poly gloves*
- *safety glasses or goggles*
- *one thermometer*
- *ice*
- *water*
- *bucket*

FOR CLASS

- *scissors*
- *staplers*
- *weighing apparatus*
- *hot-melt glue*
- *adhesive tape*
- *liquid latex*
- *insulating materials*
- *reflective materials*
- *layer separation materials (yarn, straw, etc.)*
- *cover materials*
- *graph paper*
- *timing device*
- *towels*
- *cornstarch or powder*

PREPARATION

THE "FABRICATION ZONE"

- *Consider quantities of workspace, materials, tools, fasteners, and available adhesives, and optimize spatial arrangements for safe, efficient access.*

THE "PERFORMANCE TESTING ARENA"

- *If space in your room allows, give each group its own separate area to performance test its prototype. If there is not enough space for this, designate a "testing station" (near a sink or drain if possible) for groups to share in rotation.*
- *You may want students to prepare the test station configuration and to determine use and cleanup guidelines by class consensus.*
- *Consider which technological tools you might add, e.g., CAD. If your students are already proficient with computerized temperature probes, spreadsheets, or graphing calculators, the data they collect during performance testing can be entered, manipulated, and printed.*

TEACHING SUGGESTIONS

Design is not linear: team processing times will vary. Nonetheless, development activities can be completed in four efficiently used class sessions—but only if you keep the pressure on.

Discussion of Homework: The Design Process (optional)

Discuss the homework in *The Design Process* activity sheet. A good initial question to pose is:

Does the diagram depicting the design process reflect the experience in designing and building you have been having?

Other questions to ask are ones from their homework:

Which elements of this process have you already experienced?

Where in the process do you think you are now?

You may wish to make the criteria you will use to assess students' technological design capability available at this point and invite discussion.

Suggest to students that if they become stuck at any point they should refer again to their portfolio sheets for ideas about what to do next. Highlight or elicit examples of how students already used or might soon use the design process loop in non-linear progression. Students may wish to record scenes illustrating their group process with photographs or video.

Starting to Redesign the Improved Glove

Students may choose to proceed with the redesign of their gloves either by improving upon their Quick-Builds, or by starting fresh. Depending on their choice, students should: (a) preserve or build upon modification conclusions reached when working with the Quick-Build system in the research phase, or (b) consciously begin anew on a distinctly different system, in which case initial research must be inserted in the development process. Advise them also to keep the selected or specified purpose of their glove constantly in mind to guide decisions.

Resources for Redesigning

Before students begin redesigning, they might individually review and then discuss as a team the *Sample Industry Handwear Description* resource sheet to define the team's design vocabulary. They could also review the *Team Situation Analysis* student activity sheet to remind themselves of modifications they identified prior to their research.

Timely Feedback

As students move beyond their Quick-Builds, it is essential that teams be allowed to grapple with the challenges of designing, building, and testing, and of revisiting these processes.

It is important, however, that students receive input at critical times. One source of input is the team itself—encourage brainstorming as an official design process to be performed by the rules. The *Team Feedback* activity gives every team a chance to share and explore ideas beyond those of the members.

Another important source of feedback is timely intervention from the teacher. Very often, a suggestion about how to solve a problem, or a reference to a diagram or picture will stimulate action. Drawings or some sample student-built prototypes from previous classes may be helpful to stalled teams. But judgment must be exercised to avoid intervening too early.

Evaluation and Reflection

Just as students previously paused to evaluate and reflect upon their Quick-Builds, they do the same again with the *Team Feedback* sheet, after they have had a chance to struggle with the redesign of their gloves or are confused and cannot continue.

You may wish to use the *Feedback* activity sheet to encourage one team to assess the work of another. For this reflection/assessment, pair each team with another for the purpose of providing feedback about each other's designs. Suggest to partner teams that they demonstrate their prototype to each other and that each team collaborate to provide written feedback to the other on the *Team Feedback* activity sheet. The goal here is two-fold: for students to share ideas, and for them to obtain helpful feedback from others.

Once groups have consulted and provided feedback to each other, provide some time and space for each team to discuss and decide their next steps. At this stage, you can assess their troubleshooting or problem solving ability to conceive of modifications that address the problems they have been encountering.

Collecting Data

To test their prototypes, students immerse their gloves in ice water and record inside temperature change over time using a common "fair test" research protocol.

Deciding: How Good Is Good Enough?

Once groups start testing the performance of their prototypes, it is important to discuss with them how to know when to end the improvement cycle.

The answer to this question depends upon your teaching goals, any criteria agreed to by the class, and what is realistic given the materials with which students are working. In addition, the depth of development should be based on sustaining interest in view of their prior experience and skills as problem solvers, designers, and builders.

Whatever the standards you set for your students (or they set for themselves), remind them of the need to analyze and improve both the glove system design and the consistency of performance testing techniques in order to obtain more reliable results. As your students are testing their glove systems, look for evidence that they are evaluating and using their findings to make both product system and measurement process improvement decisions.

Design Self-Assessment

As a final development activity, students reflect upon what they have done thus far in *Reflections on Design*. They are asked to identify positives and negatives about their current design and then to briefly describe their team approach and process. This activity sheet is brief, presenting opportunity for you to add additional questions. Science, math, and technology students might list or describe anticipated problems of actually producing their devices in mass quantities and various sizes to match their projections of consumer demand.

Assessing Students' Design and Build Capabilities

There are several key elements of students' design and build capabilities you could assess throughout the development phase:

- *How well students are able to develop solutions.*
  Developing ideas through to workable solutions is at the core of technological design. Look for evidence of students' ability to do this, both in your ongoing observations of students at work and in the responses they give to the five steps in their *Development Assignment* sheets.

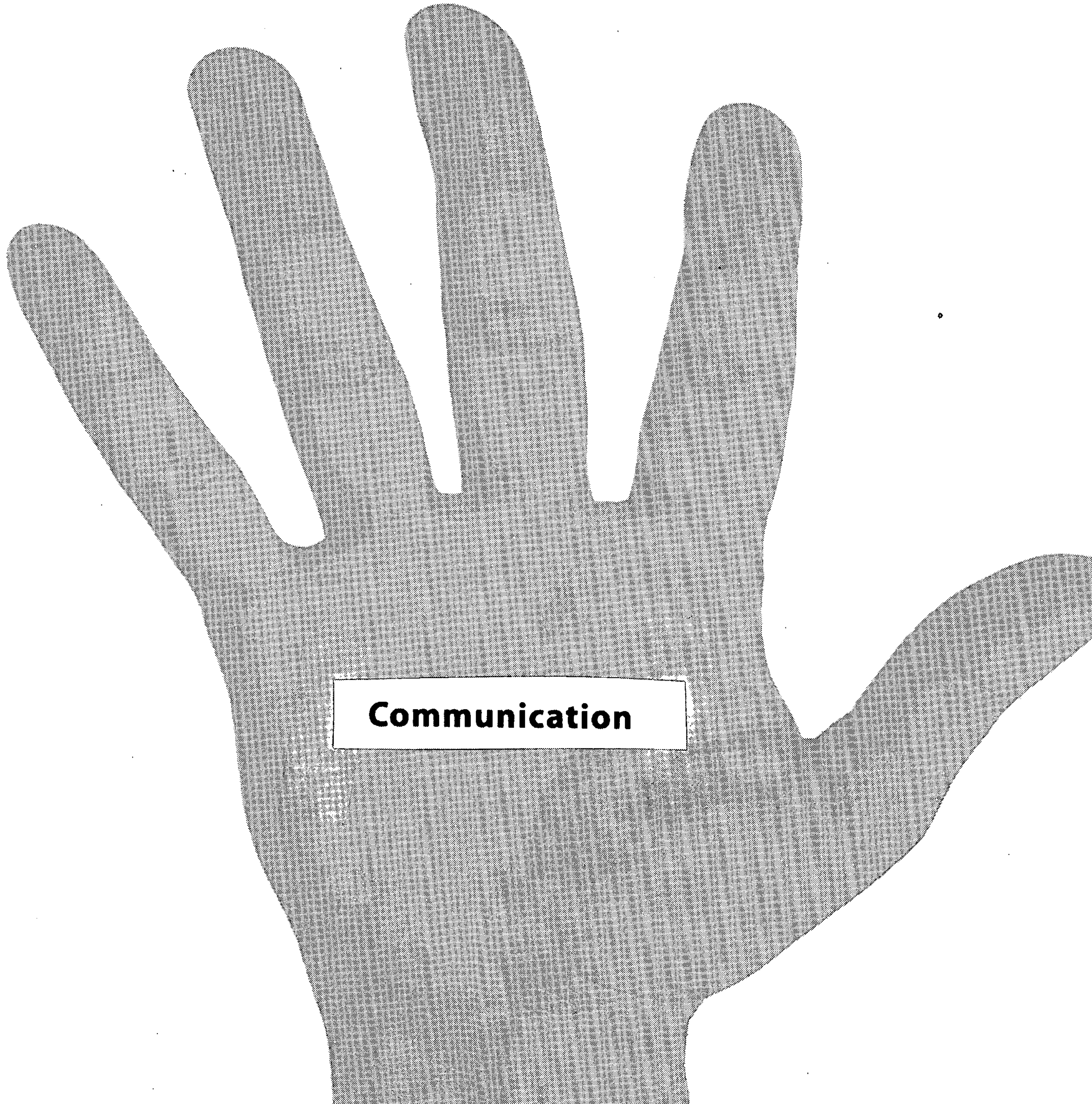
- *How well students are able to evaluate the processes they have used.*
  This includes the extent to which they are able to identify strengths and weaknesses of their prototypes. Look for evidence of students' ability to do this, both in your ongoing observations of students at work and in the responses they give on the activity sheet *Reflections on Design*.

