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ABSTRACT

This Unified Sciences and Mathematics for Elementary Schools (USMES) unit challenges students to find the best way to produce an item in quantities needed. The challenge is general enough to apply to many problem-solving situations in mathematics, science, social science, and language arts at any elementary school level (grades 1-8). The Teacher Resource Book for the unit is divided into five sections. Section I describes the USMES approach to student-initiated investigations of real problems, including a discussion of the nature of USMES "challenges." Section II provides an overview of possible student activities with comments on prerequisite skills, instructional strategies, suggestions when using the unit with primary grades, flow charts illustrating how investigations evolve from students' discussions of manufacturing problems, and a hypothetical account of intermediate-level class activities. Section III provides documented events of actual class activities from grades 2, 5, 6, and 6/7. Section IV includes lists of "How To" cards and background papers, bibliography of non-USMES materials, and a glossary. Section V consists of charts identifying skills, concepts, processes, and areas of study learned as students become involved with the activities. (JN)

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UNIFIED SCIENCES AND MATHEMATICS FOR ELEMENTARY SCHOOLS:
Mathematics and the Natural, Social, and Communications Sciences in Real Problem Solving.

Manufacturing

Second Edition

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CHALLENGE: FIND THE BEST WAY TO PRODUCE IN QUANTITY AN ITEM THAT IS NEEDED.

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Preface

The USMES Project

Unified Sciences and Mathematics for Elementary Schools: Mathematics and the Natural, Social, and Communications Sciences in Real Problem Solving (USMES) was formed in response to the recommendations of the 1967 Cambridge Conference on the Correlation of Science and Mathematics in the Schools.* Since its inception in 1970, USMES has been funded by the National Science Foundation to develop and carry out field trials of interdisciplinary units centered on long-range investigations of real and practical problems (or "challenges") taken from the local school/community environment. School planners can use these units to design a flexible curriculum for grades one through eight in which real problem solving plays an important role.

Development and field trials were carried out by teachers and students in the classroom with the assistance of university specialists at workshops and at occasional other meetings. The work was coordinated by a staff at the Education Development Center in Newton, Massachusetts. In addition, the staff at EDC coordinated implementation programs involving schools, districts, and colleges that are carrying out local USMES implementation programs for teachers and schools in their area.

Trial editions of the following units are currently available:

Advertising	Nature Trails
Bicycle Transportation	Orientation
Classroom Design	Pedestrian Crossings
Classroom Management	Play Area Design and Use
Consumer Research	Protecting Property
Describing People	#School Rules
Designing for Human Proportions	School Supplies
#Design Lab Design	School Zoo
#Eating in School	Soft Drink Design
Getting There	Traffic Flow
Growing Plants	#Using Free Time
Manufacturing	Ways to Learn/Teach
Mass Communications	Weather Predictions

*See *Goals for the Correlation of Elementary Science and Mathematics*, Houghton Mifflin Co., Boston, 1969.

#Available fall 1976.

USMES Resources

In responding to a long-range challenge, the students and teachers often have need of a wide range of resources. In fact, all of the people and materials in the school and community are important resources for USMES activities. USMES provides resources in addition to these. One resource for students is the Design Lab or its classroom equivalent: using the tools and supplies available, children can follow through on their ideas by constructing measuring tools, testing apparatus, mo[illegible]ls, etc. Another resource for students is the *"How T[illegible]" Cards*. Each set of cards gives information about a specific problem; the students use a set only when they want help on that particular problem.

Several types of resources are available for teachers: the *USMES Guide*, a *Teacher Resource Book* for each challenge, *Background Papers*, a *Design Lab Manual*, and a *Curriculum Correlation Guide*. A complete set of all these written materials comprise what is called the USMES library. This library, which should be available in each school using USMES units, contains the following:

1. *The USMES Guide*

   The USMES Guide is a compilation of materials that may be used for long-range planning of a curriculum that incorporates the USMES program. In addition to basic information about the project, the challenges, and related materials, it contains charts assessing the strengths of the various challenges in terms of their possible subject area content.

2. *Teacher Resource Books* (one for each challenge)

   Each book contains a description of the USMES approach to real problem-solving activities, general information about the particular unit, edited logs of class activities, other written materials relevant to the unit, and charts that indicate the basic skills, processes, and areas of study that may be learned and utilized as students become engaged in certain possible activities.

3. *Design Lab Manual*

   This contains sections on the style of Design Lab activities, safety considerations, and an inventory of tools and supplies. Because many "hands-on" activities may take place in the classroom, the Design Lab Manual should be made available to each USMES teacher.

4. *"How To" Cards*

These short sets of cards provide information to students about specific problems that may arise during USMES units. Particular computation, graphing, and construction problems are discussed. A complete list of the "How To" Cards can be found in the USMES Guide.

5. *Background Papers*

These papers are written to provide information for the teachers on technical problems that might arise as students carry on various investigations. A complete list of the Background Papers can be found in the USMES Guide.

6. *Curriculum Correlation Guide*

This volume is intended to coordinate other curriculum materials with the Teacher Resource Books and to provide the teacher with the means to integrate USMES easily into other school activities and lessons.

The preceding materials are described in brief in the USMES brochure, which can be used by teachers and administrators to disseminate information about the program to the local community. A variety of other dissemination and implementation materials are also available for individuals and groups involved in local implementation programs. They include *Preparing People for USMES: An Implementation Resource Book*, the USMES slide/tape show, the Design Lab slide/tape show, the Design Lab brochure, the USMES newsletter, videotapes of classroom activities, a general report on evaluation results, a map showing the locations of schools conducting local implementation of USMES, a list of experienced USMES teachers and university consultants, and newspaper and magazine articles.

Acknowledgments

Besides the contributors listed at the beginning of the book, we are deeply indebted to the many elementary school children whose investigations of the challenge form the basis for this book. Without their efforts this book would not have been possible. Many thanks to the Planning Committee for their years of service and advice. Many thanks also to other members of the USMES staff for their suggestions and advice and for their help in staffing and organizing the development workshops. Special thanks also go to Christopher Hale for his efforts as Project Manager during the development of this book.

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Because Tri-Wall was the only readily available brand of three-layered cardboard at the time the project began, USMES has used it at workshops and in schools; consequently, references to Tri-Wall can be found throughout the Teacher Resource Books. The addresses of companies that supply three-layered cardboard can be found in the Design Lab Manual.

Introduction

Using the Teacher Resource Book

When teachers try a new curriculum for the first time, they need to understand the philosophy behind the curriculum. The USMES approach to student-initiated investigations of real problems is outlined in section A of this Teacher Resource Book.

Section B starts with a brief overview of possible student activities arising from the challenge; comments on prerequisite skills are included. Following that is a discussion of the classroom strategy for USMES real problem-solving activities, including introduction of the challenge, student activity, resources, and Design Lab use. Subsequent pages include a description of the use of the unit in primary grades, a flow chart and a composite log that indicate the range of possible student work, and a list of questions that the teacher may find useful for focusing the students' activities on the challenge.

Because students initiate all the activities in response to the challenge and because the work of one class may differ from that undertaken by other classes, teachers familiar with USMES need to read only sections A and B before introducing the challenge to students.

Section C of this book is the documentation section. These edited teachers' logs show the variety of ways in which students in different classes have worked at finding a solution to the challenge.

Section D contains a list of the titles of relevant sets of "How To" Cards and brief descriptions of the Background Papers pertaining to the unit. Also included in section D is a glossary of the terms used in the Teacher Resource Book and an annotated bibliography.

Section E contains charts that indicate the comparative strengths of the unit in terms of real problem solving, mathematics, science, social science, and language arts. It also contains a list of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in the unit. These charts and lists are based on documentation of activities that have taken place in USMES classes. Knowing ahead of time which basic skills and processes are likely to be utilized, teachers can postpone teaching that part of their regular program until later in the year. At that time students can study them in the usual way if they have not already learned them as part of their USMES activities.

A. Real Problem Solving and USMES

*If life were of such a constant nature that there were only a few chores to do and they were done over and over in exactly the same way, the case for knowing how to solve problems would not be so compelling. All one would have to do would be to learn how to do the few jobs at the outset. From then on he could rely on memory and habit. Fortunately--or unfortunately depending upon one's point of view--life is not simple and unchanging. Rather it is changing so rapidly that about all we can predict is that things will be different in the future. In such a world the ability to adjust and to solve one's problems is of paramount importance.**

Real Problem Solving

USMES is based on the beliefs that real problem solving is an important skill to be learned and that many math, science, social science, and language arts skills may be learned more quickly and easily within the context of student investigations of real problems. Real problem solving, as exemplified by USMES, implies a style of education which involves students in investigating and solving real problems. It provides the bridge between the abstractions of the school curriculum and the world of the student. Each USMES unit presents a problem in the form of a challenge that is interesting to children because it is both real and practical. The problem is real in several respects: (1) the problem applies to some aspect of student life in the school or community, (2) a solution is needed and not presently known, at least for the particular case in question, (3) the students must consider the entire situation with all the accompanying variables and complexities, and (4) the problem is such that the work done by the students can lead to some improvement in the situation. This expectation of useful accomplishment provides the motivation for children to carry out the comprehensive investigations needed to find some solution to the challenge.

The level at which the children approach the problems, the investigations that they carry out, and the solutions

*Kenneth B. Henderson and Robert E. Pingry, "Problem-Solving in Mathematics," in *The Learning of Mathematics: Its Theory and Practice,* Twenty-first Yearbook of the National Council of Teachers of Mathematics (Washington, D.C.: The Council, 1953), p. 233.

that they devise may vary according to the age and ability of the children. However, real problem solving involves them, at some level, in all aspects of the problem-solving process: definition of the problem; determination of the important factors in the problem; observation; measurement; collection of data; analysis of the data using graphs, charts, statistics, or whatever means the students can find; discussion; formulation and trial of suggested solutions; clarification of values; decision making; and communications of findings to others. In addition, students become more inquisitive, more cooperative in working with others, more critical in their thinking, more self-reliant, and more interested in helping to improve social conditions.

The USMES Approach

To learn the process of real problem solving, the students must encounter, formulate, and find some solution to complete and realistic problems. The students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of their hypotheses and conclusions. In real problem-solving activities, the teacher acts as a coordinator and collaborator, not an authoritative answer-giver.

The problem is first reworded by students in specific terms that apply to their school or community, and the various aspects of the problem are discussed by the class. The students then suggest approaches to the problem and set priorities for the investigations they plan to carry out. A typical USMES class consists of several groups working on different aspects of the problem. As the groups report periodically to the class on their progress, new directions are identified and new task forces are formed as needed. Thus, work on an USMES challenge provides students with a "discovery-learning" or "action-oriented" experience.

Real problem solving does not rely solely on the discovery-learning concept. In the real world people have access to certain facts and techniques when they recognize the need for them. The same should be true in the classroom. When the students find that certain facts and skills are necessary for continuing their investigation, they learn willingly and quickly in a more directed way to acquire these facts and skills. Consequently, the students should have available different resources that they may use as they recognize the need for them, but they should still be left with a wide scope to explore their own ideas and methods.

Certain information on specific skills is provided by the sets of USMES "How To" Cards. The students are referred only to the set for which they have clearly identified a need and only when they are unable to proceed on their own. Each "How To" Cards title clearly indicates the skill involved--"How to Use a Stopwatch," "How to Make a Bar Graph Picture of Your Data," etc. (A complete list of the "How To" Cards can be found in Chapter IX of the USMES Guide.)

Another resource provided by USMES is the Design Lab or its classroom equivalent. The Design Lab provides a central location for tools and materials where devices may be constructed and tested without appreciably disrupting other classroom activities. Ideally, it is a separate room with space for all necessary supplies and equipment and work space for the children. However, it may be as small as a corner of the classroom and may contain only a few tools and supplies. Since the benefits of real problem solving can be obtained by the students only if they have a means to follow up their ideas, the availability of a Design Lab can be a very important asset.

Optimally, the operation of the school's Design Lab should be such as to make it available to the students whenever they need it. It should be as free as possible from set scheduling or programming. The students use the Design Lab to try out their own ideas and/or to design, construct, test, and improve many devices initiated by their responses to the USMES challenges. While this optimum operation of the Design Lab may not always be possible due to various limitations, "hands-on" activities may take place in the classroom even though a Design Lab may not be available. (A detailed discussion of the Design Lab can be found in Chapter VI of the USMES Guide, while a complete list of "How To" Cards covering such Design Lab skills as sawing, gluing, nailing, soldering, is contained in Chapter IX.)

Work on all USMES challenges is not only sufficiently complex to require the collaboration of the whole class but also diverse enough to enable each student to contribute according to his/her interest and ability. However, it should be noted that if fewer than ten to twelve students from the class are carrying out the investigation of a unit challenge, the extent of their discovery and learning can be expected to be less than if more members of the class are involved. While it is possible for a class to work on two related units at the same time, in many classes the students progress better with just one.

The amount of time spent each week working on an USMES challenge is crucial to a successful resolution of the problem. Each challenge is designed so that the various investigations will take from thirty to forty-five hours, depending on the age of the children, before some solution to the problem is found and some action is taken on the results of the investigations. Unless sessions are held at least two or three times a week, it is difficult for the children to maintain their interest and momentum and to become involved intensively with the challenge. The length of each session depends upon the age level of the children and the nature of the challenge. For example, children in the primary grades may proceed better by working on the challenge more frequently for shorter periods of time, perhaps fifteen to twenty minutes, while older children may proceed better by working less frequently for much longer periods of time.

Student interest and the overall accomplishments of the class in finding and implementing solutions to the challenge indicate when the class's general participation in unit activities should end. (Premature discontinuance of work on a specific challenge is often due more to waning interest on the part of the teacher than to that of the students.) However, some students may continue work on a voluntary basis on one problem, while the others begin to identify possible approaches to another USMES challenge.

Importance of the Challenge

Although individual (or group) discovery and student initiation of investigations is the process in USMES units, this does not imply the constant encouragement of random activity. Random activity has an important place in children's learning, and opportunities for it should be made available at various times. During USMES activities, however, it is believed that children learn to solve real problems only when their efforts are focused on finding some solution to the real and practical problem presented in the USMES challenge. It has been found that students are motivated to overcome many difficulties and frustrations in their efforts to achieve the goal of effecting some change or at least of providing some useful information to others. Because the children's commitment to finding a solution to the challenge is one of the keys to successful USMES work, it is extremely important that the challenge be introduced so that it is accepted by the class as an important problem to which they are willing to devote a considerable amount of time.

The challenge not only motivates the children by stating the problem but also provides them with a criterion for judging their results. This criterion--if it works, it's right (or if it helps us find an answer to our problem, it's

Role of the Teacher

a good thing to do)--gives the children's ideas and results a meaning within the context of their goal. Many teachers have found this concept to be a valuable strategy that not only allows the teacher to respond positively to all of the children's ideas but also helps the children themselves to judge the value of their efforts.

With all of the above in mind, it can be said that the teacher's responsibility in the USMES strategy for open classroom activities is as follows:

1. Introduce the challenge in a meaningful way that not only allows the children to relate it to their particular situation but also opens up various avenues of approach.

2. Act as a coordinator and collaborator. Assist, not direct, individuals or groups of students as they investigate different aspects of the problem.

3. Hold USMES sessions at least two or three times a week so that the children have a chance to become involved in the challenge and carry out comprehensive investigations.

4. Provide the tools and supplies necessary for initial hands-on work in the classroom or make arrangements for the children to work in the Design Lab.

5. Be patient in letting the children make their own mistakes and find their own way. Offer assistance or point out sources of help for specific information (such as the "How To" Cards) only when the children become frustrated in their approach to the problem. Conduct skill sessions as necessary.

6. Provide frequent opportunities for group reports and student exchanges of ideas in class discussions. In most cases, students will, by their own critical examination of the procedures they have used, improve or set new directions in their investigations.

7. If necessary, ask appropriate questions to stimulate the students' thinking so that they will make more extensive and comprehensive investigations or analyses of their data.

8. Make sure that a sufficient number of students (usually ten to twelve) are working on the challenge so that activities do not become fragmented or stall.

Student success in USMES unit activities is indicated by the progress they make in finding some solution to the challenge, not by following a particular line of investigation nor by obtaining specified results. The teacher's role in the USMES strategy is to provide a classroom atmosphere in which all students can, in their own way, search out some solution to the challenge.

USMES in the Total School Program

Today many leading educators feel that real problem solving (under different names) is an important skill to be learned. In this mode of learning particular emphasis is placed on developing skills to deal with real problems rather than the skills needed to obtain "correct" answers to contrived problems. Because of this and because of the interdisciplinary nature of both the problems and the resultant investigations, USMES is ideal for use as an important part of the elementary school program. Much of the time normally spent in the class on the traditional approaches to math, science, social science, and language arts skills can be safely assigned to USMES activities. In fact, as much as one-fourth to one-third of the total school program might be allotted to work on USMES challenges. Teachers who have worked with USMES for several years have each succeeding year successfully assigned to USMES activities the learning of a greater number of traditional skills. In addition, reports have indicated that students retain for a long time the skills and concepts learned and practiced during USMES activities. Therefore, the time normally spent in reinforcing required skills can be greatly reduced if these skills are learned and practiced in the context of real problem solving.

Because real problem-solving activities cannot possibly cover all the skills and concepts in the major subject areas, other curricula as well as other learning modes (such as "lecture method," "individual study topics," or programmed instruction) need to be used in conjunction with USMES in an optimal education program. However, the other instruction will be enhanced by the skills, motivation, and understanding provided by real problem solving, and, in some cases, work on an USMES challenge provides the context within which the skills and concepts of the major subject areas find application.