- *To what extent do students exhibit ownership of the task? Did it change with time? How much initiative did they take?*
  Look for evidence of this in your ongoing observations of your students.

SIDE ROADS

The Design Process

The *Design Process* sheet in Appendix A provides one possible way to think of the design process and may be used either as an example or as the template you want all your students to follow. If you use it as a template, be sure to indicate that this is your choice and not the only possible way to view design. Point out to students that there are many situations where it is useful to have everyone follow a common system even though many other systems would be equally good.



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OVERVIEW—COMMUNICATION

2 DAYS

You have completed the research and development phases of the *Construct-a-Glove* challenge. You have redesigned, built, and tested an insulated glove system. But you will not be recognized for your effort without effectively documenting and communicating what you have done.

One measure of success of your Research and Development (R&D) team is whether you have applied the criteria and specifications to come up with a useful, marketable product. In the marketplace it is the comparison to other products that determines success. Sometimes this comparison is based on measurable differences; other times, it is based on an image that has been effectively communicated to the buying public. To decide how to market your glove, realistically assess the strengths and limitations of your product and compare it with that of other teams. Based on these factors, determine a practical market niche for your product.

Scope of Work

- Present your redesigned insulated glove system in a product prospectus which outlines the rationale, substance, and outcome of your effort.
- Specify the materials and performance parameters for your prototype product.
- Write a suggested marketing plan for launching your product, or "next steps" for further improvement.

CREATING A PRODUCT PROSPECTUS

The final activity is for you to communicate the results of your work in a product prospectus. Your goal is to include information that would interest and inform others about your glove system.

An important skill for you to demonstrate in your product prospectus is the ability to communicate clearly about your glove system in writing. The writing of each section should be well organized and clear enough for someone unfamiliar with your team's product prototype to understand.

You may find it interesting to consult several real product brochures before you begin, but don't feel that yours needs to be just like these. Be original, thinking about better ways of describing your team's glove as a system.

Consult the table of contents shown below for a list of the topics you should address in your writing. Some of these topics, like your sketches and specifications, have already been done. Others, like the statement of purpose or scientific principles involved, still need to be written.

Product Prospectus: Insulated Glove

Table of Contents

I. Guiding Principles

II. System Overview
   - A. Parts and Materials Specifications
   - B. Performance Specifications

III. The Science Behind Our Product

IV. Appendices (Optional)
   - A. Similar Product Comparison
   - B. Care and Cleaning
   - C. Disclaimers and Warranty

Members of your team may wish to divide the responsibility for each of the sections that need to be written. Before you do so, read the suggestions below and clarify what each section will be about.

Suggestions for Product Prospectus Sections

In your *Guiding Principles* section, you should state any specialized activities or functions that your insulated glove system supports. Take into consideration what level of movement and dexterity your design provides and what activities such handwear allows. This section should be a total team effort so that sections that follow are unified by reference to the agreed purpose. First brainstorm as a team, then assign the actual writing—based on the brainstorming notes—to one member.

The *System Overview* can include a sketch of your glove system with labeled parts.

The *Parts and Materials Specifications* section could list details such as size, shape, composition, and quality of each component part.

The *Performance Specifications* section is an appropriate place to describe the capabilities of your product. What are the minimum and maximum temperatures, wind conditions, levels of compression, etc., that your glove can handle and still provide hand comfort? How confident are you of your projections? (Your actual range of performance tests may have been restricted by time and opportunity.)

In the *Science Behind Our Product* section, you can discuss the scientific principles involved in the materials and configuration of your handwear. Consult and reference any appropriate sources to clarify your points persuasively to potential consumers.

Appendices are optional. Use them if you wish to include any additional information such as the following:

For *Product Comparisons*, describe each team's product in terms of its strengths and weaknesses. Think of yourself as an employee of a large handwear industry manufacturer and your team's glove system as one in a range of choices for users with differing needs.

For *Care and Cleaning* advice, you might let the user know what kind of periodic treatment you think your glove product will need to continue performing well.

Disclaimers and Warranty address what your team as manufacturer will be responsible for should some failure occur with regard to durability, performance, etc., in comparison to assurances and claims.

SNAPSHOT *of Understanding:*

What I now know about Homeothermy, Heat Transfer, and Research and Development.

You have met the challenge to design, build, and performance test a prototype model of an insulated glove system. To meet the performance specifications, you investigated heat transfer physics, biological temperature regulation, principles of insulation technology, and design process. One of your first steps was to record a snapshot of your understanding about key topics in this unit. By answering similar questions below, you can compare what you know now with your previous answers and self-assess what you have learned.

1. What are the parts of the hand significant to the design of an insulated glove with specific dexterity? Make a sketch and label its parts or describe in words.

2. List as many special purpose kinds of gloves as you can. Place a "T" by those specifically designed to provide thermal protection.

Example	Welding - T

3. Describe what process your team used to design your insulated glove.

4. Describe several key differences between *homeothermic* and *poikilothermic* animals.

5. Describe mechanisms and behaviors for human body temperature regulation.

6. Distinguish between **temperature** and **heat** and describe how are they related.

NEXT STEPS

Choose one or more of the following extension topics and commit your thoughts in writing.

1. Present your views on the historical significance and impacts of gloves on human accomplishment.

2. Review the diversity of specialized gloves in the context of contemporary human inventiveness.

3. Describe promising market niches for new specialized gloves that might be developed to improve human capability, safety, comfort, etc.

4. Outline a comprehensive marketing plan for launching your team's glove design into a profitable product cycle.

2 DAYS

OVERVIEW—COMMUNICATIONS

Student teams summarize their learning by creating a product prospectus that includes information about specific applications for their glove system, its construction, principles of operation, and performance parameters. The activity sheet *Product Prospectus* provides a set of topics for students to address, along with explanatory text. In the final assessment, students answer questions similar to those at the very beginning of the unit.

Time

Two class sessions

One class for team *Product Prospectus* writing. Additional time needed as homework.

One class for team product prototype presentation, reflection, and final self-assessment.

TEACHING SUGGESTIONS

Creating the Product Prospectus

Discuss with your students which topics to include in their product prospectus and suggest that they develop a plan for delegating tasks within their teams to get the work done. Each team begins work with group brainstorming of possible intended uses or markets for their glove system. Suggest to teams that they take into consideration what their design's strengths and weaknesses are compared to other team's products. Encourage team members to review each other's contributions before assembling their final document.

An important skill for students to demonstrate in their *Product Prospectus* is the ability to communicate clearly in writing and graphics. Your grading rubric should emphasize content, organization, and clarity.