In order for real problem solving taught by USMES to have an optimal value in the school program, class time should be apportioned with reason and forethought, and the sequence of challenges investigated by students during their years in elementary school should involve them in a variety of skills and processes. Because all activities are initiated by students in response to the challenge, it is impossible to state unequivocally which activities will take place. However, it is possible to use the documentation of activities that have taken place in USMES trial classes to schedule instruction on the specific skills and processes required by the school system. Teachers can postpone the traditional way of teaching the skills that might come up in work on an USMES challenge until later in the year. At that time students can learn the required skills in the usual way if they have not already learned them during their USMES activities.

These basic skills, processes, and areas of study are listed in charts and lists contained in each Teacher Resource Book. A teacher can use these charts to decide on an overall allocation of class time between USMES and traditional learning in the major subject disciplines. Examples of individual skills and processes are also given so that the teacher can see beforehand which skills a student may encounter during the course of his investigations. These charts and lists may be found in section E.

Ways In Which USMES Differs From Other Curricula

As the foregoing indicates, USMES differs significantly from other curricula. Real problem solving develops the problem-solving ability of students and does it in a way (learning-by-doing) that leads to a full understanding of the process. Because of the following differences, some teacher preparation is necessary. Some teachers may have been introduced by other projects to several of the following new developments in education, but few teachers have integrated all of them into the new style of teaching and learning that real problem solving involves.

1. <u>New Area of Learning</u>--Real problem solving is a new area of learning, not just a new approach or a new content within an already-defined subject area. Although many subject-matter curricula

include something called problem solving, much of this problem solving involves contrived problems or fragments of a whole situation and does not require the cognitive skills needed for the investigation of real and practical problems. Learning the cognitive strategy required for real problem solving is different from other kinds of learning.

3. Interdisciplinary Education--Real problem solving integrates the disciplines in a natural way; there is no need to impose a multi-disciplinary structure. Solving real and practical problems requires the application of skills, concepts, and processes from many disciplines. The number and range of disciplines are unrestricted and the importance of each is demonstrated in working toward the solution of practical problems.

3. Student Planning--To learn the process of problem solving, the students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of the hypotheses and conclusions. In real problem-solving activities the teacher acts as a coordinator and collaborator, not as an authoritative source of answers.

4. Learning-by-Doing--Learning-by-doing, or discovery learning as it is sometimes called, comes about naturally in real problem solving since the problems tackled by each class have unique aspects; for example, different lunchrooms or pedestrian crossings have different problems associated with them and, consequently, unique solutions. The challenge, as defined in each situation, provides the focus for the children's hands-on learning experiences, such as collecting real data; constructing measuring instruments, scale models, test equipment, etc.; trying their suggested improvements; and (in some units) preparing reports and presentations of their findings for the proper authorities.

5. Learning Skills and Concepts as Needed--Skills and concepts are learned in real problem solving

as the need for them arises in the context of the work being done, rather than having a situation imposed by the teacher or the textbook being used. Teachers may direct this learning when the need for it arises, or students may search out information themselves from resources provided.

6. Group Work--Progress toward a solution to a real problem usually requires the efforts of groups of students, not just individual students working alone. Although some work may be done individually, the total group effort provides good opportunities for division of labor and exchange of ideas among the groups and individuals. The grouping is flexible and changes in order to meet the needs of the different stages of investigation.

7. Student Choice--Real problem solving offers classes the opportunity to work on problems that are real to them, not just to the adults who prepare the curriculum. In addition, students may choose to investigate particular aspects of the problem according to their interest. The variety of activities ensuing from the challenge allows each student to make some contribution towards the solution of the problem according to his or her ability and to learn specific skills at a time when he or she is ready for that particular intellectual structure.

B. General Papers on Manufacturing

1. OVERVIEW OF ACTIVITIES

Challenge:

Find the best way to produce in quantity an item that is needed.

Children often see a need for some item that many students could use in the classroom or the school. The class may wish to have enough math games so that all students in the class can use them. Students may see a need for aprons for those working in the Design Lab. Often such a need arises as a result of work on another USMES challenge such as Orientation, School Supplies, Classroom Design, or Designing for Human Proportions. For example, students working on a School Supplies challenge may decide to make some needed item to sell to others in the school. The class may decide to make their items for use in their own classroom or as a contribution to others in the school, or they may decide to sell their items to others. As a preliminary activity they may conduct an opinion survey to determine possible demand for the product.

Once a class has identified a needed item that they wish to produce in quantity, they may begin work on the challenge. The class may first discuss various aspects of making the product: creating product designs, testing and pricing possible materials, obtaining needed tools, and collecting measurement data to determine what sizes are needed. Students may then form groups to investigate these areas. These groups then present their findings to the class, using graphs, if needed, to support their recommendations.

Next, some of the students may figure out the steps involved in making the product by constructing prototypes of the product. While one group of students investigates costs of materials, other students may raise money to purchase the supplies or conduct surveys to determine customer preferences for design and price.

When students begin making the product, they work in any way they choose--individually, in groups, or on an assembly line. During a class discussion of the best way to work, the students may decide to time each step and organize an assembly line. Groups then form to set up the work area and assign jobs, using flow charts and diagrams if needed. Other groups may organize the finances, launch an advertising campaign, and investigate ways of distributing the product. Once production is in progress, the students may suggest changes in the assembly line to improve efficiency, to alleviate boredom, and to ensure quality control.

Unless orders were taken throughout production, or unless the product is to be contributed to the class or the school, the students organize a sale. This might entail setting up a sale area, designing a work schedule, and determining a sale price based on survey results and production costs. At the end of the sale, an evaluation of production and distribution procedures may be made. The students may also then decide what to do with the profits. The class may conduct surveys to find out whether there is still a demand for their product or to determine customer satisfaction. If the product was for their own use or was contributed to other classes, students may observe its use and make recommendations for future changes.

Work on the Manufacturing challenge may lead naturally to other USMES units--Advertising, Consumer Research, or School Supplies.

Although many of the activities in the Manufacturing unit may require skills and concepts new to the children, there is no need for preliminary work on these skills and concepts because the children can learn them when the need arises. In fact, children learn more quickly and easily when they see a need to learn. Consider counting: whereas children usually learn to count by rote, they can, through USMES, gain a better understanding of counting by learning or practicing it within real contexts. In working on Manufacturing, children also learn and practice graphing, measuring, working with decimals, and dividing. Although dividing seems necessary to compare fractions or ratios, primary children can make comparisons graphically; sets of data can also be compared graphically or by subtracting medians (half-way values). Furthermore, instead of using division to make scale drawings, younger children can convert their measurements to spaces on graph paper. Division may be introduced at the proper grade level during calculation of percentages, averages, or unit costs.

2. CLASSROOM STRATEGY FOR MANUFACTURING

Each USMES unit revolves around a challenge--a statement that says, "Solve this problem." The success or failure of the unit depends largely on (1) the relevance of the problem for the students and (2) the process by which they define and accept the challenge. If the children see the problem as a real one, they will be committed to finding a solution;

they will have a focus and purpose for their activities. If the students do not think the problem affects them, their attempts at finding solutions will likely be disjointed and cursory.

The challenge as stated in the Manufacturing resource book is general enough to apply to many situations. Students in different classes define and reword the challenge to fit their particular situation and thus arrive at a specific class challenge. "Find the best way to produce in quantity an item that is needed" has been restated by some classes in terms of a specific item such as a student directory to help new students or a tic-tac-toe game that is needed in class.

The Process of Introducing the Challenge

Given that a Manufacturing problem exists, how can a teacher, without being directive, help the students identify the challenge that they will work on as a group? There is no set method because of variations among teachers, classes and schools. However, USMES teachers have found that certain general techniques are helpful in introducing the Manufacturing challenge.

One such technique is to turn a spontaneous discussion of a recent event relating to items that are needed in the classroom or school toward the Manufacturing challenge. For example, the class may wish they had more of a particular game to use during free time, or they may observe that another class has a particular item that they also would like to have in quantity.

A class of sixth and seventh graders in East Lansing, Michigan, recognized a need in their classroom for a quantity of three-dimensional tic-tac-toe games. Only one of these popular games was available to 110 students, and during their math recreation time, the students would stampede to be the first to reach the game. Then there would be complaints and debates about who should play next and how long a game should last. Students frequently asked, "Why can't we have more games?" Therefore, when the teacher challenged the class--"Given a four-week period, what product could we manufacture to satisfy one of your needs?"--the students listed tic-tac-toe games among the possible products and voted to produce them.

Often, work on one challenge leads to another. For example, the Manufacturing challenge may arise from work on Designing for Human Proportions, Classroom Design, Orientation, Soft Drink Design, or Consumer Research.

An intermediate class in Portland, Oregon, was working on the School Supplies unit when they became involved in the Manufacturing challenge. The class had been operating a school store for two months; food and stationery were the main items for sale. After the class had decided to think about other craft items that they might make and sell in the store, one boy brought in a bead necklace he had made to show to the class. The class then decided that they would make necklaces in quantity to sell in their store.

In East Lansing, Michigan, a class of seventh graders working on the Orientation challenge, "Find ways to orient yourself and/or others to new school situations," came up with the idea of posting a list of names of new students. This led to the idea that student directories should be published and sold to the entire school, and the class became involved in the Manufacturing challenge.

When children encounter a problem that leads to a related USMES challenge, one group of children may begin work on the second challenge while the rest of the class continues with the first challenge. However, there should be at least ten to twelve students working on any one challenge; otherwise, the children's work may be fragmented or superficial or may break down completely.

Sometimes the discussion of a broad problem may encompass the challenges of several related units. For example, a discussion of problems in the classroom may lead to Classroom Design, Manufacturing, Classroom Management, or School Supplies. If the discussion concerns raising money for a class field trip, this could lead to the Manufacturing, Soft Drink Design, or Growing Plants challenges.

An experienced USMES teacher is usually willing to have the children work on any one of the several challenges that may arise during the discussion of a broad problem. While this approach gives the children the opportunity to select the challenge they are most interested in investigating, it does place on the teacher the additional responsibility of being prepared to act as a resource person for whichever challenge is chosen.

Classroom experience has shown that children's progress on the Manufacturing challenge may be poor if the teacher and students do not reach a common understanding of what the challenge is before beginning work on it. This is particularly true if the students can see no real need for the product being manufactured. Having no shared focus for their work, the children will lack the motivation inherent in working together to solve a real problem. As a result, they may quickly lose interest.

When a class decides to work on a Manufacturing challenge, they may do so for two reasons. They may wish to make some item that is needed by the class. In this case, deciding what item to manufacture is fairly straightforward. However, a class may decide to work on the Manufacturing challenge in order to make money for some other purpose. In this case, it may be difficult for the class to decide on a specific item to produce. They may decide to manufacture two or more items rather than choosing one specific item. The class may then break down into small groups, each of which is making its own item. Because only a small number of students can then work on any one item, the class will not have the opportunity to explore different methods (such as an assembly line) of making an item and will not be able to find the best way to produce an item in quantity. In addition, the class may become fragmented in their activities and lose interest and enthusiasm in the challenge.

One intermediate class could not decide on one specific item to manufacture and chose to work on four items: candles, pillows, jewelry (beads), and T-shirts. After discussing the materials needed for each item, the class formed two groups: Beads and Candles. The Candles Group made little progress for some time while the members of the Beads Group worked individually to string beads for necklaces. After the beads were completed and sold, only eight students were still interested in making candles. The remainder of the class decided to work on wood carvings, terrariums, and paper flowers, with each person working individually. Although the Candle

Group divided the labor into five parts, none of the other groups considered alternative ways of making their product.

To avoid this problem, the teacher must ensure that the class as a whole agrees on one item before beginning work on the challenge. The students may suggest many different possible products; they must then use some method to reduce the number of suggested products to one item.

Children usually solve this problem by one of two methods or by some combination of the two methods. The class may use elimination voting to narrow a large list of possibilities to ten or fifteen items and then discuss each one of the possible items in detail, assessing the feasibility of making it and determining the tools and materials needed. Alternatively, they may design an opinion survey listing many items, administer it to other classes in the school, and subsequently analyze the top items in more detail. They may also reduce the number of possibilities before conducting the survey. Finally they vote to determine the one item that will best satisfy the members of the class. (A system of rating choices often simplifies this task.)

In one fifth-grade class, the challenge was to manufacture some item to sell so that the class could earn money for a camping trip. After discussing many possible products, the class decided on five possible items: T-shirts, leather wristbands, wooden plaques, dough plaques, and marble men. The class then decided to survey a representative part of the school to find out which of the five items the other students would be willing to buy. They also included possible prices for each item in order to find out how much students would be willing to pay for each item. After giving the survey and tallying the results, the class found that T-shirts were the preferred item and therefore decided to make T-shirts.

One sixth-grade class with no specific needs in mind began with a list of thirty-eight items that they felt might be useful to them or someone else. When the class discussed how they might vote on the items, one student pointed out that if each person chose one *item then everyone would vote for his or her own idea and no clear-cut choice would emerge from the voting. After discussing several other possibilities, the class decided that each person should choose five items with first choice counting as five points, second choice as four points, etc. The tallying group then counted up the votes using this procedure and presented the top eight choices to the class for discussion.*

Initial Work on the Challenge

Once a class has chosen a specific item to manufacture, the students, if they haven't already done so, list various aspects of producing the item such as the materials and tools needed, their cost and availability, the design of the item, and the quantity of items they wish to produce. They may decide they need to design and construct a prototype of their item. In addition, the class may need to measure other students in order to find out what size (or sizes) to make their item.

After a fifth-grade class had decided to manufacture backpacks, the class discussed how they would do this. They looked at a backpack belonging to one of the students and, after trying it on the teacher, two fifth-grade students, and one first-grade student, decided to use it as their pattern but to make the straps adjustable. The class then listed criteria for choosing their material with the most important factors being strength, durability, ease of sewing, low price, and washability.

After one class decided to make T-shirts, they listed areas that they felt needed to be investigated: price of T-shirts and decals, permission from the principal, letter to parents asking to borrow irons, layout of the order form, and setting up the manufacturing process.

Next, the children set priorities for the tasks they consider necessary. Most of these tasks are carried out by small groups of children. It is important that priorities be set so that some groups do not become stalled in their progress because others have not completed their work. For example, a group formed to determine the sales price of the item would probably have little work to do until the prototype design has been selected and possible materials determined.

As various groups complete their work, their members join other groups or form new groups to work on additional tasks.

In one sixth-grade class, four groups worked in assembly line fashion to make stained glass candle holders while two other groups worked on developing new products and a third group worked on advertising. After several weeks the class held a discussion of this grouping and decided that the members of the two development groups should join the assembly line groups in order that production be more efficient. Later, when students in the first assembly line group finished their job, they joined the fourth assembly line group in painting the tile grouting. Several sessions later, the groups had reformed with some students working in the group that needed the most help on a particular day.

Refocusing on the Challenge

As a class works on a Manufacturing challenge, the children's attention should, from time to time, be refocused on that challenge so that they do not lose sight of their overall goal. Refocusing is particularly important with younger children because they have a shorter attention span. Teachers find it helpful to hold periodic class discussions that include group reports. Such sessions help the students review what they have accomplished and what they still need to do in order to find some solutions to the problem. These discussions also provide an opportunity for students to participate both in evaluating their own work and in exchanging ideas with their classmates.

One fifth-grade class involved in manufacturing backpacks spent two days testing an assembly line method for making the packs. The class then met as a group to discuss whether this was the best way to produce the backpacks, and to examine the advantages and disadvantages of their method. They talked about whether each student should work at only one job or *be allowed to trade jobs with other students. The class found that trading jobs relieved boredom and gave them the opportunity to learn new skills but also caused some confusion and slowed down the mass production process. The class consensus was that trading jobs resulted in a better product. A subsequent statement that some backpacks were incorrectly made led to a discussion of quality control.*

Work done by students on the Manufacturing challenge can be hampered by a premature focus on mass production as the only way to produce an item in quantity. Rather than having the children realize the need for mass production by trying other methods first, some classes have discussed the advantages of mass production too early in the unit. The students then cannot discover for themselves the need for pooling forces and organizing an assembly line. On the other hand, if the students do not discuss the "best buy" to produce their item, or if the teacher does not suggest that the students compare different ways of making the product, the students may work individually the whole time without considering other alternatives. Both problems can be avoided if a discussion to determine the best way to produce an item in quantity is held after the students have tried whatever method they first suggested.

Resources for Work on the Challenge

When children try to decide on solutions before collecting and analyzing enough data or encounter difficulties during their investigations, an USMES teacher helps out. Instead of giving answers or suggesting specific procedures, the teacher asks open-ended questions that stimulate the students to think more comprehensively and creatively about their work. For example, instead of telling the class that someone should be in charge of checking the quality of finished products, the teacher might ask, "How can you be sure that you aren't selling a defective product to a customer?" To help the children be organized in taking and filling orders, the teacher, rather than giving the class an order form to use, might ask, "How are you going to keep track of all the people who want your product? How will you know what size is right for a customer?" Other examples of non-directive, thought-provoking questions are given at the end of this section.

The teacher may also refer students to the "How To" Cards for information about specific skills such as drawing graphs.

or conducting a survey. If many students, or even the entire class, need help in particular areas, such as using fractions, the teacher should conduct skill sessions as these needs arise. (Background Papers provide teachers with additional information on general topics applicable to most challenges and on specific problems such as how to design an opinion survey which are often applicable to the Manufacturing challenge.)