Remind students that both in science and in technology, communication is key to success.

Completing the Snapshot of Understanding

After students complete the final *Snapshot of Understanding* (allow about 20 minutes), provide a brief time for them to compare their new answers with those on their pre-unit *Snapshot*.

MATERIALS

FOR EACH STUDENT

Student Activity Sheets

- Overview—Communication
- Product Prospectus
- Snapshot of Understanding

Optional

- Next Steps

FOR EACH TEAM (optional)

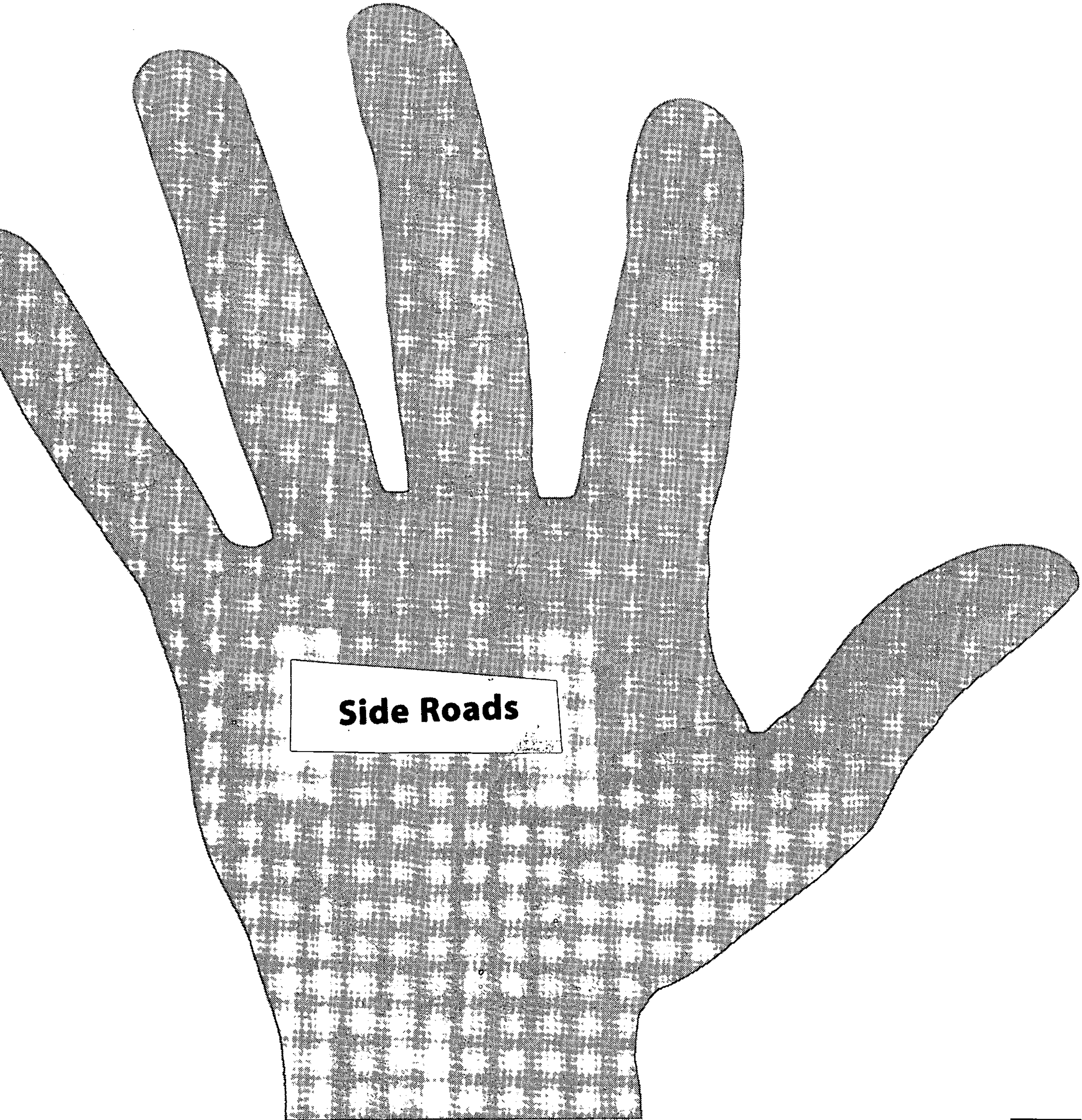
- *flexible seating to facilitate team discussions and writing*
- *word processing/graphics stations and presentation tools*

PREPARATION

- *Consider spectator invitations if opting for oral presentations, or for market introduction of prototypes.*
- *Provide (or have students bring in) a few different examples of product marketing media.*
- *Customize the* Product Prospectus *table of contents to fit the time and education objectives for your class (or encourage students to make such decisions).*
- *Arrange for use of word processing/graphics (or CAD) computer stations.*
- *Prepare a grading plan for your evaluation of the team and individual effort.*

NEXT STEPS

In many ways, *Construct-a-Glove* is just a beginning in the process of examining gloves. If there were enough time, a great deal more could be done. The *Next Steps* section of the student pages suggests a few projects students could undertake after the unit. You will probably be adding your own options to this list each time you teach the unit.


Side Roads

SIDE ROADS

The following pages correspond to the Side Road suggestions made in each activity. Many of these are key activities but they have been put in the Side Roads section because they can fit in several different places and exactly when they are used is a matter best decided in response to student questions and feedback. Some activities may be profitably used more than once. An analysis of the design process, for example, will provide different insights in the Research Section from what will be seen in the Development Section.

- *Sample Industry Handwear Description*
- *Thermal Factoids*
- *Information Search Strings*
- *Inquiry Process*
- *Homeothermic Regulation*
- *Design Process*

SAMPLE INDUSTRY HANDWEAR DESCRIPTION

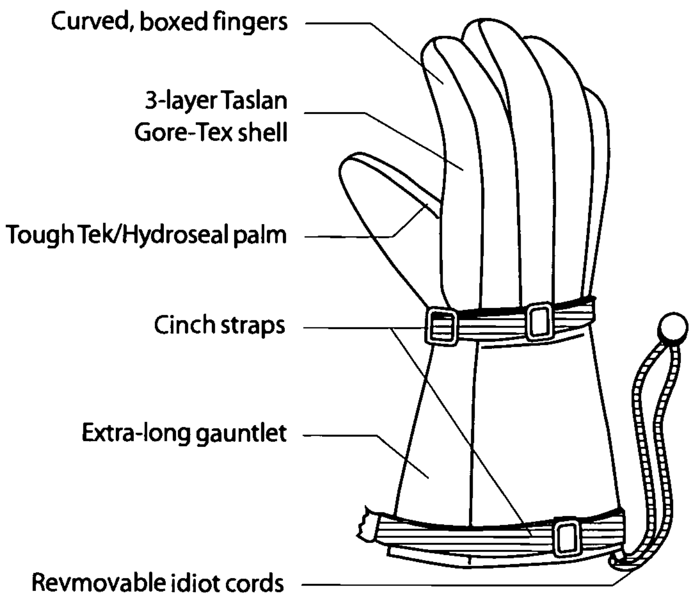
Assignment

Read the following glove description and independently create your own one-page flyer highlighting features of your team's Quick-Build glove. Use drafting, sketching or illustration methods, and labeling styles as assigned by your teacher.

[Reprinted with permission of Outdoor Research, Inc., Seattle, WA as posted online at http://www.orgear.com, last visited March 2000]

Expedition Modular Gloves—Technical Information

Expedition Modular Gloves can be used in a wide range of mountaineering, skiing, and cold weather adventure situations. It is an extremely warm glove with excellent dexterity for those super cold ice climbing days in Canada or lift skiing in deep powder in the Rockies. Any time dexterity is important, but you can't afford to lose much warmth in the process, this is the handwear of choice.



Technical Features and Benefits—Shell Specifications

Fingers and Thumb Strongly Curved
The curved shape of the fingers and the thumb follows the position of function of the hand. This reduces the work the hand must do to hold an ice tool, ski pole, or ascender. It also lets the hand relax in its natural position without resistance.

Box Construction
The box-like construction gives each finger its high volume, resulting in lower pressure on the hand and therefore a much warmer glove by design.

Three-Layer Taslan Gore-Tex with Laminated ToughTek/Hydroseal Palm
Gore-Tex is used to achieve the best possible waterproof, vapor permeable, and windproof combination. Due to the complex construction of these gloves, the seams are not factory sealed, so the shells are not considered waterproof, but with the addition of the GT Liners (see description below) the hand can be kept fully dry. For most mountaineering and skiing situations it is as much durability as a person will need. Highly windproof and vapor-permeable.

Cinch Strap Adjustment at Wrist and Cuff
Velcro at the wrist keeps the glove from slopping around or sliding off the hand. It is placed slightly forward of the narrow point of the wrist. This is a deliberate design feature. It is more effective at keeping the fingers in the ends of the mitt. The cinch strap at the cuff keeps snow and wind out of the mitt and gives the wearer the option of venting excess vapor when working hard. Quick one-handed operation and no flapping strings. When closed, Velcro Cinch Straps do not flap around in the wind like typical draw cords. This can be important when working with the hands near the face as in ice climbing. Also nice when skiing.

Form-Fitting Thumb
In the coldest conditions it is imperative that a glove does not put pressure on the hand at any point, especially at the thumb. For this reason the Expedition Glove is constructed out of several separate pieces of material to create a high volume, form fitted section. This is one of the keys to the great warmth of this glove.

Extra Long Gauntlet
The gauntlet is long enough and big enough to accommodate even the poofiest down parka sleeves. For the nastiest blowing spindrift this is the only way to go. Combined with the cinch straps, the gauntlet creates a seal that is impenetrable, even when you're skiing with the aid of a snorkel.

Removable Idiot Cords
When the mitts are removed for manipulation of small objects, these cords act as keepers, allowing the wearer to dangle the mitts from the wrists. Once you get dialed into this feature you will quickly want to add it to all of your handwear!

Technical Features and Benefits—Liner Specifications

Standard Moonlite Pile Liner

- High warmth to weight ratio.
- Extremely durable, maintains its loft well.
- Fast drying.
- Palm and finger side walls are one layer of pile for dexterity.
- Back of hand and back of thumb have two layers of pile for extra warmth.

Poron Foam for Back of Hands at Knuckles

- Protects knuckles from being bashed while ice climbing or skiing.

Flat Seams at Palm

- Flat seams allow excellent "touch" and dexterity of the fingers.

Seam Allowance on outside of Liner

- The extra material from the seams is placed on the outside, away from the hand, for warmth and comfort.

Strongly Curved Box Construction

- Follows the position of hand in the resting position.
- Matches the curve of the shell.

GT Liner

- The GT liner is a single liner of Moonlite Pile covered by Gore-Tex and a final layer of WickLine. It lacks the Poron Knuckle guard of the standard but retains the curved shape and box seam construction.
- Totally waterproof for use in sloppy conditions.

THERMAL FACTOIDS

A common misconception is to confuse heat and temperature, or believe they are the same. Test your own understanding by marking "T" for true or "F" for false by each of the statements in Section A below. Section B provides a quick experiment you can do yourself, or alternatively, make an outcome prediction and verify with another classmate. Section C contains true information for reading and use in your research and development.

Section A: Temperature vs. Heat

______ When a material is hot, it has more thermal energy than when it is cold. Thermal energy is the total potential and kinetic energy associated with the random motion and arrangement of the particles of a material.

______ Temperature is the hotness or coldness of a material.

______ Heat is thermal energy that is absorbed, given up, or transferred from one body to another.

______ The temperature of a body is a measure of its ability to give up heat to or absorb heat from another body. Heat will flow from a body with a higher temperature to a body with a lower temperature, even if the cooler body contains more thermal energy.

______ Temperature is a physical property that determines the direction in which heat energy will flow between substances.

______ There is no instrument that directly measures the amount of thermal energy a body gives off or absorbs. Therefore, quantities of heat must be measured by the effects they produce.

Section B: On the Other Hand...

The following experiment, as best we can tell, was first performed 400 years ago. Try it on your own, with classmates, or at home with your family. Be prepared to describe and explain what happens.

(1) Fill three open-top containers with water of different temperature as follows: (a) hot, but not scalding; (b) very cold, with or without ice; and (c) lukewarm or room temperature.

(2) Immerse one hand in the hot container and the other hand in the cold container.

(3) Switch the hand from the hot water to the lukewarm container. Determine whether the water in that container feels "warm" or "cool." Then remove your hand.

(4) Switch the other hand from the cold water to the lukewarm container, and again declare the water either "warm" or "cool."

(5) Record your findings or predictions, and explain below:
water in the third container feels: warm / cool (circle one) to the hot hand
water in the third container feels: warm / cool (circle one) to the chilled hand
Explanation:

Section C: Actual Factual Factoids

The calorie was defined as the quantity of heat needed to raise the temperature of one gram of water one degree Celsius.

The calorie is also defined as a specific number of joules: 4.186.

The Calorie (with a capital C) used in dietary tables by biologists and dietitians to measure the energy value of foods is equal to the kilocalorie (one thousand of the calories normally used by physicists).

The heat capacity of a body is the quantity of heat needed to raise its temperature 1°C.

Specific heat is the heat capacity of a material per unit mass.

Heat capacity = $Q/\Delta T$, where Q is the quantity of heat needed to produce a change (Δ) in the temperature of the body, ΔT.

Specific heat: $c = Q/m\Delta T$, where "c" is specific heat and "m" is mass.

Water conducts heat away from the body 25 times faster than does air because water has a greater density, therefore a heat capacity 50 times greater than air.

Staying dry is key to cold weather comfort and survival.

The metabolism of an organism is very closely tied to temperature. Within the narrow range of temperatures to which the active organism is tolerant, the metabolic rate increases with increasing temperature and decreases with decreasing temperature in a very regular fashion.

The relationship between metabolic rate and temperature is often expressed in terms of a value called the Q_{10}. This value is a measure of the rate increase for each 10°C rise in temperature. Thus if the rate doubles for each 10°C rise in temperature, the Q_{10} is said to be 2; if the rate triples for each 10°C rise, the Q_{10} is said to be 3; etc.

The exponential nature of the Q_{10} relationship radically affects the activity of poikilothermic ("cold blooded") organisms as the temperature of their surroundings changes.

Two classes of animals, mammals and birds, have evolved a mechanism that makes them much less dependent upon environmental temperatures and frees them for successful exploitation of more varied habitats. These "warm blooded," or homeothermic, animals maintain a relatively constant body temperature even when the environmental temperature fluctuates widely.

INFORMATION SEARCH STRINGS
Structured Class Internet Information Search

- If possible, prepare a quick demonstration showing students the steps to accessing the Internet and what to expect—either real-time or pre-taped via feed to a TV monitor in the classroom. A few cautionary words about censorship, commercialism, and privacy issues should be included at the outset. Consult your school policy and lab director for assistance.

- Set an objective, assignment, or contest that requires each student or pair of students to turn in a search path or research result printout at the end of the session. Inform students how the deliverable will be used for assessment.

- Schedule enough time for the activity so that the slower navigators will be able to satisfy predetermined destinations (with provisions for speedsters to move beyond).

- Consider pairing students: inexperienced with familiar, confident with scared, leaders with followers, disciplinary problems with angels, etc., to create peer teaching opportunities and reduce individual distractions from allowing you to gain group attention. Pairing will also decrease the network traffic in your lab, which could otherwise decrease computer response times.

- If your lab or media center administrator has not already done so, prepare a brief but precise list of sequential steps to start up, log on, connect to the Internet, and select and arrive at a search screen. Duplicate this and provide it as a handout to each pair of navigators. Some "don'ts" may need to be listed, such as "do not double click"; include easy-to-remember explanations such as "you don't need to tell the machine twice," or more technical reasons such as "double-clicking slows the processor because it must sort through duplicate instructions and may exceed its memory by opening and displaying duplicate screens."