USMES teachers can also assist students by making it possible for them to carry out tasks involving hands-on activities. During work on the Manufacturing challenge, children may need to visit stores in order to purchase necessary materials and supplies. The teacher can help by supervising such trips. If the children's tasks require them to design and construct items, the teacher should make sure that they have access to a Design Lab. Any collection of tools and materials kept in a central location (in part of the classroom, on a portable cart, or in a separate room) can be called a Design Lab. A more detailed account of the Design Lab may be found in the USMES Guide.

Valuable as it is, a Design Lab is not necessary to begin work on the Manufacturing challenge. To carry out construction activities in schools without Design Labs, students may scrounge or borrow tools and supplies from parents, local businesses, or other members of the community.

A fifth-grade class in Marina, California produced leather wristbands in their classroom without using the facilities of the Design Lab. The teacher was able to borrow leather tools from his friends. After each student had made his/her own wristband, the class decided that an assembly line would help speed up production for the wristbands they were selling to other students. The class identified the different jobs which needed to be done, and, after timing the steps and determining the number of people needed, each job was assigned to a particular location in the classroom.

Seventh graders in East Lansing, Michigan, were able to manufacture student directories to help newcomers at school, without the use of a Design Lab. They revised the grids used by the testing service to make forms to collect information. After hiring mothers *to type stencils for each page of the directory, several students organized an assembly line in the cafeteria, with tables set up for collating, stapling, and inspecting.*

The extent to which any Design Lab is used varies with different classes because the children themselves determine the direction of the investigations.

Culminating Activities

Students usually continue to work on the Manufacturing challenge until they have successfully manufactured the needed item. If they are making the item to fulfill a class need, they may then evaluate the quality of their item and discuss what they might do differently if they were to make that item again. If students in other classes appear to need or want their product, the class may decide to continue production of their item for sale to other students. The class may decide that they will conduct an opinion survey to see what the demand is for their item before resuming production.

If students have been producing an item to sell to others, their next step after completing production is to set up some system for selling their item. They may decide to run a store during certain hours of the day (recess, before school), or they may already have taken orders for their product. In connection with the sale of their item, students often organize an advertising campaign using posters, announcements over the intercom, or flyers.

When the students have sold all of the items produced, they may evaluate their work by conducting an opinion survey of customers to see whether they are satisfied with the item. They may also evaluate their manufacturing process in terms of its efficiency. The students may feel that the response to their item has been so positive that it might be worthwhile to resume production. They may therefore conduct a survey of others in the school to see if there is still a demand for the product, or they may write letters describing their item to storekeepers and businessmen who may be interested in selling the item. If the class decides to resume production, they may evaluate their product and procedure and implement changes that will improve their product.

One fifth-grade class, after using all their available leather to produce wristbands that had been ordered, discussed whether they should continue manufacturing the wristbands. Because some members of the class reported that other students had asked whether the class would be ready to take orders again soon, and because another student felt that the fourth-grade students had not had an opportunity to order the wristbands, the class decided to resume production. They next considered changes that would make production of the wristbands easier and more profitable. They decided to use leather strips rather than leather scraps as they had done previously in order to reduce cutting time, and to make size models for cutting out wristbands.

A class making three-dimensional tic-tac-toe games planned to make enough for their class and sell only ten of them. But student demand for the games was so great that the class decided to sell all thirty-six of the games. After completing production and sale of the games, the class filled out a written evaluation of their manufacturing procedure, and then met to discuss what they would do with their (unexpected) profit.

3. USE OF MANUFACTURING IN THE PRIMARY GRADES

Primary children can work successfully on the Manufacturing challenge although their level of expertise and sophistication may be different from that of older children. They will be able to conduct opinion surveys, take measurements, construct bar graphs and histograms, and design and produce simple items, utilizing mass production and quality control.

Because primary-age children are chiefly interested in their own experiences, a teacher may decide to wait to introduce the challenge until some incident occurs that relates directly to the children's own experiences. A child may notice that everyone in the class wishes to use a particular game during recess or free time but that only one such game is available, or the class as a whole may need folders for their work or boxes for their pencils and crayons.

Once the children are involved in the challenge, the primary teacher may find that several short sessions every day are preferable to two or three extended periods each week. This helps to prevent the children's losing interest because of long periods of time between sessions.

Primary children are usually quite realistic about their ability to make a particular item and do not choose to produce an item that appears too difficult or complex in construction. If the item suggested appears to be too difficult, a primary teacher can make the children aware of possible problems in making the item by asking questions such as, "What steps would be involved in making this?" or "Could you tell me how to make this?"

Once a primary class has decided to make an item in quantity, each child may make a design; the class may then discuss which design they wish to use. One primary class decided to make folders for use in their classroom. After examining a folder that had been used the previous year, each child drew and constructed a design for a folder. The class next discussed the designs and chose one of them to be made in quantity.

The children may need assistance in obtaining information about the materials they need and in purchasing them. Many primary children are capable of calling various stores and doing comparison shopping so that they can get the best buy for their money. The teacher can help out by making sure the children think about what they will say before they actually telephone. Sometimes it is helpful for a child to write down what he or she plans to say before calling.

Once the children have obtained the necessary materials and are ready to begin production, they discuss the steps involved in making their item. The teacher may then ask them what would be the best way to handle these jobs and the class may decide to work individually or in groups.

The teacher should be careful not to impose higher standards of quality on the product or process than the children wish to have. It may appear that the children waste time and materials, make a mess, and construct their item sloppily, but the children will be aware of this, too. The teacher may bring these things to the attention of the class by asking questions such as, "How many more of these will we be able to make with the materials available?" When one primary class saw that workmanship was poor and that materials were being wasted, they appointed a checker to inspect the finished items and formulated rules in order to improve the quality of the work.

In the course of working on the Manufacturing unit, the children gain important language arts skills as they communicate their ideas in discussions, telephone conversations, letters, and posters; listen to the ideas of others; and read catalogs and books for information and directions. They learn to organize their ideas as they list the things that are involved in making their item and as they break the manufacturing process into a series of steps. As they write letters and make posters, they see the need for legibility and correct spelling.

Manufacturing also provides many opportunities for children to learn and practice counting and computational skills. In one primary class the children counted and recorded how many children in other classes wished to buy their folders so that they might make an adequate supply. Children often need to find out the cost per unit of their materials and supplies in order to set a price for their item. Since this may involve division, the teacher may wish to give a skill session on slope diagrams so that the children can find the cost per unit without dividing. Slope diagrams may also be used to compare unit costs for different brands of the same item when they need to decide which brand is the best buy. In addition to computation involving costs and number of items needed, the children may need to count votes or compute the responses on an opinion survey.

Primary children may also become involved in simple measurements while working on the Manufacturing challenge. In many cases the class may need to decide on a size for their item and on some method of ensuring that all items are the same size. The children may use pieces of string or cardboard strips of equal lengths to perform their measurements, or, if they need to be more exact, they may learn how to use a ruler or meter stick. Later, the class may construct patterns to trace in making their item. Children may also want to know how long it takes for one item to be made. The teacher may wish to give a skill session on the use of a stopwatch if the children have trouble using one.

Tallying and graphing are easily introduced to primary children when they see the need to organize and make pictures of their information. They may wish to find out and show which item or design is preferred by their class or some other class as they begin to work on the Manufacturing challenge. One class conducted a survey that included fifteen sample items; students in other classes were to pick the items that they preferred. After the survey was taken and the results tallied, the class depicted the data on bar graphs. Bar graphs and bar graph histograms may be made in a variety of ways by primary children to enable them to make a clear connection between the data and the picture. Children may use colored squares of paper or wooden blocks representing each child and paste or stack them in columns representing different preferences. The tallest column will then show the most preferred item. Many times primary children do not realize clearly that one item is strongly preferred over another until they can see such a visual representation of the numbers.

While working on the Manufacturing challenge, the children may utilize the Design Lab to produce their item. Experience in many schools has shown that primary children are able to work in the Design Lab and can use most hand and power tools, although care should be taken to instruct and supervise the students in their use. Primary children working on USMES challenges have designed and built planters, macrame holders, tables, and animal boxes from Tri-Wall and lumber in the Design Lab.

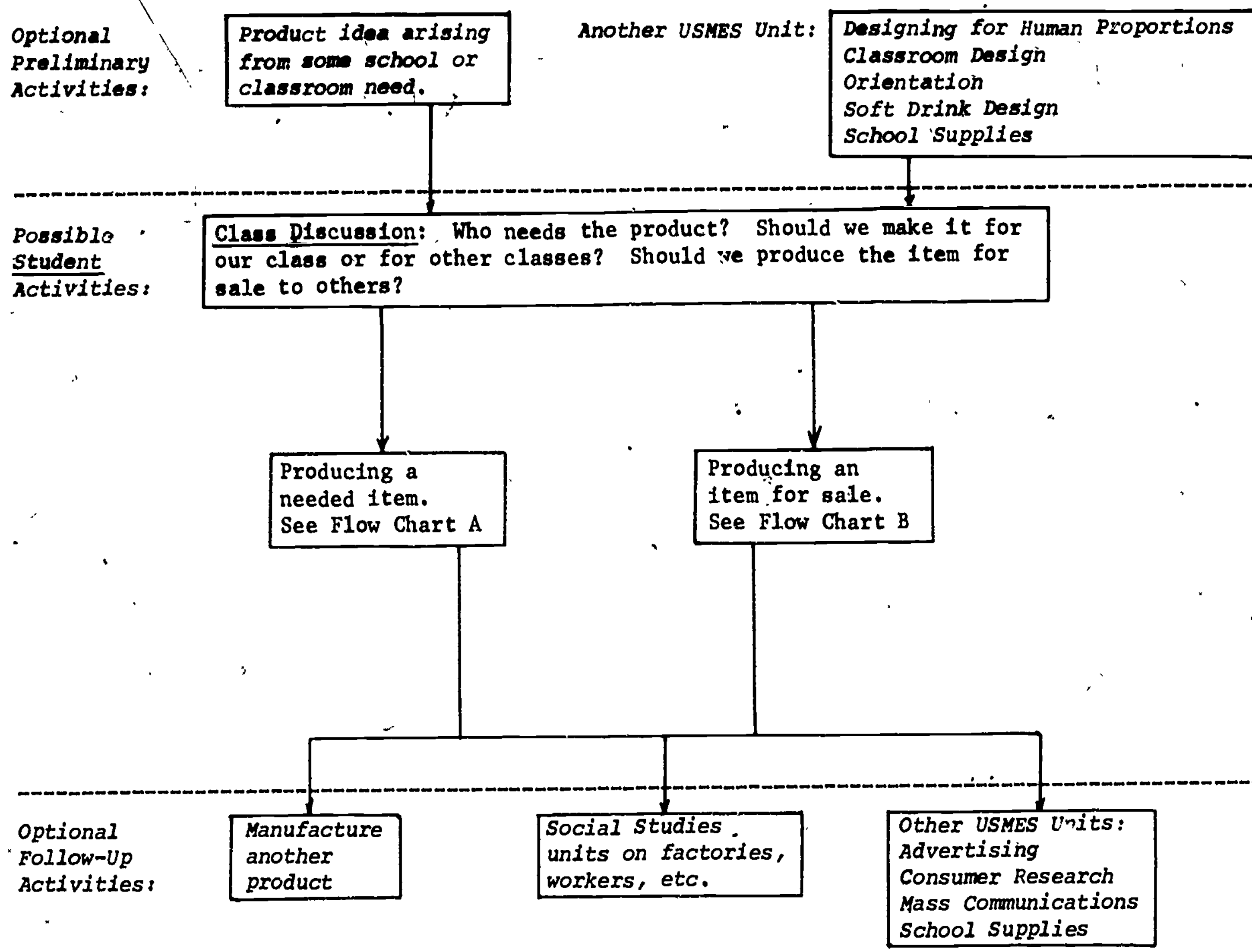
4. FLOW CHART

The following flow charts present some of the student activities--discussions, observations, calculations, constructions--that may occur during work on the Manufacturing challenge. Because each class will choose its own approach to the challenge, the sequence of events given here represent only a few of the many possible variations. Furthermore, no one class is expected to undertake all the activities listed; a class usually works on just one of the aspects represented by the several charts.

In working on the Manufacturing challenge, a class must decide whether they wish to produce their item primarily to fulfill a school or classroom need, either for themselves or other classes, or whether they wish to produce the item to sell to others. Once this decision is made, possible activities may differ. For this reason, the Manufacturing Flow Chart has been divided into two parts: Flow Chart A, Producing a Needed Item, and Flow Chart B, Producing an Item for Sale.

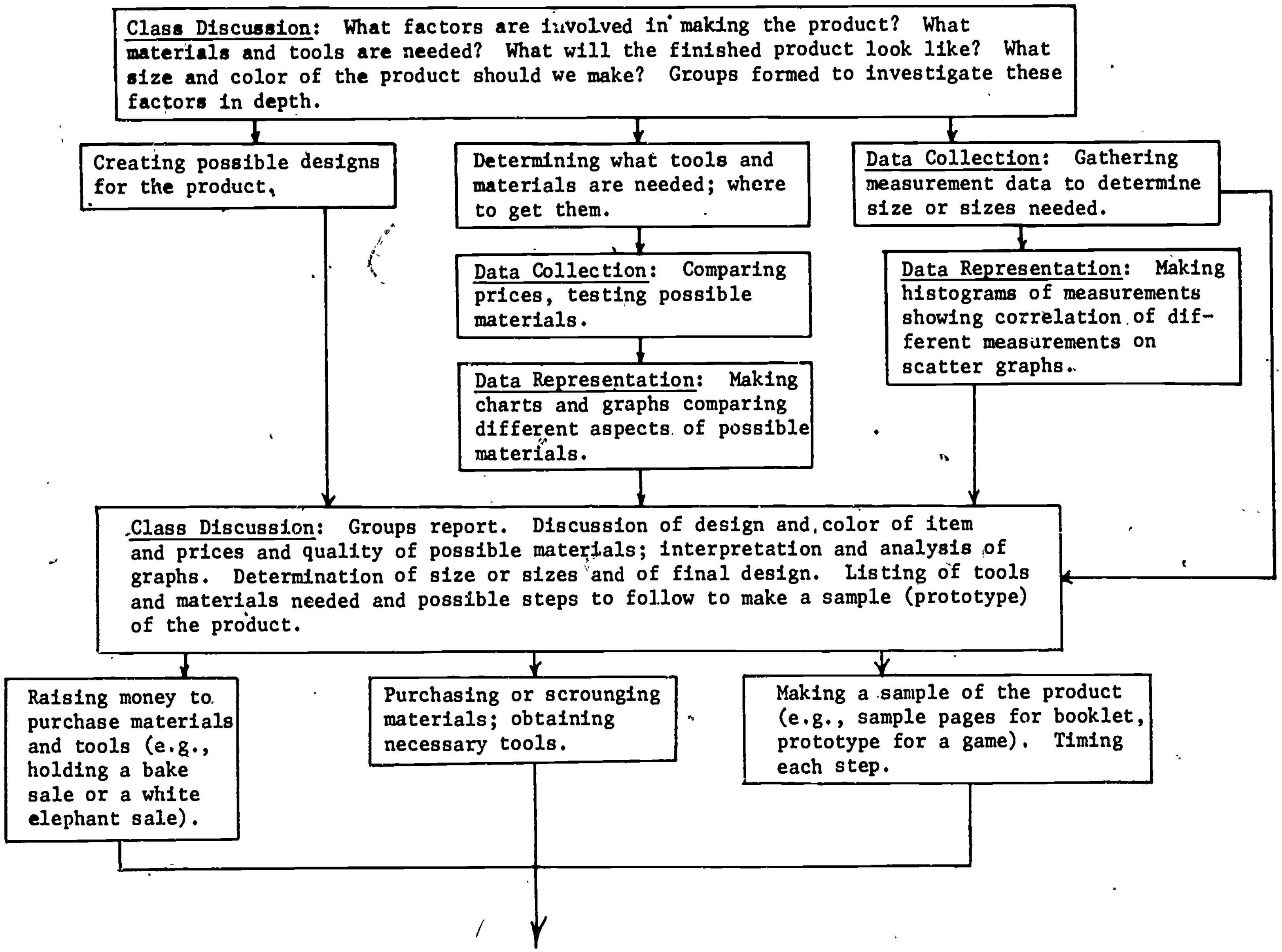
These flow charts are not lesson plans and should not be used as such. They instead illustrate how comprehensive investigations evolve from the students' discussion of the Manufacturing problem.

Challenge: Find the best way to produce in quantity an item that is needed.



FLOW CHART A

Producing a Needed Item



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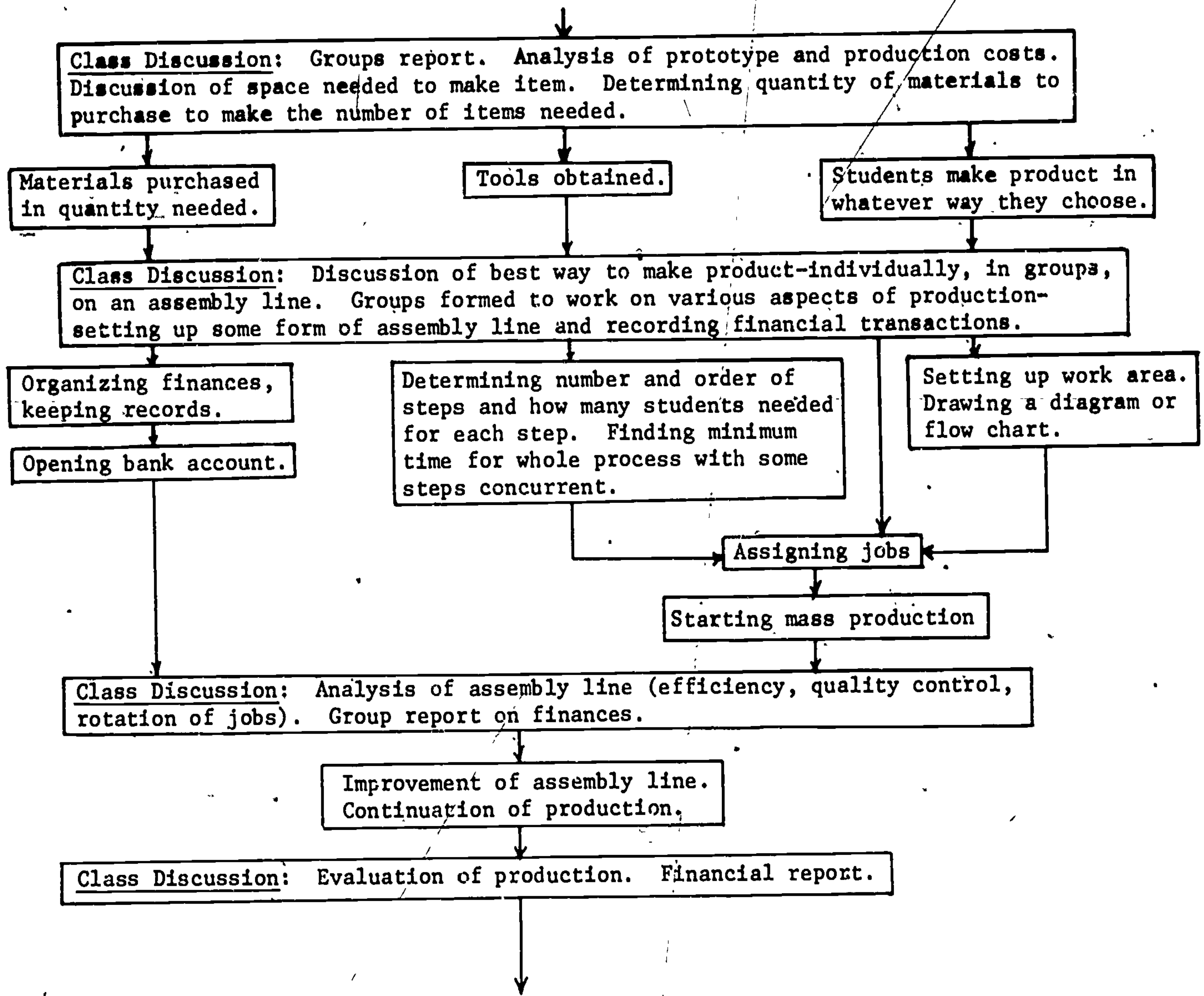

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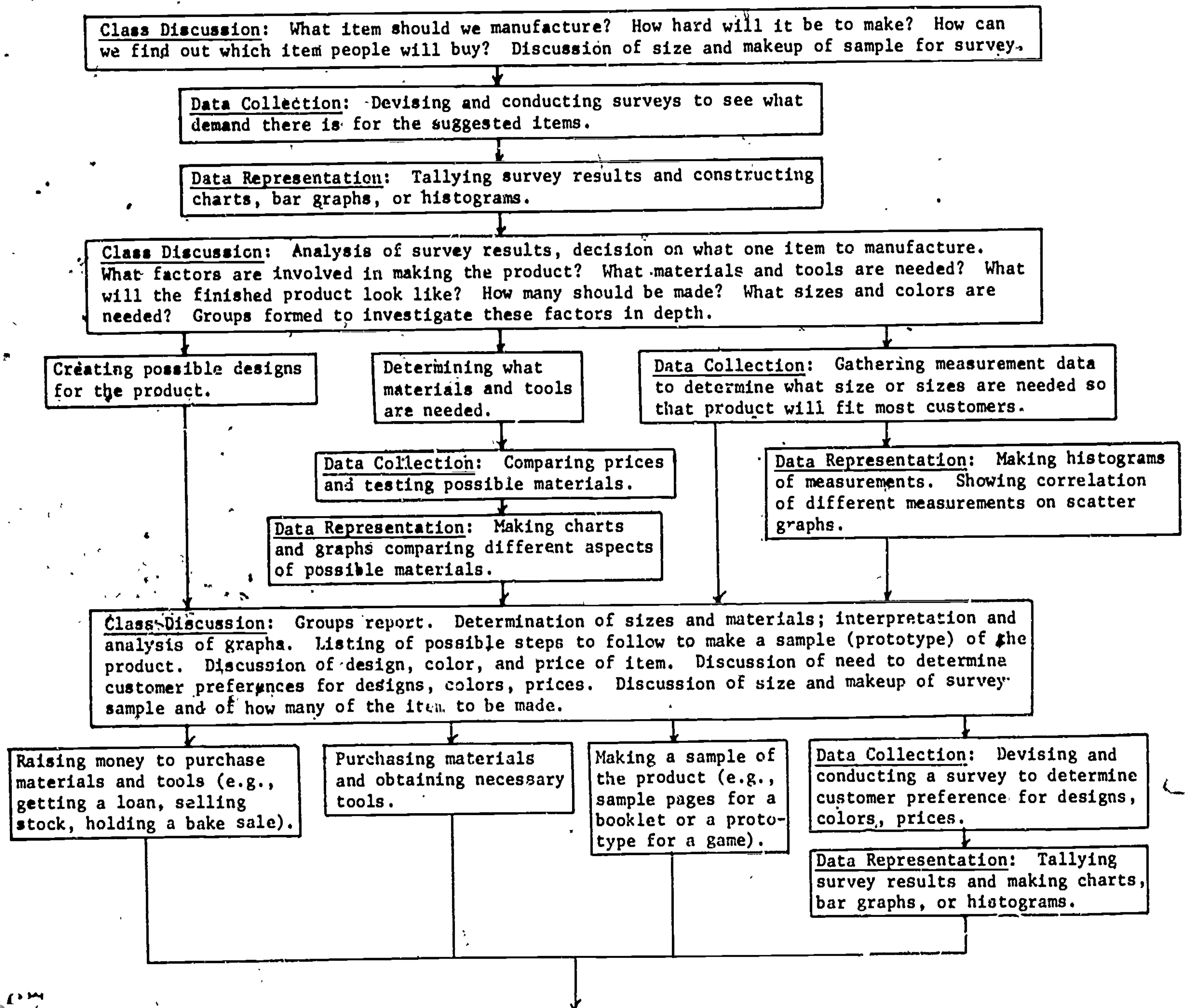
FLOW CHART B

Producing an Item for Sale



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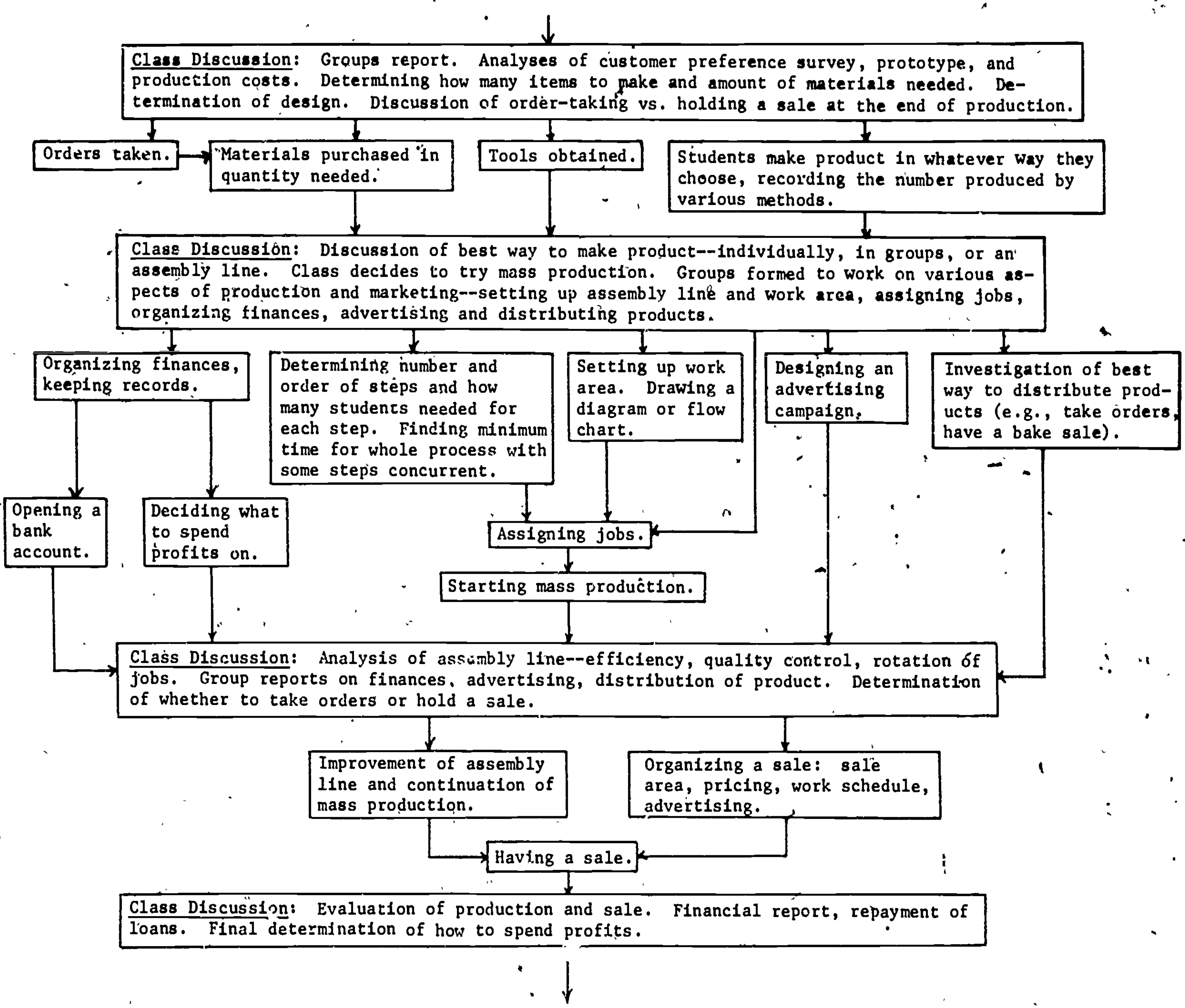

(Return to main flow chart.)

5. A COMPOSITE LOG*

This hypothetical account of an intermediate-level class describes many of the activities and discussions mentioned in the flow chart. The composite log shows only one of the many progressions of events that might develop as a class investigates the Manufacturing challenge. Documented events from actual classes are italicized and set apart from the text.

When school has been in session for several weeks, a student in the class remarks that he wishes the class had more then two geoboards because many children in the class are interested in using them and one is never available when he wants to use it. Other students in the class agree that there is a need for more geoboards. The teacher asks if they would like to make enough geoboards so that everyone in class could have one. All the students respond eagerly to this idea; some wish to use them in doing math problems on area and perimeter; others want to use them for making designs during their free time.

The teacher asks how they might make geoboards. One student says that wood must be cut to size and nails then put in each board. Another student adds that the wood should probably be sanded so that students do not get splinters from the geoboards. The teacher asks if wood is the only material that they might use for the geoboards. The class then suggests that Masonite or Tri-Wall might also be used. One student feels that the geoboards will be safer, more durable, and have a better appearance if they are painted, since the paint will protect the surface of the boards.

The discussion then turns to whether the geoboards should be made just like the ones already in the classroom. One student says that in the school she came from the geoboards were different because they had only five rows of nails, with much wider spaces between the nails. In deciding what kind of geoboards to make, many questions come up, such as--

How big should the boards be?
How thick should the board be?
How many nails should we use?
What kind of nails should we use?
What about the spacing of the nails?

One student remaks, "We need to make up some designs."

Another student says, "We need to find out what materials we can use." The class decides to break into four groups to investigate materials for the base, kinds of nails, types of paint, and possible designs.

A fifth-grade class manufacturing wristbands decided that their first steps in making the wristbands should be to find out what materials and tools were needed

*Written by USMES staff

and to create a design for the wristbands. Among the suggestions offered during class discussion were the following:

1. *There should be two different designs, a sports design for boys and a flower design for girls.*

2. *The class should take a survey of what designs people like.*

3. *Snaps or buckles should be used as fasteners.*

(See log by William Kucher.)

At the next class session, the group working on materials for the base decides to go to the industrial arts room to see if they can find scrap pieces of Tri-Wall, Masonite, and different kinds of wood. The industrial arts teacher shows them pieces of pine and plywood and suggests that either of these would be quite suitable for geoboards. The group notes that both come in varying thicknesses and that the pine comes in boards of varying widths whereas the plywood comes in large sheets.

After discussing the materials that are available in terms of how geoboards are used, the group decides that the main qualities that the geoboard base should have are strength and durability, low price, a surface that does not splinter easily, and a surface that will hold nails well. They offer several suggestions for testing the scrap samples:

1. observe samples to see if they are warped

2. pound each sample with a hammer to see how strong and hard the surface is

3. pound nails in and try pulling them out to test nail-holding ability

4. saw the samples to see if they break or splinter

5. drop weights on the samples to see if they crack or break

Material	Sizes Available	Prices	Test 1 Warped?	Test 2 Surface Broken?	Test 3 Holds Nails Well?	Test 4 Splinters when Sawed?	Test 5 Cracks or breaks under weight?
TRIWALL	4'x6' 4'x8' (all 1/2" thick)	$5.45 $7.45	Yes	Yes	No	No	No
MASONITE	4'x8' 1/4" thick	$4.49	NO	NO	YES	NO	NO
PLYWOOD	4'x8' 1/2" thick 3/8" thick 1/4" thick	 $12.99 $10.99 $8.29	NO	NO	YES	YES	NO
PINE	12" (11 1/4") wide 10" (9 1/4") wide	1.25/ft (32 sq ft = $40.00) 1.05/ft (32 sq ft = $33.60)	YES	YES	YES	NO	NO

Figure B5-1

The group then decides to try these tests on each of the samples. In addition they call several lumber companies to get prices on the wood and masonite. (The industrial arts teacher has informed them that the Tri-Wall costs $7.45 for a 4' x 8' sheet.)

They record their results on a chart showing the different materials considered, the information gathered, and the tests conducted. (See Figure B5-1.) The group decides that although they have recorded the results for Test 5, they should not use these results in deciding which material to use because they did not use a heavy enough weight to affect any of the materials.

The Nails Group begins their investigation by looking at the nails in one of the two geoboards already in the classroom. They note that they are made of brass, are about 3/4" long, and have a small rounded head. In discussing why this type of nail was used, they begin to list characteristics that nails for geoboards should have:

1. Nails should be the right length so they don't stick out bottom of board but are tall enough to put rubber bands on.

2. The head of the nail should be just right--if too big, it will get in the way of rubber bands; if too small, bands will slip off.

3. Nails should not rust.

4. Nails should stay in wood well.

The Nails Group then decides that they should visit the local hardware store to look at various nails available and to obtain their prices before recommending a type of nail to the class. The Nails Group returns from the hardware store with prices for several different types of nails that they feel might be suitable but cannot come to a decision on which nail might be best. The group makes up a chart with a picture of each nail and its price to show the rest of the class.

After calling the paint store, the Paint Group lists several kinds of paint and the good and bad points of each:

Oil base--durable, slow drying, messy, doesn't wash off with water

Flat water base--fast drying, washes off with water, wears off and dirties easily

Shiny water base--washes off with water, dries fairly rapidly, durable

From Pamela Johnson's and Stanley Myk's class, grades 6-7.

They plan to recommend the shiny water base paint to the class on the basis of their information from the paint store.

During their discussion, several questions come up which cannot be resolved:

What color paint should we use?
How much paint do we need?
Is one brand better than another? How can we tell?
What price should we pay for paint?
Should we scrounge paint from people who have leftover paint they don't need?

The group decides to ask these questions during the next class discussion.

The Design Group first lists what they wish to do:

1. Observe and measure geoboard in the classroom

2. Look in catalogues at other geoboards

3. Draw up possible designs for geoboards

While some members of the group measure and make a scale drawing of the geoboard in the classroom, others go to the library to look through catalogues or draw up their own designs. After much research, discussion, and drawing, the Design Group has four different designs to present to the class.

In one sixth-grade class manufacturing aprons, all of the students drew a design for the apron. A committee then went through the designs and chose four that they felt were most representative of those submitted. The class voted on the four designs and picked one to manufacture. (See log by Barbara Dahlberg.)