- The structure of search commands will have to be covered, as well as how to limit a search by combining key words. You might want to prepare a list of key words that you have tried and found productive for groups to pick from according to their interests or assigned objective. Having everyone achieve a common destination and then diverge will increase the class' overall depth of exploration if results are to be shared.

- After the search, you may wish to provide a list of known Web sites from your own reference and resource list and invite students to submit additions to it. Providing short-cut instructions on how to GO TO or OPEN a known URL, as well as creating and using bookmarks, will be helpful to avoid confusion.

The following Web sites were active and helpful during the development of the curriculum:

http://www.orgear.com/
(check the Tech Manual on this home page for glove specs)

http://www.monolithicdome.com/articles/rfairy/
(R-value limitations)

http://www.laser.org/archives/1994/msg00485.html
(anecdotal: thermal regulation)

http://www.landsend.com/
(Lands' End, Inc. 3-layer gloves)

http://www.princeton.edu/~oa/safety/hypocold.html
(hypothermia and cold weather injuries)

HOMEWORK—INDIVIDUAL INFORMATION SEARCH

For each topic you independently research, record below your sources or search engines, key words, Boolean search strings, and useful Web site Universal Resource Locator (URL) addresses or bibliographic citations.

Source/Search Engine	Key Words/Search String	Resultant URL/Citation	Notes

Compare your search technique and results with your team members and highlight two strategic search "tips" below.

1.

2.

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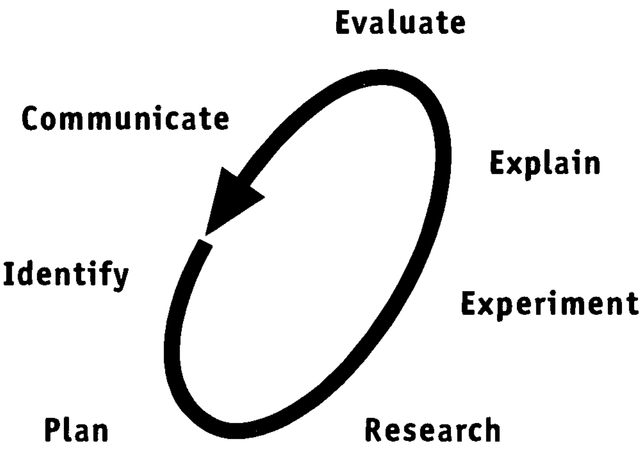
INQUIRY PROCESS

The inquiry process can be described with seven basic elements. It is often viewed as a cycle of action that repeats until the investigators have reached a satisfying solution.



SCILINKS
THE WORLD'S A CLICK AWAY

Topic: scientific inquiry
Go to: www.scilinks.org
Code: CAG06

Identify and clarify questions. Understand the issue or problem, and make a testable hypothesis.

Plan appropriate procedures. Brainstorm, draw and write ideas, clarify their ideas, and suggest possible strategies or methods.

Research major concepts. Learn what is known about the situation from sources other than actual investigation, and obtain information from preliminary experiments. Decide what technology, approach, equipment, and safety precautions are useful. Document your experiments and log your data.

Experiment. Use tools and measuring devices to conduct experiments. Use calculators and computers to store and present data.

Explain logical connections. Analyze your data. Formulate explanations using logic and evidence, and possibly by constructing a physical, conceptual or mathematical model.

Evaluate alternatives. Compare your explanations to current scientific understanding and other plausible models. Identify what needs to be revised, and find the preferred solution.

Communicate new knowledge and methods. Communicate results of your inquiry to your peers and other in the community. Construct a reasoned argument through writing, drawings, and oral presentations. Respond appropriately to critical comments.

Questions

Read the following questions, but do not answer them until after your team has experienced working together on the *Construct-a-Glove* design challenge research activities.

1. Make your own checklist of team activities that correspond to steps in the cycle described above.

2. Create your own version of the inquiry process using words and pathways that fit your team's activity.

3. What shape is your inquiry pathway diagram (circle, spiral, cascade, other)?

4. How and where do the seven steps described above fit within your process description?

HOMEOTHERMIC REGULATION

Classification of life forms aids in identification, and reveals possible relationships between organisms. There are variations in classification systems, and not all scientists agree on all details. Nevertheless, such systems are useful to organize similar and distinguishing information about life forms. Study of such systems also gives insights into changes that appear over time because of the environment and other factors. In the broadest scientific classification of living things, modern humans belong to the Kingdom *Animalia*. Further, we belong to the: subkingdom *Metazoa*, section *Deuterostomia*, phylum *Chordata*, subphylum *Vertebrata*, class *Mammalia*, subclass *Theria*, order *Primates*, genus *Homo*, species *Sapiens*.

Another classification of animals is based on body temperature regulation. Animals obtain energy by cellular respiration, converting chemical energy of food by oxidation of carbohydrates, fats, and proteins into high-energy phosphate bonds of ATP (adenosine triphosphate). Cells are more efficient at converting energy for use than man's most elaborate nuclear electric power plant. Even so, 40–60 percent of the released energy of respiration is in the form of "waste" heat (compared to 65–70 percent waste heat in producing electricity). Most animals (and all plants) promptly lose this heat energy to their environments. Such animals are called "cold-blooded." Scientists use the term "poikilothermic," meaning "of variable temperature." Only birds and mammals (including humans) have developed insulation (fur, feathers, and fat) and respiratory and circulatory feedback mechanisms to retard the loss of metabolic "waste" heat to the environment. The heat conserved by these warm-blooded animals allows them to maintain a higher body temperature, which sustains a higher metabolic rate (Q_{10}) and increased level of activity. (Refer to *Thermal Factoids* activity and biology texts for further information.)

The following questions may help you relate your scientific research and technological development for this project to naturally occurring systems. Insights gained here may stimulate further design innovations.

Questions

1. Does the overall metabolic process of animals function more like a furnace or a refrigeration unit? Explain your answer.

2. List several advantages homeotherms gain by maintaining a higher and more constant body temperature than poikilotherms.

3. What added benefits do homeothermic humans get from creating, wearing, and continuously improving insulated gloves?

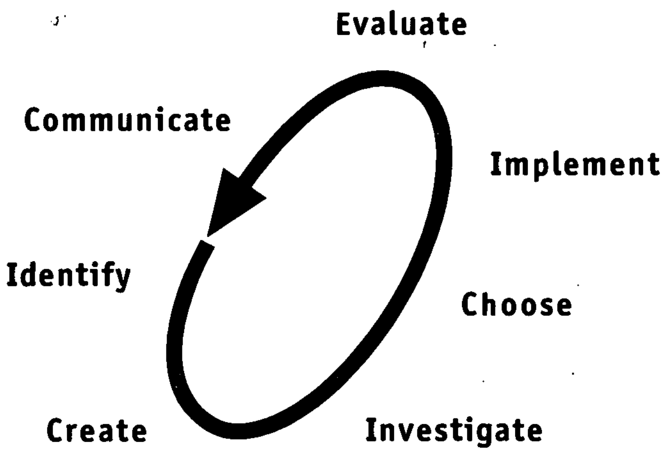
4. Give two examples of how other animals cope with environmental extremes without gloves.

5. Because humans benefit from gloves, would a frog or a bird benefit from having gloves designed for them?

6. Suggest an event from history that might have been different without the development of gloves.

DESIGN PROCESS

The design process can be described with seven basic elements. It is often viewed as a cycle of action that repeats until the designers have reached a satisfying solution.



Identify and clarify the situation. Understand the challenge or problem, including the criteria for success and constraints on the design.

Create solutions. Brainstorm, draw and write ideas, and suggest possible strategies or methods.

Investigate possibilities. Learn what is known about the situation, and what technology or approach could be useful. Conduct experiments to test your ideas.

Choose a solution. List the solutions most likely to be successful, and make decisions for how well each solution meets the design challenge or solves the problem.

Implement the design. Learn that a successful design often depends on good fabrication, whether it is a scaled or life-sized version of the product.

Evaluate the design. Perform tests to obtain the feedback that informs them about the parts of the design that worked or needed improvement.

Communicate the solution. Present your designs to your peers and others in the community, communicating your ideas through drawings, writing, formal presentations, informal discussions.

Questions

After reading about the design process, answer the following questions:

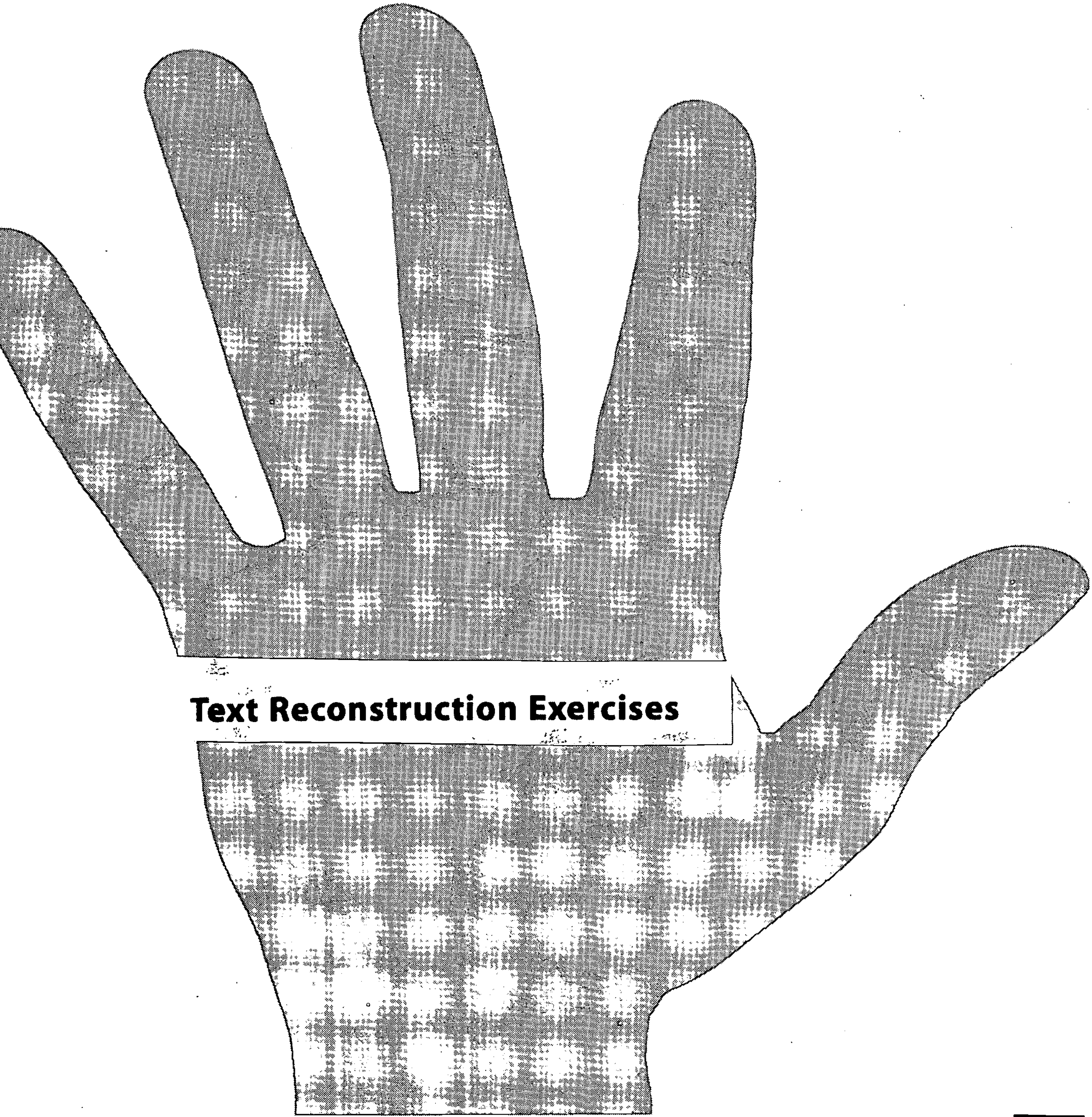
1. What elements of the process have you already experienced?

2. What elements have you not yet experienced?

3. Where in the process do you think you are now?

4. What will be your next steps?

Text Reconstruction Exercises



For more information on Text Reconstruction Across the Curriculum contact: The Institute for TRAC Research, P.O. Box 7336, Albuquerque NM. Tel. (505) 831-2654 or visit the New Intelligence Web site at http://www.newintel.com

TEXT RECONSTRUCTION

The jumbled paragraphs in the expla nation of key ideas are examples of Text Reconstruction (TR). This well-established technique for reading and writing improvement has roots going back to Benjamin Franklin as well as a number of famous authors. Many teachers find that including TR in a reading assignment highly motivates students and results in a much higher rate of homework completion. We suggest you read Chapter 5 of *Why Johnny Can't Write* for complete instructions on how to design your own exercises. Additional exercises can be found in *How to Analyze, Organize, & Write Effectively*.

An instructional process that uses design or inquiry places great demands on class time. It is impossible to cover all essential content within the few hours per week students spend in class. Science and technology courses must therefore insist that students learn from reading. This means they must also provide realistic opportunities for students to improve their ability to learn from reading.

Text Reconstruction works as a method of improving reading skills by focusing student attention on the most important elements of the reading task. First, it changes the reader's perception of his or her role from that of a passive absorber of information to that of an active agent who must sort out a puzzle. This is probably the main reason TR exercises are popular with students. Secondly, TR forces students to pay attention to the logic of a paragraph. In science, it is not the separate ideas that are important, but rather the logic that ties them together. When passively reading a paragraph, one can easily miss that logic, but in TR it is impossible to complete the task without thoroughly understanding these interconnections. A student who reconstructs a paragraph will understand its structure and meaning far more deeply than a student who memorizes every word but considers them only in their current order.

In the *Science by Design* series, we employ various techniques to encourage student reading and writing. These are not extras, but rather essential elements of the program. The exercises included assume that your students are relatively strong readers. If your students are weak readers or are unused to serious homework, then you will need to increase the amount of attention you pay to improving reading skills. Text Reconstruction can be used to convert any kind of reading assignment into a stimulating puzzle. The more use you make of TR, the more your students will read and the better they will understand.

HOMEOTHERMIC PROCESSES

The paragraphs below describe the homeothermic process and its relation to gloves. To prevent this information from falling into the hands of rival glove manufacturers, the order of the sentences in each paragraph has been jumbled. Your task is to rearrange the sentences in their correct order. Good luck.

Homeothermic Processes

____ Most animals depend on the sun or on thermal hot springs to keep themselves warm. ¶1

____ It involves burning fuel (food) in the body to create heat and using the blood flow as a means of getting that heat distributed evenly.

____ A small but a very familiar group of animals are known as warm blooded because they keep themselves warm.

____ The homeothermic process is the process these animals use to keep themselves at a comfortable temperature.

____ The system is very similar to that in a house that is heated by pumped hot water.

____ The heart and other working muscles produce heat.

____ This heat warms the blood that runs through these warm organs and this warmed blood is then pumped to other areas of the body that may be cooler in temperature.

____ Using the blood flow as a means of conducting heat is a very clever design because this is not what blood was originally invented to do and it is not even now the primary mission of blood flow. ¶2

____ Actually the blood in such animals can be hot or cold depending on the surrounding temperature.

q2 cont.

____ Many organisms that are not homeothermic use blood for these primary missions; these organisms are called cold blooded.

____ That primary mission is bringing oxygen and nutriants to the cells and taking away carbon dioxide and waste products.

____ Blood can still carry warmth to colder regions of the body but usually it is from a warm skin to a colder interior.

q3

____ In these circumstances, heat can be radiated to the environment by passing overheated blood through the colder surface areas of the body.

____ When an organism is very active it can get too hot.

____ These surface areas are some times cooled by the evaporation of sweat.

____ The hands, ears, and feet are major areas for heat loss because they have lots of blood flow and a big surface area to volume ratio.

____ This evaporation system works just like many of the airconditioning systems used in houses that have central airconditioning connected to the same pumped hot water as is used for heating.

____ This big surface area to volume ratio acts like the fins on radiators.

____ Hands, ears, and feet are very useful when you are too hot.

____ To protect the rest of the body, the homeothermic system will reduce blood flow to these extremities when body temperature is too low.