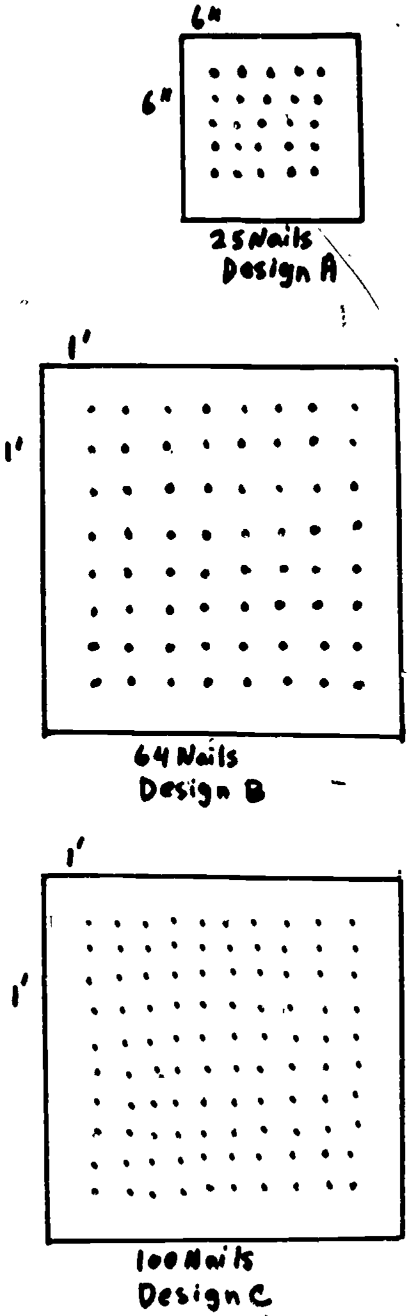

Figure B5-2

When the class meets as a group again, they begin by trying to decide on one design. They first vote on the four designs presented to them by the Design Group with the result that the votes are split evenly among the three designs pictured in Figure B5-2.

One student asks, "What do we do now?"

The teacher replies, "You still need to decide which design to pick. When you voted, what did you vote for?"

The student answers, "The design we liked best."

The teacher asks, "What about the design you liked second best?"

Another student responds, "We didn't vote for that--but we could! How would that help though?"

One girl replies, "Let's give points to the designs depending on how well we liked them." She goes to the board and writes: Best design -- 2 points
Second best -- 1 point

The class then decides to vote again, this time to rate the best and second best designs. After the number of points are calculated, the results are as follows:

	Number of Points		
	2 Points (Best)	1 Point (Second best)	Total
Design A	18	9	27
Design B	20	12	32
Design C	18	7	25

One student states, "I'm glad Design B won because we can use it for chess and checkers, too."

Another responds, "That's why I voted for Design B."

A combination fourth- and fifth-grade class manufacturing bookmarks had to decide between six different shapes. After a skill session on rating the choices, the class voted by assigning points ranging from six for their first choice to one for their sixth choice of shapes. When the votes were tallied, the three most popular shapes were a rectangular shape, a square shape, and a diamond shape. After much *discussion, the class decided that the rectangular shape, which received the highest vote, should be the only pattern used. (From log by Marlene Johnson.)*

The class next considers which material should be used as the base for the geoboard. After the Base Group shows and explains their chart, one boy notices that the winning design was one foot by one foot but that pine does not come in one-foot widths. The class then decides that plywood would be the best material because it will be easy to cut one foot-square boards from it and because Masonite is too thin and Tri-Wall will not hold nails well. The Base Group recommends a thickness of 3/8" and a size of 2' x 4', (small enough for the students to handle easily) which the class accepts.

The Nails Group then presents their chart on nails. After the class has looked at the different nails, they decide a moderately priced nail similar to that used in the present geoboards would be best. A member of the Base Group remarks that the industrial arts teacher told them that the nails should be about twice as long as the wood is thick, which would be 3/4" long (3/8" x 2). This is accepted by the class, but one girl remarks, "Now that we have decided on which type of nail and how long, we have to figure out how much nails for all the boards will cost."

The class also discusses the problem of where they will get the money for their geoboards. After several suggestions have been made, the teacher mentions that the PTA has a fund for school supplies and that if the students can present their need and costs to the PTA Board, then the PTA would probably cover the cost of materials for the geoboards. It is resolved by the class that a group be formed to work on costs of materials and on a presentation to the PTA.

When the class making aprons found they needed funds to buy fabric, a committee was formed to investigate the possibility of a loan. After listening to the report of the committee, their teacher granted the students a loan of $50.00. Since the students planned to sell their aprons to others in the school, they were able to repay the loan with profits obtained from the sale of the aprons. (See log by Barbara Dahlberg.)

The Paint Group first presents their choice of paint and then puts their list of questions on the board. Since many people in the class feel that scrounging the paint is a good idea, it is decided that the Paint Group should write a notice about bringing in unneeded paint to be read to other classes in the school. "If that does not get us enough paint, then we can think about buying some," one student comments. The Paint Group agrees to shelve the rest of their questions until they find out whether or not they will need to buy paint.

Another student wonders, "What do we do now? We have to wait to find out about the money and paint before we can begin to make our geoboards."

The teacher asks, "How are you actually going to make your geoboards?" A student suggests building a sample geoboard to find out, and several other students volunteer to help him find scraps of wood, nails, and paint and get the proper tools.

At the end of the discussion, the teacher asks for a volunteer to review what the class has decided so that everyone will know what to do.

STUDENT: The Cost Group has to figure out the cost of wood and other materials for the class, contact the PTA, and prepare a report to give to the PTA Board asking for the money we need. The Paint Group has to write a notice for other classes. The Sample Group has to get materials and tools together and make a sample geoboard.

Several sessions later the Sample Group reports to the class. The student who built the sample geoboard lists on the chalkboard the steps that he used in making the sample:

1. Measuring wood
2. Cutting wood
3. Sanding wood
4. Painting wood
5. Marking the grid for lines and nails
6. Putting in nails

He explains that, working alone, it took him about one and a half hours on two different days to make the geoboard and that painting the board was very time-consuming because he had to paint one coat, wait an hour, paint a second coat, and let the board dry overnight. Another student remarks that if each person makes their own geoboard, it will waste a lot of time since there are not enough saws, hammers, or paintbrushes for everyone to use one at the same time.

One student remarks, "We should have a bunch of people paint all of the geoboards."

Cost of Materials for Geoboards

Plywood: One 4'x8' sheet (3/8" thick) cut into four pieces $10.99

Nails: At 64 nails per board, need 2048 nails. One box costs $.45 and contains 200 nails. Need 11 boxes at $.45 per box $4.95

Paint: free

Rubber bands: Need 5 packages at $.59 a package $2.95

Total	$18.89
Tax (5%)	.95
Total including Tax	$19.84

Figure B5-3

"Yes," another responds, "we could have some people cutting the geoboards and others sanding the geoboards. Then making the geoboards would take less time."

The teacher asks the class if they are sure that this is the best way to make the geoboards. The class feels that making the geoboards assembly-line fashion would be best, because it would take less time than having each person working individually.

A student then comments, "We need to know how long each step takes. Then we can figure out how many people should be working on each step."

The Sample Group is delegated to make another sample geoboard with several people working on the sample while others time the steps and observe the process.

During the next few sessions each group works on its tasks. When the Cost Group has its report ready for the PTA, they ask for a class meeting to discuss the report before its presentation. The class approves of the report with a few minor changes; the Cost Group now eagerly awaits their scheduled meeting with the PTA Board. (See Figure B5-3 for the list of materials and costs made up by the Cost Group.)

A few days later the class meets again to hear reports. The Cost Group states that they have obtained the needed funds from the PTA and are now ready to buy materials. The Paint Group reports that they have scrounged more than enough paint. The Sample Group presents their list of steps and times to the class:

Measuring and Marking Wood	3 min. 30 sec.
Cutting Wood	4 min. 40 sec.
Sanding Wood	3 min. 40 sec.
Painting Wood (2 coats)	9 min. 30 sec.
Marking the Grid	9 min. 15 sec.
Setting and Pounding Nails	11 min. 35 sec.
TOTAL TIME	42 min. 10 sec.

One member of the Sample Group remarks that marking the grid is the most difficult and time-consuming task. Another student suggests that perhaps he could make a tool that will mark the grid faster. The class agrees that this would be a good idea, and several other students volunteer to help him.

The class then discusses the fact that the paint must dry before any of the steps following painting can be done. "We should split the work into two parts, since painting the boards means we cannot finish in one day", a student suggests. The rest of the class agrees that they need some sort of system for making the geoboards.

A student suggests, "We should work on the first four steps one day and then work on the last two steps the next day."

Another student remarks, "We will need more people working on the last two steps because they take more time." The class decides that the Sample Group should plan an assembly line for the rest of the class.

One student is worried about making all the nails the same height. The class offers several suggestions: Mark nails with paint to show how deep they go into the wood, or make a device that will keep the nails at the same height as they are hammered in. The student who plans to work on a tool for marking the grid agrees to work on this device also.

A class of sixth- and seventh-grade students in Lansing, Michigan, manufactured three-dimensional tic-tac-toe games. Before making a prototype of the game, the students constructed a template that indicated the location of the pegs on the base of the game. This tool enabled the students to shorten production time considerably. After producing a prototype of the game, the class listed the steps in making the game and the time required for each one. (See log by Pamela Johnson and Stanley Myk.)

During the next few days, the Cost Group purchases the materials, the Sample Group works on their plan and a new group, the Tool Design Group, works on tool designs. As soon as the groups have finished their tasks, the class holds a group meeting in preparation for the actual production. The Sample Group presents the following plan to the class:

DAY 1

Mark one-foot squares on boards	4 people
Cut boards	6 people
Sand boards	3 people
Paint boards	12 people
Passing boards between groups	3 people

DAY 1

mark 1" squares on board	6 people
Cut boards	3 people
Sand boards	4 people
Paint boards	12 people
Pass boards between groups	3 people

DAY 2

mark grid	6 people
Set holes for nails	9 people
Pound nails	10 people
Pass boards	3 people

Figure B5-4

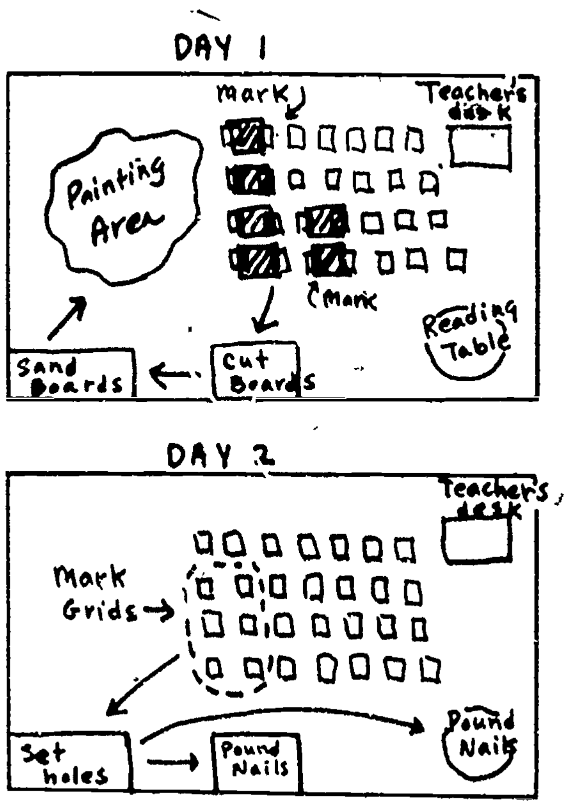

Figure B5-5

DAY 2

Mark grid	12 people
Set holes for nails	4 people
Pound nails	10 people
Passing boards	2 people

The group also shows the class tentative layouts of work areas in the classroom for each day.

During class discussion of the plan and layouts several important points are brought up:

- There are only three saws available so six people are too many to cut boards.
- The workbench area for pounding nails is not big enough for ten people. It is decided to use the reading table for pounding nails also.
- The Tool Design Group feels that marking the grids will be a faster job with the tool they invented, and therefore not as many people will be needed to do it.
- Once the marking of the wood is completed, the group working on that step will have nothing to do.
- Everyone should try to bring a paint brush and a hammer from home.

After the Sample Group revises the plan and layouts to reflect suggested changes (see Figures B5-4 and B5-5) the Tool Design Group demonstrates the tools they have invented for marking the grid and keeping the nails at the same height. One of the students explains that the grid-marking tool (see Figure B5-6) should be placed exactly on top of each board being produced with the nails pointing down and then should be pressed in slightly by pounding with a hammer. This will leave marks on the board where the nails go; the grid can be drawn in by cross-hatching along the nail marks. The tool for keeping the nails at the same height (see Figure B5-7) will be used for one row of nails at a time. By hammering the nails in the large drilled holes to the height of the tool, all nails will be 3/8" above the board (the thickness of the tool).

The class decides that the Tool Design Group should make

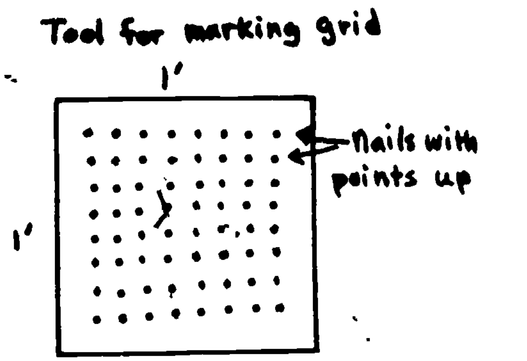

Figure B5-6

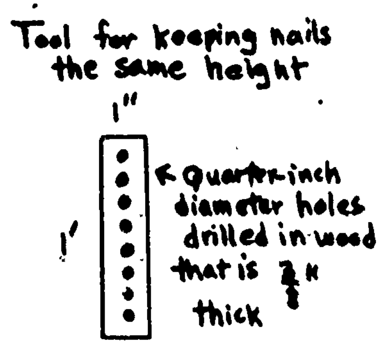

Figure B5-7

up six tools for marking the grid and ten tools for keeping the nails the same height. Since these tools are needed only for Day 2, the Tool Design Group will work on them during Day 1 and other students who do not have a job can join them.

The class then talks about choosing people for the various jobs. They decide that cutting the boards should be done by students with experience in using a saber saw and all other jobs are open to those interested. A sign-up sheet is posted and students sign up for the jobs they want, keeping in mind the number of people needed for each job.

A seventh-grade class in Lansing, Michigan, designed and produced a school directory. They determined the sequence of production procedures as follows:

collating pages and covers

straightening piles

inspecting

stapling

final inspection

stacking finished product

They organized the assembly line in the cafeteria and made a flow diagram. (From log by Howard King.)

The next day, the students begin production. Although there is a small tieup at the cutting area, everything goes smoothly. At the end of the hour, all of the boards have been marked, cut, and sanded. Two need their first coat of paint and eight need a second coat of paint. One student comments that it is confusing to keep track of where in the assembly line the boards are each day. Another student then volunteers to make a chart showing the work done each day. (See Figure B5-8.)

Because fewer people are needed for marking grids, the Paint Group decides to set up during Day 2 and finish the boards left from Day 1. When production ends on Day 2, all boards are completed except for the ten that the Paint Group has just finished. These ten boards will be completed at the next session. But one student in the class remarks that some of the boards have crooked nails and some of the grid

	Number of Boards with Job Completed				
Jobs Completed	Wed	Thurs	Fri	Mon	Tues
Squares Marked	32				
Boards Cut	32				
Boards Sanded	32				
Boards Painted One Coat	30				
Boards Painted Second Coat	22				
Grid marked	0				
Holes Set	0				
Nails Pounded	0				

Figure B5-8

lines are not quite right. The class decides to appoint an inspector to check the boards and send back those with poor workmanship.

A second-grade class manufacturing folders for their papers became aware that some of the folders were being made sloppily. During a class discussion it was decided that checkers would be chosen for each group. In addition, the following suggestions were made for improving the quality of the work:

1. *All groups work more slowly and carefully.*
2. *Tracers should have one person hold the pattern while the other traces.*
3. *Cutters should cut on the line.*
4. *Those folding should first make a line to show where to fold, then fold.*
5. *Gluers should check the folded areas carefully before gluing, and after gluing should wipe excess glue with a paper towel and hold the glued part down for a count of twenty-five.*

(See log by Linda Lopos.)

Since all the boards have been painted, the class repeats Day 2 at their next session. Several students who have been pounding nails complain that they are tired of their job and other students volunteer to switch jobs with them. One group of students that worked on marking and cutting the boards volunteers to fix the rejected boards. They are able to fix all of the boards except one that was cut too small.

When the last board has been completed, the students gather to discuss the results of their work. All agree that the job was a lot easier than anticipated "because we worked together." One student calculates that it took only about 6 minutes to make one geoboard, (thirty-two geoboards in three hours), a lot less time per board than the forty-two minutes that it took the Sample Group to make their board. When the teacher asks what helped most to save time, the class says:

"We worked faster when we got used to using the tools."

"We had the classroom set up so that everyone could work efficiently at their job."

As the discussion ends, one boy remarks, "We forgot to get rubber bands!"

The class decides to donate the four extra geoboards to another fourth-grade class. Several days later, one of the third-grade teachers asks if the class would be willing to make geoboards for her class too. Before deciding to do this, the class decides to survey the school to find out if other classes also want geoboards.

"The geoboards are easy to make," states one student, "so we should make enough for everyone who wants one."

When the fifth-grade class making wristbands considered whether or not to continue production, they decided to do so because few fourth graders had had an opportunity to order the wristbands. Before resuming production, the class listed possible activities to improve their procedures:

1. *Work in shifts so that students who were bored could change jobs.*
2. *Survey students in the school to determine the number of prospective customers.*
3. *Design an inventory chart to keep track of supplies on hand and supplies needed.*

(See log by William Kucher.)

6. QUESTIONS TO STIMULATE FURTHER INVESTIGATION AND ANALYSIS

- What factors should you consider before deciding to make a product?
- What will the product look like when it's finished?
- * How can you find out if there is a demand for the product?

*This question applies to an item that is being manufactured for sale to others.--ED.