____ Eventually, however, the homeothermic system will give up on saving these parts of you and will allow them to freeze and fall off.

____ To outsmart the homeothermic system, people have invented gloves, earmuffs, and socks.

____ This is good in the short term but not a wise choice in the long term.

____ As the temperature of the hands, ears, and feet begins to fall the body sends short bursts of blood to keep them warm enough to avoid freezing.

____ But they become very dangerous when you are too cold.

____ These inventions allow people to live in places like North America and Europe where they probably should never have gone to in the first place.

HEAT ENERGY TRANSFER EXERCISE

The paragraphs below describe the concept of heat transfer. To prevent this information form falling into the wrong hands the order of the sentences in each paragraph has been jumbled. Your task is to rearrange the sentences in their correct order. Good luck.

Heat Transfer

¶1

____ Heat, which is a form of energy, naturally flows from hot areas to colder areas.

____ The property of materials that determines how fast heat will flow is called thermal conductivity.

____ Other materials such as wood and paper have a relatively low thermal conductivity.

____ If air is trapped so it cannot move around, it becomes a very good thermal insulator.

____ Materials with a low thermal conductivity are called thermal insulators.

____ This is why we wear bulky sweaters when we want to be hot.

____ But heat will flow more rapidly in some materials than in others.

____ Many metals, such as copper, have a high thermal conductivity.

¶2

____ These new insulators affect how we dress and the design of the buildings in which we live and work.

____ New, lighter, thinner, less expensive thermal insulators are being invented every year.

____ Thermal insulators are very important for clothing and for building construction.

HOMEOTHERMIC PROCESSES TEXT RECONSTRUCTION KEY

The four paragraphs below show the correct order of sentences in the Homeothermic Text Reconstruction exercise.

Paragraph 1

1. Most animals depend on the sun or on thermal hot springs to keep themselves warm.
2. A small but a very familiar group of animals are known as warm blooded because they keep themselves warm.
3. The homeothermic process is the process these animals use to keep themselves at a comfortable temperature.
4. It involves burning fuel (food) in the body to create heat and using the blood flow as a means of getting that heat distributed evenly.
5. The system is very similar to that in a house that is heated by pumped hot water.
6. The heart and other working muscles produce heat.
7. This heat warms the blood that runs through these warm organs and this warmed blood is then pumped to other areas of the body that may be cooler in temperature.

Paragraph 2

1. Using the blood flow as a means of conducting heat is a very clever design because this is not what blood was originally invented to do and it is not even now the primary mission of blood flow.
2. That primary mission is bringing oxygen and nutriants to the cells and taking away carbon dioxide and waste products.
3. Many organisms that are not homeothermic use blood for these primary missions; these organisms are called cold blooded.
4. Actually the blood in such animals can be hot or cold depending on the surrounding temperature.
5. Blood can still carry warmth to colder regions of the body but usually it is from a warm skin to a colder interior.

Paragraph 3

1. When an organism is very active it can get too hot.
2. In these circumstances, heat can be radiated to the environment by passing overheated blood through the colder surface areas of the body.
3. These surface areas are some times cooled by the evaporation of sweat.
4. This evaporation system works just like many of the airconditioning systems used in houses that have central airconditioning connected to the same pumped hot water as is used for heating.
5. The hands, ears, and feet are major areas for heat loss because they have lots of blood flow and a big surface area to volume ratio.
6. This big surface area to volume ratio acts like the fins on radiators.

Paragraph 4

1. Hands, ears, and feet are very useful when you are too hot.
2. But they become very dangerous when you are too cold.
3. To protect the rest of the body, the homeothermic system will reduce blood flow to these extremities when body temperature is too low.
4. As the temperature of the hands, ears and feet begins to fall the body sends short bursts of blood to keep them warm enough to avoid freezing.
5. Eventually, however, the homeothermic system will give up on saving these parts of you and will allow them to freeze and fall off.
6. This is good in the short term but not a wise choice in the long term.
7. To outsmart the homeothermic system, people have invented gloves, ear muffs, and socks.
8. These inventions allow people to live in places like North America and Europe where they probably should never have gone to in the first place.

HEAT ENERGY TRANSFER TEXT RECONSTRUCTION KEY

The two paragraphs below show one correct way to order the sentences in the Heat Energy Transfer Text Reconstruction exercise. There may be other reasonable orders but you should accept them only if students can justify their choices.

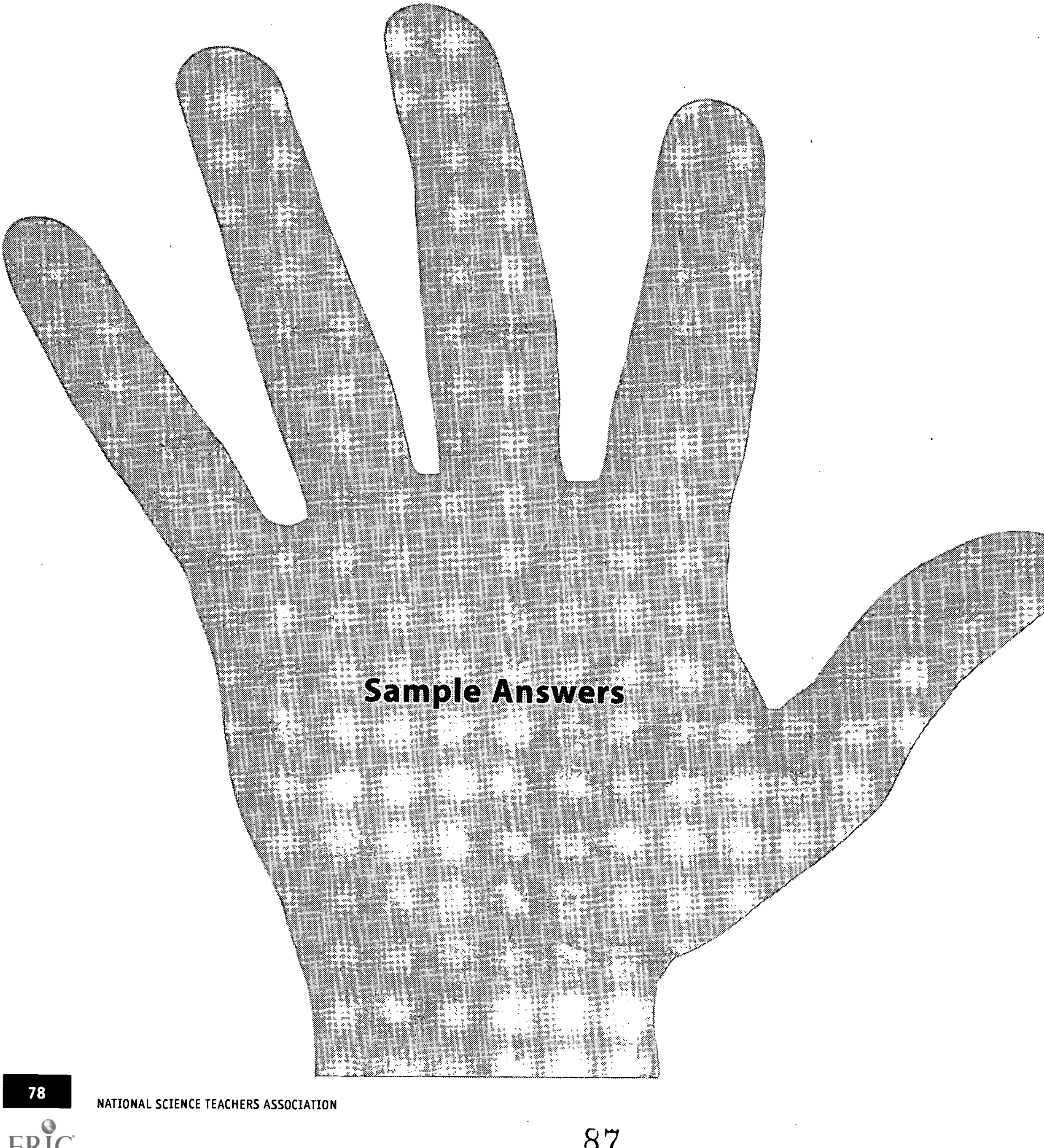
Paragraph 1

1. Heat, which is a form of energy, naturally flows from hot areas to colder areas.
2. But heat will flow more rapidly in some materials than in others.
3. The property of materials that determines how fast heat will flow is called thermal conductivity.
4. Many metals, such as copper, have a high thermal conductivity.
5. Other materials such as wood and paper have a relatively low thermal conductivity.
6. Materials with a low thermal conductivity are called thermal insulators.
7. If air is trapped so it cannot move around, it becomes a very good thermal insulator.
8. This is why we wear bulky sweaters when we want to be hot.