- * How can you determine what to charge for the product?
- How can you figure out what sizes to make?
- How can the class decide on the best design?
- * How can you find out what designs customers would prefer?
- What tools and materials are needed to make the product? Where will you get them?
- Where can you get the money to buy necessary materials?
- Where will you make the product? How can you find out how much space you need?
- How can you be sure of getting the best materials for your purposes?
- How do you know how many to make?...how much material to buy?
- What steps are involved in making the product?
- How long does each step take?
- How could you make the product in less time?
- What is the best way to make the product (individually, in groups, on an assembly line, by subcontracting)?
- What is a good way to decide how many people to assign to each job on the assembly line?
- What is the best way to organize the work area?
- How can you make the assembly line more efficient?
- How can you remedy boredom on the job?
- How can you insure high quality?

*These questions apply to an item that is being manufactured for sale to others.--ED.

* ● What is the best way to distribute the product (take orders, have a sale)? What is involved in organizing a sale?

* ● How can you let others know about the product?

* ● How can you stimulate sales of your product?

● How can you keep track of your finances?

* ● Where can you keep the money you make? What can you do with the profits?

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*These questions apply to an item that is being manufactured for sale to others.--ED.

C. Documentation

1. LOG ON MANUFACTURING

by Linda Lopos*
Ernest Horn School, Grade 2
Iowa City, Iowa
(September-December 1975)

ABSTRACT

This second-grade class began work on the Manufacturing challenge of making math folders in quantity while working on a School Supplies challenge. (Their other activities centered around finding the best place for a Lost and Found Box in the room.) After choosing oaktag as the material for the folders and deciding on a design and size, the class made samples and used them to take orders from the other primary classes. A total of fifty-eight folders were requested. After a class discussion of the best way to make the folders, the students divided the labor into five steps and formed groups to work on each step in an assembly line. During production, students found that problems of sloppy workmanship and boredom had to be resolved. When sixty folders had been made, several children conducted a survey within the class to determine where and when they should sell the folders. With place and times determined, the class advertised the sale of the folders with posters, notes, and announcements, set up a work schedule, and sold the folders at regular times each day in their classroom until all the folders had been sold. In preparation for an open house to be held at their school, the class evaluated their activities and constructed a flow chart showing what they had done.

Near the beginning of the school year I asked the children to bring fifteen cents each to school so that I could purchase folders for their math booklets. But when I found that the folders would have to be ordered and that their price had increased to twenty-five cents, I asked the class whether anyone could think of a better way to supply the folders. Several children volunteered to bring some from home or to buy enough for everyone, but, after some discussion, the class decided that these were not practical solutions to the problem. Then one boy suggested that the class make the folders. The other children thought this was an excellent idea.

*Edited by USMES staff

The class discussed possible materials for making the folders, and decided on oaktag. They then listed the following things to be done:

1. Find out where to get the oaktag and how much it would cost
2. Find out how much oaktag is needed
3. Design a folder
4. Make the folders

The class formed four groups to work on each of these areas; the children volunteered for the group in which they wished to work.

The Design Group, composed of nearly half of the class, wanted to work on designing a folder immediately. They began by experimenting with various methods of making folders without drawing a design first.

While the Design Group worked on the folders, the group whose task was to find out where to get the oaktag sent a delegation of four children to the office to ask about it. The children returned with the following information:

1. The school has packages of white oaktag that the children could purchase.
2. The oaktag was 24" by 36" in size.
3. The oaktag cost $15.00 for a package of 100 sheets.

The group decided to try and find out the cost of one sheet of oaktag. One girl suggested that we take a random price and add it one hundred times to see whether we reached $15.00. She then suggested that the random price be $0.15. After adding $0.15 ten times to get $1.50, and then adding $1.50 ten times, the group was delighted to find that the result was $15.00.

The group working on finding how much oaktag was needed for one folder took a folder left from the year before and measured it. They found that it was 20¼" x 17½" in size.

At the next session, the Design Group displayed five different designs of folders that they had made. Some of the designs were made of two sheets of construction paper and had pockets, others were made with only one sheet. Last year's folder, constructed from a single piece of paper larger than those that the Design Group had used, was also displayed.

The class then discussed how they could decide on the best way to make the folders. They first decided to vote on

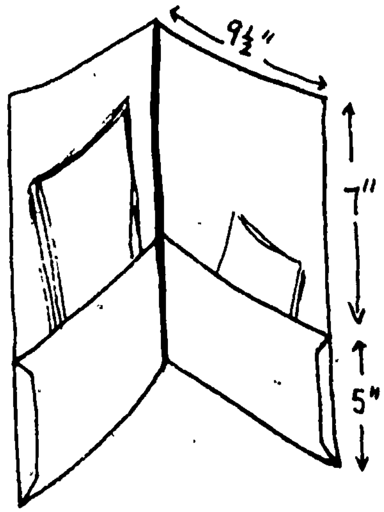


Figure C1-1

whether to use the folder design of last year or one of the new designs. When the vote was taken, the result was--

last year's folder	12
new design	15

When I asked the children why they did not want to use the design from last year, several replied, "Because it took more paper." The class still had to decide which of the new designs would be best. They concluded that the best way to find out would be to test each design by putting the math materials in each of the folders to see which held them the best.

When the class met again, they decided on the final design for their folder. They determined--first by measuring and then by placing the opened folder on a sheet of oaktag--that two folders could be made from each sheet. Several children then made up two samples of the folder to show to other classes so that they might order folders also. (See Figure C1-1.)

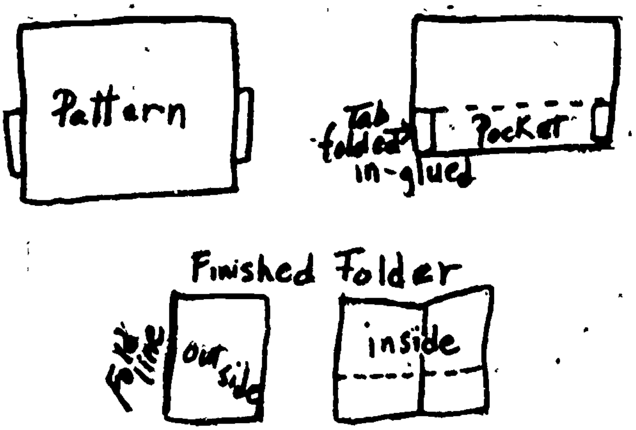
The next day, four girls went to the other primary classes to tell them that we were making folders and to ask how many children wanted one. A total of fifty-eight folders were requested.

The class next discussed how they would make the folders. The following steps were listed on the board:

1. Cut the sheets of oaktag in half
2. Trace an outline of the folder on each piece
3. Cut out the outline
4. Fold each piece into a folder
5. Glue the tabs of the folder

I asked the class what they thought would be the best way to handle the tasks. One boy said, "Divide the class into five groups--one for each task." I asked the class how many people should be in each group. Another student volunteered to go to the board and show the class her idea for deciding. She drew five circles on the board to represent each group. She then put a tally mark in each circle, one at a time, until she had counted up to twenty-five (there were twenty-five children in class that day). This resulted in five children being in each group. The children then volunteered for the task they wished to do.

Stations were set up in the room for each group and the class started to make folders. The following sketch shows the steps in making the folders and the finished product.



The class was very excited and many of the children were trying to hurry through their tasks. This resulted in sloppy work; several children became aware of this and complained about the appearance of some of the folders.

After about twenty minutes of work, it was time to clean up. I called the class together and asked them how they thought things were going. Several children commented that people were being sloppy. When I asked them why they thought this was happening, one student replied that everyone was excited and wanted to hurry. Suggestions were made that we have a checker for each group and that more class time be scheduled for the work on the folders.

We continued our discussion of improving the sloppy work at the next class session. Many suggestions for better work were made for each group. After agreeing that all groups should work more slowly and carefully, the following suggestions for each group were listed on the board:

Tracers:	Have one person hold the pattern while another person traces.
Cutters:	Make sure you cut *on* the line.
Folders:	Make a line to show where to fold before folding.
Gluers:	Check folded areas carefully before gluing. Wipe excess glue with a paper towel. Hold the glued part down for a count of twenty-five.

The class also decided that one person from each group should inspect the work being done.

The class then worked on the folders for about twenty minutes. They seemed much more particular about their work. The "inspectors" were rejecting poorly done work and the class as a whole was taking great pride in their work. One child commented, "This is just like a factory."

The class continued to construct the folders for several more class sessions. While circulating among the groups, I noticed several things:

1. The children had been complaining to each other about poor workmanship. The reject piles seemed to be getting larger.
2. Some children were getting bored and wanted to change jobs.
3. Some work areas were overloaded with work, especially the folding and gluing areas.

I decided to bring up these problems with the class. As a result, jobs were reassigned with some children keeping the job they were doing previously and others changing their jobs.

Four of the children formed a new group to work on advertising the folders. They decided to make posters but did not know when or where the sale would be. They finally decided that they should survey the other primary classes as well as their own to find out when and where to sell the folders. But, when the group brought up their idea of a survey with the rest of the class, most of the children did not think that they should ask the other classes where and when the folders should be sold. One boy, whose father runs a store, said, "My dad doesn't ask anyone when we should have our store open." The majority of the children felt that our class should decide where and when to sell the folders, and a new group of children volunteered to develop a survey to be used in our class.

When the Survey Group met later in the day, they decided that the survey should include these two questions:

1. Where should we sell the folders?
2. When should we sell our folders?

I asked the group how many different answers they could get from the class in response to these questions. One girl suggested that the survey should have a selection of times

1. Put an X in the box next to the place where we would sell folders. (Students were to mark only 1)

- ☐ our room
- ☐ gym
- ☐ by front door of School
- ☐ other_____

2. Put an X in the box next to the best time to sell folders. (Students could mark more than 1)

- ☐ right after school
- ☐ during any recess
- ☐ between 8:20 and 8:30

Figure C1-2

and places on it. After revising the survey to include these choices, the group made up a ditto master and then made twenty-seven copies of the survey. (See Figure C1-2 for a copy of the survey.) The Survey Group gave the children about ten minutes to answer the survey; they then tallied the results.

At the next class session, the Survey Group reported on the results of the survey. The following information was listed on the board:

Where		When	
gym	10	recess	16
our room	16	before school	16
by front door	2	after school	12
other	0		

When I asked the class if anyone could think of another way to show these results, one girl with previous USMES experience said that we could make a graph. Most of the class was interested in doing this. One group of ten students made bar graphs showing the "where" data and another group worked on graphs showing the "when" data. (See Figures C1-3 and C1-4 for examples of these graphs.) The students counted the boxes both horizontally and vertically on the graph paper and found that there were not enough boxes to show sixteen responses (the greatest number of responses on the survey) on the graph if each box was worth one response. One student then suggested that each box "should be worth two." The children were then able to complete their graphs, with those having previous experience helping those who had none.

The children who were not involved in graphing the survey data discussed where in the room the folders should be sold and who was to do the selling. One girl suggested making up a schedule for selling the folders to make sure everyone had a turn.

Since sixty folders had been completed, the class met to decide on how they would advertise and sell them. After much discussion the class decided that they needed to do the following things:

1. Make posters
2. Make notes to pass out to the other primary classes
3. Announce the sale of folders to other primary classes

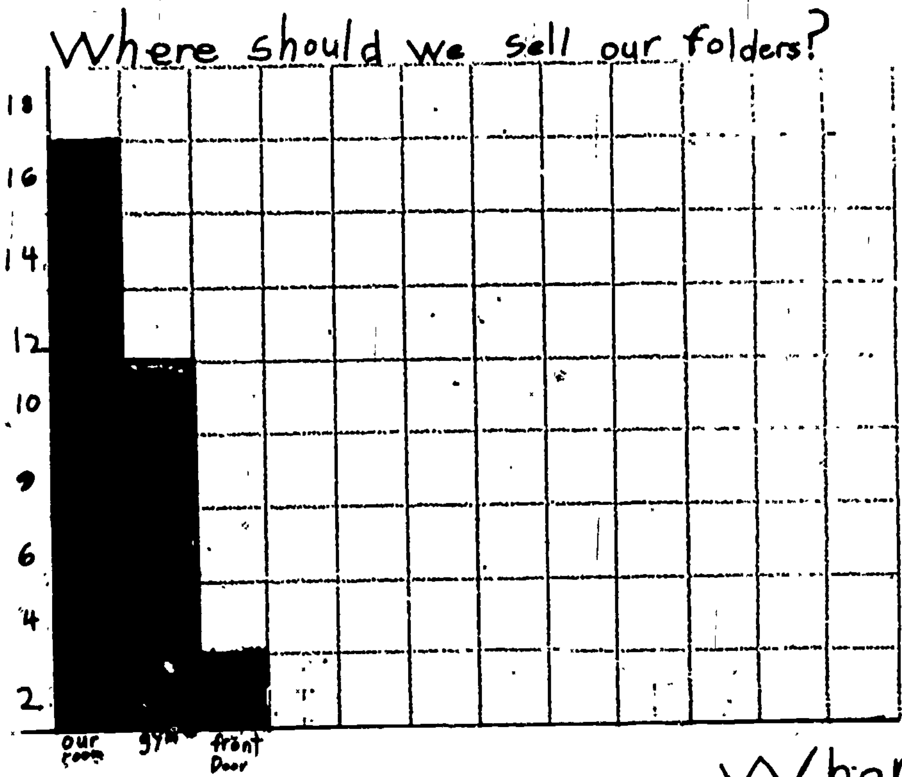


Figure C1-3

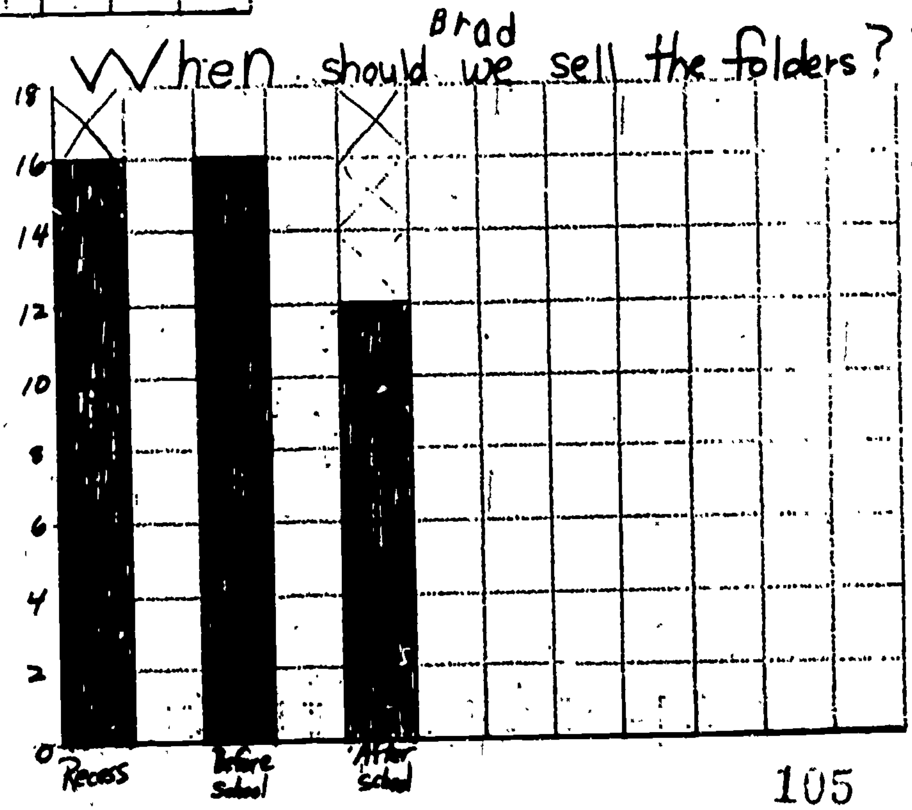


Figure C1-4

Go to Mrs. Lopos' Room for folders. At 8:20 to 8:30 AM, morning and afternoon recesses.

The sale will begin Thursday, Oct. 9th They are 10¢ each

Figure C1-5

There will be a sale of pocket folders in Mrs. Lopas' room beginning on Thursday. The folders will be 10¢ each. You may come between 8:20 and 8:30 any morning or during morning and afternoon recesses. This does not include lunch recess.

Figure C1-6

4. Survey the class to find out where in the room the folders should be sold
5. Make out a work schedule for those interested in selling

The children volunteered to work in one of the five groups. The Poster Group designed posters on "practice paper." They planned to copy them onto oaktag with felt-tip markers.

The Note Group composed a note to be given to all of the primary children. Several members of the group went to the teachers in the primary section to get the number of children in each class so that they could make the correct number of copies, which were then run off on the ditto machine. (See Figure C1-5.)

The group working on announcements wrote up an announcement and made four copies for the four members of the group. The announcement was divided into two reading parts so that each child would have a chance to read. After practicing the parts during recess, the children visited the other primary rooms to read the announcement. (See Figure C1-6.)

The Survey Group decided that the three most reasonable places in the room to sell the folders were the art center, the reading table, and the front of the room. Accordingly, they listed these places on the survey (as well as the "other") and asked their classmates to choose one of them as the best place to sell the folders. (See Figure C1-7.) They planned to conduct the survey at the next class session.

The Work Schedule Group made up a chart of times and days for selling the folders. After eliminating the names of seven people who did not wish to sell folders, they wrote in the names of the remaining twenty children, two for each block of time. (See Figure C1-8.)

The Survey Group conducted their survey with the following results:

Art Center	11	Reading Table	6
Front of Room	10	Other	0

When the class discussed the results of the survey, it was pointed out that since the art table was always set up for art activities during the morning, it would be difficult to clear it in time to sell folders during morning recess and then have it ready for the next group using the art center. The class then decided they should take a hand vote to choose between the art center and the front of the room. The front of the room won by a vote of twenty-three to four.