Paragraph 2

1. Thermal insulators are very important for clothing and for building construction.
2. New, lighter, thinner, less expensive thermal insulators are being invented every year.
3. These new insulators affect how we dress and the design of the buildings in which we live and work.

Appendix C



Identifying Factors and Variables

Activity 2, p. 18

Glove System Variables	Range of Variation
Example: convection seal at wrist	*no seal — loose — tight*
Amount of insulation	*lots > little*
Fit	*tight > bulky*
User-Related Variables	**Range of Variation**
Example: starting state of user's hands	*chilled — normal — hot & sweaty*
Level of metabolism	*sluggish < very active*
Clothing	*scant < very warm*
Design Factors	**Constraints**
Example: wrist seal pressure	*prevent convection without constricting blood circulation*
Insulation thickness	*bulk reduces movement*
Flexibility of glove material	*material may tear easily*

TEAM SITUATION ANALYSIS

Activity 2, p. 19

Most Significant Variables	Suggested Modifications
Example: Direct heat loss through conduction	*Slow heat flow with more layers of insulation*
waterproof materials	*build out layer*
soft interior	*line interior*
thin, flexible insulators	*make middle layer*
sewing seams with waterproof seals/glue	*construct seams that won't leak*

Activity 3, p. 27–28

INVESTIGATING HEAT TRANSFER AND INSULATION

The research experiments you design for this activity should help you determine the best of available insulation materials and application systems to use in your insulated glove prototype. To arrive at a suitable experimental design, you might try listing anticipated problems in procedure or interpretation, and posing solutions. A couple of sample considerations are offered to stimulate thought:

Problem: Metabolic and circulatory feedback effects vary among and within human hands, thus the temperature inside a glove depends on the hand as well as the glove.

Solution: *Replace a radiating human hand with a water-filled glove at known initial temperature. Measure heat loss over time. How does this control of variables affect interpretation of your results?*

Problem: Immersion in ice water provides fast experimental results, but requires that outer materials be waterproof, unduly limiting material choices.

Solution: *Adapt the experimental set-up to use a source of constant cold air temperature, such as a refrigerator or an air conditioner. Or, use a thin waterproof disposable film glove as an outer layer and devise a correction factor for the insulating effect.*

1. Write down your research protocol for evaluating gloves.

   1. *Cover glove with thin waterproof glove.*

   2. *Line inside with waterproof glove and fill with room temperature water, 0.25 liters.*

   3. *Place glove in ice water and measure time for water in glove to drop to 5 °C.*

"FAIR TEST" COMPARISON

Activity 3, p. 29

A "fair test" comparison is a comparison among two or more designs in which no design is given an advantage.

Product Comparisons

1. Observe differences between your Quick-Build insulated glove and a commercial glove that has been designed to be worn in cold weather.

Quick-Build Glove	Commercial Glove
stiff—hard to move	*flexible*
bulky	*thin*
falls apart	*stays together*
keeps hand warm	*sort-of keeps hand warm*

2. Using your research protocol, compare the insulation effectiveness of the commercial glove to your Quick-Build product.

3. Do the results of your research protocol fit with your understanding of how the two gloves compare?

   Protocol shows our gloves as best, but commercial glove would last longer.

4. Decide whether changes need to be made in your protocol. Is it a fair test?

   *We need to add **durability** and **flexibility** to our protocol.*

Activity 4, p. 37

TEAM FEEDBACK

Factors	Suggested Modifications
insulation leaks out	*seal cuff*
glove too bulky	*reduce insulation*
seams leak	*design waterproof seams*
glove looks awful	*hire fashion designer*

Activity 4, p. 38

REFLECTIONS ON DESIGN

➤ What is the one feature of your insulated glove system about which you are most proud?

Our glove is better insulated than the commercial glove.

➤ Describe the concerns you have with the present design.

The glove drips whipped cream.

➤ Describe in a paragraph or two the approach your team took in the designing and building of your prototype. Include a problem your team encountered with the performance tests and how you went about solving it.

We could not think of a good insulator that was cheap, flexible, and wouldn't flatten down. We thought of using peanut butter, but that was too sticky. Then we decided to use whipped cream.

baseline data: data taken to determine conditions before an experiment is started

bioregulation: a biological process that controls the value of a variable. For example, bioregulation keeps body temperature constant in homeothermic animals

brainstorming: a group problem-solving technique which involves the spontaneous contribution of ideas from all members of the group

calorie: the amount of heat needed to increase one gram of water by one degree Celsius

cellular respiration: the conversion within the cell of nutrients (such as sugar molecules) into chemical energy, by reacting the food with oxygen (O_2); byproducts are carbon dioxide and water

conduction: the flow of thermal energy through a substance from a higher- to a lower-temperature region

constraints: restrictions imposed on a system or process

convection: the movement of heat through a fluid (such as liquid or gas), e.g., the free or forced movement of warm air throughout a room

criterion: a standard on which a judgment or decision may be based

design factors: a set of **variables** and **constraints** considered critical to a successful design

dexterity: skill and ease in using the hands

"fair test" comparison: a comparison among two or more designs in which no design is given an advantage

friction: resistance to sliding, a property of the interaction between two solid bodies in contact

heat: the amount of internal **kinetic** energy of atoms and molecules that flows from a warmer to a cooler environment (see **temperature**)

heat capacity: the amount of heat required (measured in **joules** or **calories**) to raise a unit of mass (measured in grams or kilograms) by one degree Celsius. For example, raising one gram of water by one degree Celsius requires one calorie of energy

homeotherm: an organism that maintains a constant internal body temperature (see **poikilotherm**)

insulation: material used to prevent transfer of heat

iteration: the action of repeating a process

joule: a metric unit for work which is the force of one **Newton** acting over a distance of one meter, where the force and the distance moved lie in the same direction; named after James Prescott Joule, a 19th-century British physicist

kinetic: of or relating to the motion of material bodies and the forces and energy with which that motion is associated

metabolism: all the physical and chemical processes by which living substance is produced and maintained; the transformations by which energy is made available for use by an organism

Newton: a metric measurement of force based on one kilogram of mass experiencing acceleration of one meter per second squared

parameter: any of a set of physical properties whose values determine the characteristics of something

performance test: a test to determine how well a design accomplishes an intended purpose

poikilotherm: an organism with a variable body temperature

prospectus: a preliminary printed statement that describes an enterprise which is then distributed to prospective participants, investors, or buyers

protocol: the plan of a scientific experiment or treatment

prototype: an original model; first full-scale and (usually) functional form of a new type or design of a construction

Q_{10}: a value representing the relationship between metabolic rate and temperature; measures the metabolic rate increase for each 10°C rise in temperature—if the rate double for each 10°C rise in temperature, the Q_{10} is said to be "2"

radiation: a type of heat transfer through exposure to a series of electromagnetic waves, such as infrared waves.

range of variation: the least and greatest values found for a specific **variable**

specific heat: the quantity of heat needed to produce a change in the temperature of a specific body mass ($Q/m\Delta T$)

specifications: the precise details of an invention, plan or proposal

system: a regularly interacting or interdependent group of items forming a unified whole

temperature: a scale for measuring thermal energy by showing how warm or cold an object is relative to something else (such as the freezing and boiling points of water)

thermodynamics: the study of heat and how heat energy is transformed from one form of energy to another

variable: an object or quality of changeable value

vasoconstriction: narrowing of the blood vessels

vasodilatation: widening of the blood vessels

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ISBN: 0-87355-177-X
PB152X1

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