Put a x in the best place you think we should sell folders.

☐ Art center

~~☐ In front of the room.~~

☐ Reading table

☐ Other ______________

Figure C1-7

The groups then continued to work on their tasks and completed all preparations for their sale (scheduled to begin on the following Thursday). The Poster Group completed their posters and hung them in all the rooms of the Primary Unit, and the Work Schedule Group posted the completed work schedule at the front of the room.

The sale of the folders was a big success. The class followed the work schedule for several weeks and revisited the other primary classes occasionally to remind the students to buy their folders. When the sale of the folders lessened considerably, the work schedule was discontinued and announcements were made in each primary class that those still interested in buying folders could purchase them before or after school. This continued until all of the folders were sold.

A week after the folders were first placed on sale, an "Open House" was held at the school. When I asked the class how we might tell those visiting our room what we had been doing, the class suggested that we write our activities on the board. Together, the class and I constructed a flow chart of our activities. (See Figure C1-9.) When the chart was completed, the students enjoyed following the arrows and reading from the boxes the story of our activities with the folders. The whole class was proud of the work they had done.

Linda trent Mike

	8:20 - 8:30	Morning recess	Afternoon recess
Mon.	dennis Emily	Ray Brad	Ellen Linda
Tues.	Kipp marc	sTacci Chad	Linda Dawn
Wed.	Elizabeth susan	Bret karen	Ellen Karen
Thurs	David Alan	Sarah Anjali	X
Friday	Doug Dawn	Bret Kipp	X

Figure C1-8

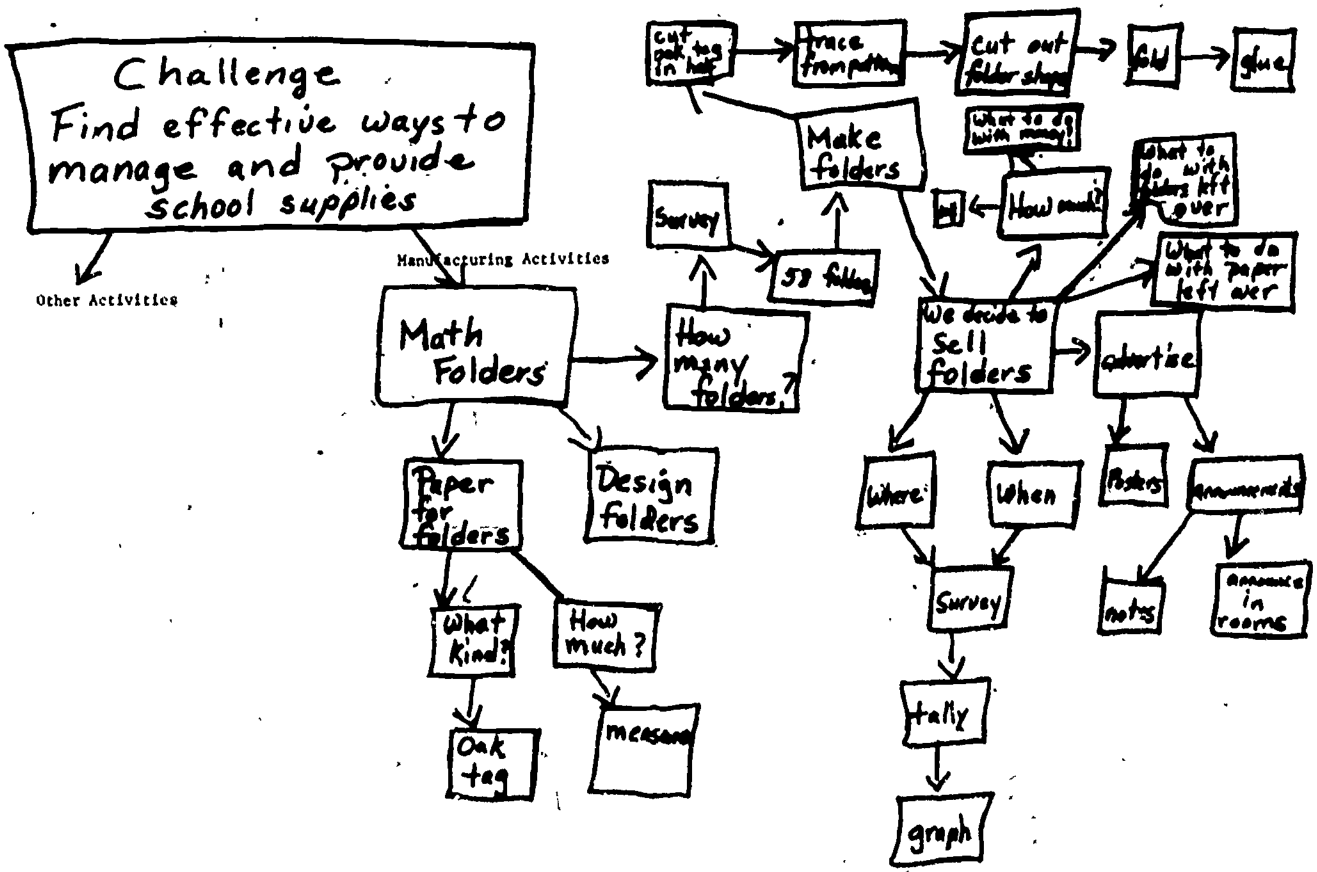

Challenge
Find effective ways to manage and provide school supplies
Other Activities
Manufacturing Activities
Math Folders
Paper for folders
What kind?
Oak tag
How much?
Design folders
How many folders?
Survey
Make folders
cut out folder shape
glue
Sell folders
advertise
Where
When
Survey
tally
graph
Posters
notes
in rooms
What to do with paper left over

Figure C1-9

2. LOG ON MANUFACTURING

by William Kucher*
Marina Vista School, Grade 5
Marina, California
(October 1973-June 1974)

ABSTRACT
This fifth-grade class was involved for nine months in the manufacture of leather wristbands. After making preliminary sketches, students noted the importance of accurate proportions. They used cardboard prototypes to determine how many wristbands could be cut from each piece of leather. A division of labor was worked out, and group leaders supervised the assembly line production. The wristband price was determined by the cost of the materials and by an informal survey of the price customers were willing to pay. Advertising posters were made and order forms were devised. A treasurer was selected to be in charge of all finances, including tax collection. During Christmas vacation, money was deposited in a class savings account. Because the demand for the wristbands was so great, production continued for the following five months, eventually changing to the manufacture of leather keychains. The class continually evaluated their progress and implemented changes for improvement.

I introduced the Manufacturing unit to my class of fifth-graders with a general discussion of manufacturing.** To the students, the word *manufacturing* meant such things as factories, engines, tools, wood, electricity, making things, and using supplies to make useful shapes. They also associated manufacturing with crushing, shaping, melting, putting things together, assembling, and molding. A variety of manufactured items was listed on the board, and the class concluded that just about everything is manufactured. I then

*Edited by USMES staff

**In many cases students begin work on this unit when the need to make an item in quantity arises in the context of work on other USMES units such as Designing for Human Proportions, Soft Drink Design, or Orientation.--ED.

asked them, "What has to be done before something is manufactured?" Their response was that materials must be gathered, plans or blueprints made, workers hired, and a product decided upon.

The next day the class generated the following list of possible products for them to make as a class:

pencils	folders
pencil holders	"slam books" (autograph books)
bookshelves	chalk boards
drinks	decorations
boxes	tool kits
books	calendars
chimes or bells	

They touched on the fact that the work could be done in the classroom, in the Design Lab when it was completed, or in a place built by the class.

Since most of the students had decided that they wanted to make something for themselves, I told them to think about what they each wished to have. We then talked about how we could make something for parents, friends, or the other students in the school after each student had made something for himself. This led to the idea of selling a product and using the profits to buy something for the class or the Design Lab.

A few days later when we discussed why people manufacture things, the class came up with the following reasons:

1. People want to make money.
2. Others might need the product.
3. The product might help other people.

The consensus was that they themselves would be interested in manufacturing something to fill a need and to make money. The discussion turned to how they might find out (before beginning production) whether a need or demand for a particular product existed. The students suggested the following ways to find out: taking orders, polling all classrooms, taking a random sample of three or four classrooms.

Other practical matters were also dealt with during this session. The class agreed that they would have to think of a product that was useful, for which they could get the necessary materials, and which they would be able to make. To get materials, they considered bringing them from home, purchasing them, or asking for donations. As for finances, of them mentioned getting a loan from a bank.

Near the end of the period, I asked each person to write down five products he or she would be interested in making. Of all the suggestions, leathercrafts (belts, purses, wallets, wristbands) and metal rings with the school name or a person's name on them really excited a group of ten students who felt that all students would want these products.

The next day, a list of sixty-four items, compiled from the students' lists, was written on the board. Each student chose ten products from the list that he/she most wanted to manufacture. These were recorded in each student's log book.

During the next period we again considered the list of sixty-four items. I asked the class to divide into groups; each group was to choose ten items from the list. The class decided that three groups would be good since too many groups would result in a list just as long as the one they were now considering.

Before group discussions got underway, we reviewed the important factors to consider before choosing a product: what the product looks like, how it is made, how it is used, who will use it, what materials and tools are needed, and what space is required.

The first group began their discussion by considering the items on the big list one-by-one; the second group collected all of their log books and used the lists of ten choices each had made previously. They awarded one point to an item for each time it occurred and then took the top ten in the point standings as their list of ten.

The third group began by discussing Marina Vista shirts. When one student pointed out that they would not be making the shirts but only marking the letters on already-made shirts, the group decided these would be a good item to sell. After choosing the ten items that they preferred most, the group priced the items, using the criteria that the price should be how much the item was worth to the person buying it. Their list (with prices) is as follows:

1. Marina Vista Shirts ($1.85)
2. Rings (leather or metal) ($.25)
3. Belts (braided leather) ($1.00)
4. Marina Vista Pins ($.10)
5. Wristbands ($.15)
6. Wallets ($1.00)
7. Bookcases ($.85)
8. Candles ($.80)
9. Vests ($1.00)
10. Binders ($.95)

I started the next session by reading the lists of products decided upon by the three groups. We then began discussing the products one-by-one, detailing the factors involved in making each product. For example, to produce leather wristbands, the students decided they could put designs on the leather with a leather burner, leather tools, an etching tool, or by painting them. Ideas of what to put on the leather included names, pictures, names of baseball teams, or peace signs. For attaching both ends of the bands, the class suggested buckles, clips, snaps, cloth, and elastic. They also noted that they would have to know the size of a person's wrist to make these wristbands. After discussing Marina Vista shirts, rings, pennants, and wristbands, all of the students seemed to prefer wristbands, with Marina Vista shirts coming in second.

Although some students in the class appeared to be eager to make a decision so that they could begin production, the class decided to continue the discussion of the products in case they found something better than wristbands. They continued to talk about various possibilities for the next three sessions, eliminating comics, binders, models, belts, pinatas, and candles. Their criteria for eliminating these products were based on whether the class really wanted to make the item, whether they could use it, whether other students would want it, the difficulties that might arise in making it, and what the costs would be.

After all the products had been discussed, the class was ready to make a decision. They chose wristbands with only two dissenting votes. Their reasons for deciding to manufacture wristbands were that they were something that everyone in the class wanted and could use, and that they also wished to make them for the other students in their school (and possibly students at other schools). The class agreed that their first steps in making the wristbands should be finding out what materials and tools were needed and buying whatever was necessary.

Students offered the following suggestions on the appearance of the bands:

1. There should be two different designs, a sports design for boys and a flower design for girls.
2. The class should take a survey of what designs people like.
3. Snaps or buckles should be used as fasteners.
4. Wristbands should be made to order.
5. There should be samples to choose from.

Following this discussion, I asked students to draw some sample wristband shapes.

A week later, we took a look at the sketches the students had created. One sketch of a wristband that included a strap

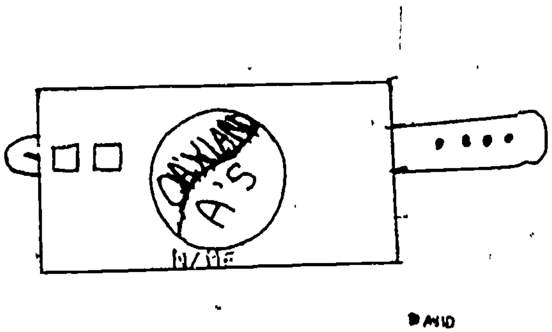


Figure C2-1

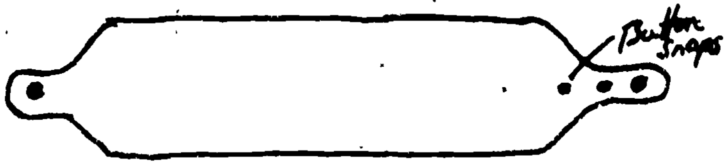


Figure C2-2

and a buckle is shown in Figure C2-1. The students were quick to notice that the sizes of the wristbands in the sketches were incorrect. Therefore, I passed out sheets of construction paper so that each student could make a pattern for a wristband that would fit him or her. Some students used the paper to measure around their wrists, while others used a measuring tape. The wristband sizes for students in the class ranged from 5" to 7". One boy included an extra set of snaps on his pattern, making his wristband adjustable. His pattern is shown in Figure C2-2.

Some students liked his idea and modified their patterns by adding extra snaps. At that point, the class decided that when they started to make wristbands for others, they would need to know now only what design a customer wanted, but also what size wrist he or she had. Some students argued that adjustable bands would fit anyone, but others thought that the range of sizes among fourth/fifth/sixth-grade customers would be too broad.*

One boy was particularly worried about how we could make sure a person who ordered a wristband would receive it. His anxiety led to a discussion of order forms, receipts, and carbon copies of orders.

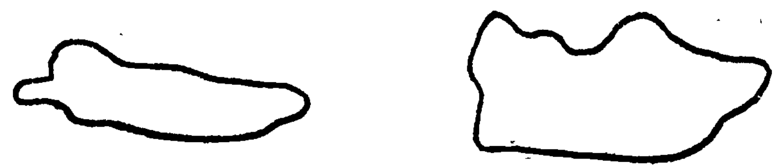
At the next session, I brought in two large pieces of scrap leather, about four to five square feet each, that I had purchased at a leather store, and tools I had borrowed from friends—leather cutters, gougers, hole punchers, and a set of decorator stamps. I demonstrated the tools and showed the class a strip of leather on which I had stamped a name. After seeing my sample, most of the students wanted to purchase a set of letter stamps but a few still wanted to try using a leather burner.

After the tool demonstration, I opened a discussion about how many wristbands the students thought we could make from the leather on hand. One student realized we had to decide on a wristband size, and so we started by figuring out the length of a wristband. Since the students liked the pattern with adjustable snaps, we all tried on the paper pattern and found that it was a little too big for everyone. The boy who had designed the pattern shortened it to 7½" and rearranged the snaps. Next, we considered how wide the wrist-

*The students might decide to measure a sample of the students to determine whether one length, made adjustable by the attachment of extra snaps, would fit all students who might want to buy a wristband. See Background Paper, *PS 4 Design of Surveys and Samples*.--ED.

bands should be and we decided that 1 3/4" would be about right.

With the size determined, the class divided into groups of three to figure out how many bands we could make out of the two scraps of leather we had. So that each group could experiment, I had traced the shapes of the leather scraps onto large pieces of paper. They looked approximately like those shown below.



Before the students started working, I reviewed the quarter-inch and half-inch markings on the ruler.

During the next session, representatives of each group explained their method for determining how many wristbands could be cut out of the leather pieces. Some of the methods were as follows:

1. Working in three different sections of the leather piece, without a plan
2. Starting at both sides and working toward the middle
3. Making a straight line across the bottom and proceeding one row at a time, from bottom to top.
4. Moving around the sides of the outline
5. Making rectangles measuring 7½" x 7" on the paper and dividing them into four wristbands

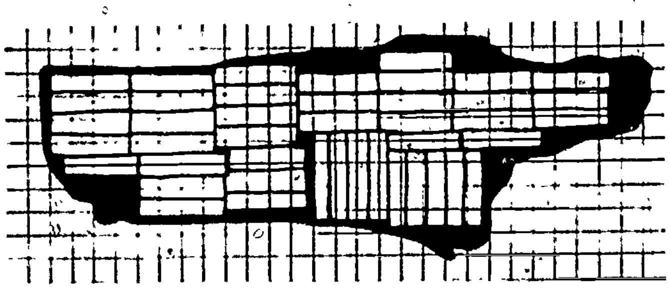


Figure C2-3

Each of these ideas was criticized in terms of how much leather was wasted. Many comments were also made about the size of the outlines, which varied by as much as 1/2" on many of the papers. It was suggested that everyone remeasure their outlines. One group said that they had made squares of 7 1/2" on the paper and then drawn in the outlines in the squares, but when one student checked by marking off some wristbands on the square, he found that they took up 7 1/2" by 6 3/4" and he had space left over.

When work resumed, three groups decided to start over. Another group made a cardboard model of the wristband to use as an outline, thus avoiding having to measure over and over. The layout for one piece of leather is shown in Figure C2-3.

The leather was approximately 54" by 20" at its greatest length and width.

A week later, the groups had finished marking the outlines, and reported that they could get fifty-five to seventy-eight bands from the large piece of leather and forty to forty-five from the small piece.* Everyone agreed that the measurements should be checked before cutting the leather, and so the students remeasured using rulers or cardboard models. As a result, the figures were readjusted to sixty-six bands for the large piece and forty-five bands for the small piece. Three suggestions for what to do next were (1) to figure out orders, (2) to learn how to use the tools, and (3) to mark and cut the leather.

The next day, a parent brought in a large box of leather scraps and we were able to experiment with the tools. One student was in charge of each of the following tools: letter stamps, designer stamps, and cutting and punching tools. A few students also worked with a leather burner. As the students experimented, several problems became apparent:

1. The hammer wasn't heavy enough to make deep impressions from the stamps.

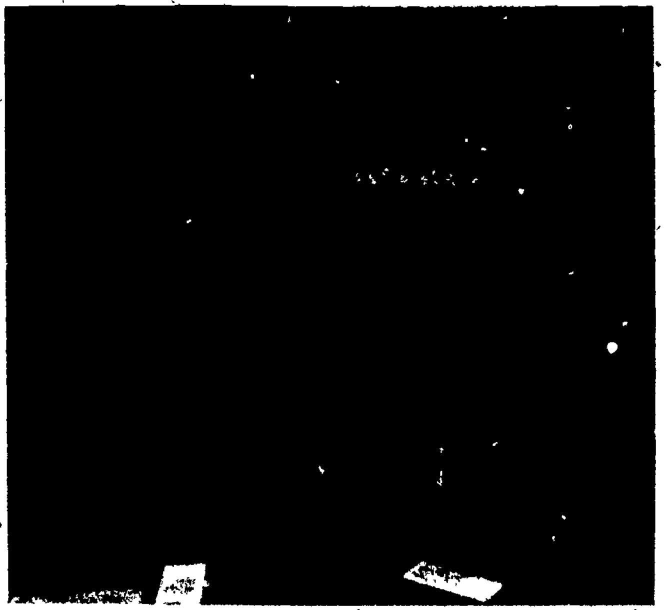
2. It was very easy to stamp the letters on upside down or backwards.

3. We had to be very careful when working with the X-acto knife because it was very sharp.

4. It was difficult to cut the leather straight.

Cutting out a wristband.

*The students might estimate the greatest number of wristbands that could be cut from the leather if no leather were wasted. This could be done by weighing both a wristband and the piece of leather and then dividing the weight of the leather piece by the weight of the wristband. A more realistic estimate might be calculated by drawing small squares of equal size on the leather piece and on the wristband and dividing the number of squares on the leather piece by the number of squares on the wristband. Each of these numbers would be larger than the number of wristbands that could actually be cut from the leather piece, but each would constitute an upper bound, thus giving some indication of the maximum number of wristbands that could be obtained from the leather.--ED.



Stamping letters.

5. Only the strongest students could work the hole puncher.

The next day we discussed possible solutions to these problems. Some students suggested using a sledge hammer on the stamps. Three ways of improving the cutting were also suggested:

1. tracing around a wooden model with the X-acto knife
2. running the knife between two blocks of wood
3. working more slowly

The students continued to experiment with the tools and work on the problem areas--cutting the leather and stamping letters and designs. One boy drew a line on the leather with a pencil before applying the letters so that his letters would line up with one another. By wetting the leather and hitting harder, students were able to make the letters penetrate deeper. Cutting was also improved when students cut along straight edges or drew lines and slowly cut along them. Meanwhile, I demonstrated how to apply snaps, and one student experimented with using laces as fasteners.

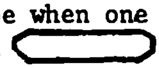
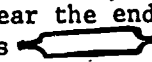
The following day some of the students began work on their own wristbands while others continued to experiment with the tools. Most of those working on a wristband began by measuring their wrists and cutting out the leather. A few were certain of their measurements and began marking their leather immediately; some of them later found that their wristbands were too small.

Because it was difficult to fit an entire name on the wristbands, one girl suggested putting first name and last initial or using only initials. The students began asking each other for help as they now realized that certain students were better at certain jobs.

I began the next session by asking the students what steps were involved in making a wristband, and they suggested the following sequence:*

*The students might look over the list of steps to see whether several could be done at the same time. Each step could then be timed and the total time to make one wristband calculated; only the longest of concurrent steps would be included in this total.--ED.

1. Measure wrist size.
2. Mark on the leather.
3. Cut the leather.
4. Edge the cut piece (I had purchased an edging tool when the class complained about the uneven edges).
5. Figure out where to put any letters or designs.
6. Wet the leather.
7. Mark letters or designs.
8. Dye the leather.
9. Put on the snaps.

The students continued to work diligently on their wristbands. They used scraps to figure out how long the bands had to be to hold two snaps on one end and one snap on the other with an overlapping piece. The class adopted a new shape when one girl used straight cuts near the ends of the band  instead of curved cuts . This new way was easier to cut and left more room for snaps. In order to center their names, some students began to place all the letters on the leather before hammering.

At the end of the period, we had a discussion about whether or not we were manufacturing. One girl thought we were like a factory because we were going through different steps to make something. But someone else mentioned that we weren't really manufacturing because we were making our own bands and that we would be manufacturing only when we took orders and made bands for other people. At that point, one boy brought up the fact that some people were better at working with the leather tools than others. This led another student to suggest that we divide the labor when we started filling orders for other people. Half the class was in favor of an assembly line; the other half preferred having each person take his own orders and make the wristbands for those orders.

The next day I demonstrated the use of the various colors of dye. Then I remarked that, because there were so many activities going on, I would not be able to assist everyone as much as I wished. As a result, the students suggested that they could help by having group leaders to supervise the use of the tools. When there were too many volunteers, we decided the leaders should be those people who were best at using the different tools.

Once the leaders had been selected by class consent, different sections of the room were set up for performing the various activities. This arrangement worked out exceedingly

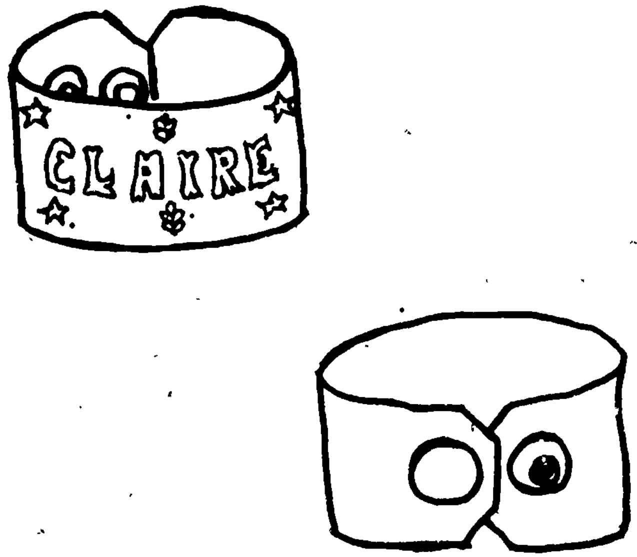


Figure C2-4

well; the leaders did a great job. The next day, since the leaders hadn't had a chance to work on their own bands, they chose capable students to replace them as leaders. A sketch of one of the completed wristbands is shown in Figure C2-4.

During several previous discussions, we had talked about how we would determine customers' sizes, establish a sale price, and handle orders. Students had made three suggestions on sizes:

1. Measure each customer's wrist with a tape measure.
2. Offer three sizes.
3. Make a model with many snaps and try it on the customer to determine his size.

A pattern for the last suggestion is pictured in Figure C2-5. The class had agreed on this last idea, but they wanted to make the bands adjustable by adding an extra snap, in case the customer's wrist became too large for the original size. They also decided to ask the customer which designs and/or what name should be stamped on the wristband.

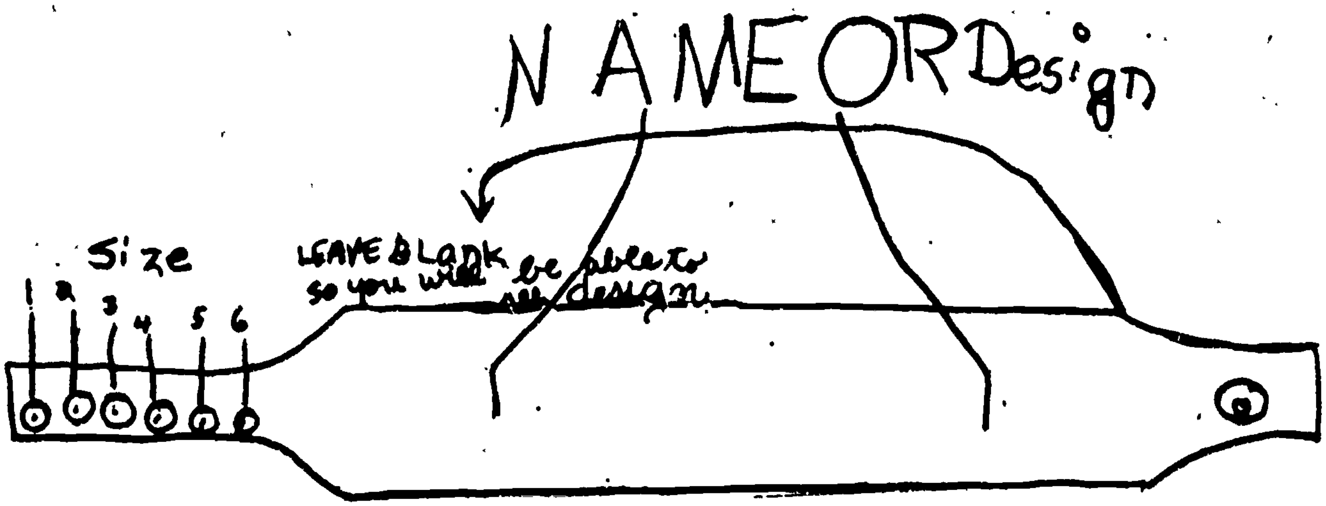


Figure C2-5

With the pattern, two boys made model wristbands to use for measuring customers. They cut out a strip of cardboard and punched five to six snap holes in it. For display purposes, they stamped all the letters of the alphabet and all the available designs on a scrap piece of leather and made samples of the various dyes.

During a discussion about the model, I asked the class what they would do if someone ordered a wristband for a relative outside of the school so that we couldn't use our model. Someone replied that we could just add ½" to their wrist size to get the wristband size. However, when we tried it out on our own wrists and wristbands, we discovered that in most cases, the wristband size was 2¼" larger than the wrist size. We came up with the following formula:

Wrist size + 2¼" = wristband size.

When we discussed price, suggestions ranged from $.50 to $4.00, with $1.00 being the most common suggestion. One student defended $4.00 as a good price by saying that handmade items are more expensive, but another student said that everyone would buy a wristband if the price was $.50. The discussion was tabled when one boy said we shouldn't set the price until we knew how much it would cost to make one wristband.

Later, after surveying six or seven people, including the principal, one boy announced that everyone in the school was willing to pay $1.00. Half the class agreed with him and half recommended lower prices of $.75 and $.90.* I proceeded to make a list on the board of the costs of the various materials that had been used to date. When the class realized they already owed $30.00, they decided that $1.00 was a good price. They reasoned that they would have to sell about thirty bands to break even; after that they would use the profits to buy new materials to make more bands.

Now that we had the price, we included it on a poster that three students had made. The poster also advertised such things as "choice of dyes" and "any writing you want." This poster was hung outside the room, and a smaller one was placed in the sixth-grade hallway.

Another topic covered was order-taking. The class decided to have five people go to the other classrooms with samples and order books, while the rest of the class worked

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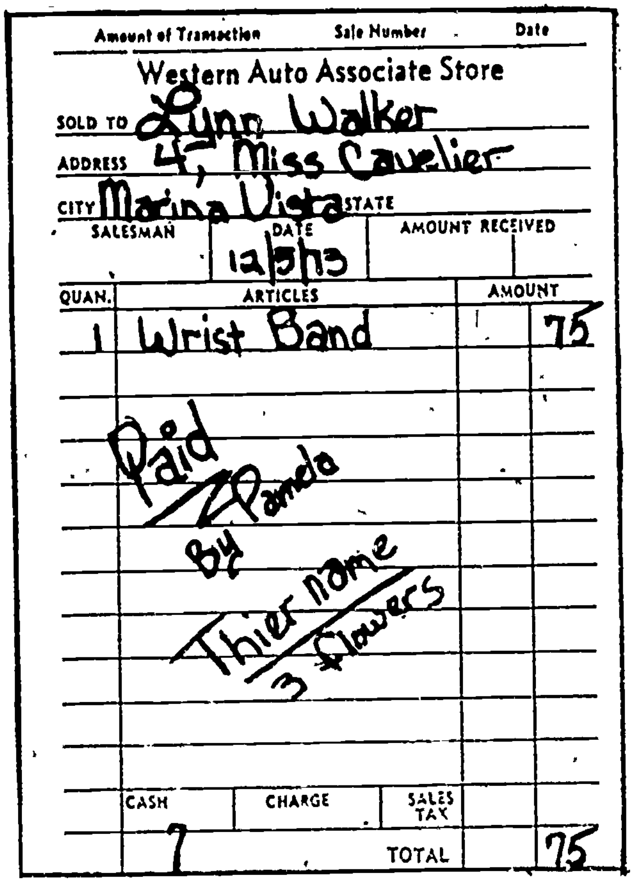
*Students might discuss whether enough students had been surveyed about the cost of the wristband. They might decide to conduct a more extensive survey to find out how much students were willing to pay. See Background Paper, *PS 4 Design of Surveys and Samples*.--ED.


Amount of Transaction | Sale Number | Date

Western Auto Associate Store

SOLD TO Lynn Walker

ADDRESS 4, Miss Cavelier

CITY Marina Vista STATE

SALESMAN	DATE	AMOUNT RECEIVED
	12/5/73	

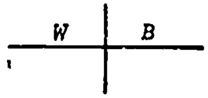
QUAN.	ARTICLES	AMOUNT	
1	Wrist Band		75
	Paid By Panda		
	Thier name 3 flowers		

CASH	CHARGE	SALES TAX	
7		TOTAL	75

Figure C2-6

on the wristbands. One student showed us an order form she had made which included a place for the customer's name, room number, and size; the name and design were to be written in the remaining space. Several girls worked on the order forms. They obtained some forms from a parent's store and devised the sample shown in Figure C2-6.

Next, I asked the students to pair off and practice writing orders, using the order forms. Some had trouble remembering to ask what designs or letters were desired and some didn't indicate whether the size they had written down was for the customer's wrist or the wristband. A suggestion was made to put a grid,



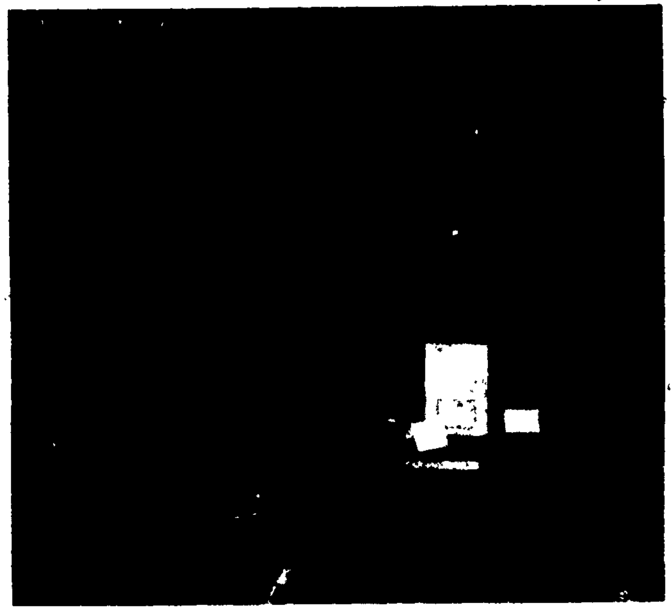
on the order form, with *W* standing for wrist size and *B* standing for band size.

Near the end of one of the periods, we had a short discussion about charging tax. Instead of giving the tax money to the government, the class felt we should give it to the school. We also decided to keep our money in the cash box we had bought, and the secretary was put in charge of it until a treasurer was elected.

The first thing we discussed after our own wristbands were finished was whether to set up an assembly line for making the wristbands that had been ordered or to have each person work alone, making wristbands for his or her own customers. The class eventually reached a compromise: the labor would be divided but the person who took the order would be responsible for seeing that it was completed correctly.

Next, we decided on the following jobs and the number of people necessary for each job:

Job	No. of Workers
1. Ordering	5
2. Planning	3
3. Cutting	4
4. Edging and U-gouging	2
5. Wetting	2
6. Stamping letters	2



Customer ordering a wristband.

Job	No. of Workers
7. Stamping designs	2
8. Dyeing	2
9. Putting on snaps	3
10. Collecting money and making deliveries	4

In those cases where more people wanted to work on a certain job than were needed, we either voted to determine who should do the work or chose the person who had demonstrated that he/she could best do the job. We also chose a treasurer and an organizer who would be in charge of planning and checking orders.

We were now ready to begin making wristbands for sale; so five students whose job was ordering went to another class to take orders. When they returned, I asked them to check with another person to make sure they had included all the necessary information. When they realized that some orders did not have sizes or designs, they went back to the other class with a measuring tape and the size models to complete the orders.

When they returned, work was begun on six wristbands. The planning group checked the orders, stapled each one to an envelope, and sent it to the cutting department. The envelope was used to transport the wristband from one department to the next. At the end of the day, the wristbands were put into folders indicating which step in the process was to be performed next.

By the end of the second day of production, we realized that certain steps were taking longer than others. For example, dyeing and cutting took a long time while wetting and edging were short jobs. Those with short jobs decided to do their homework or amuse themselves when they had downtime. At the letter-stamping area, two boys devised a new way to center the names on the bands by starting with the middle letter and working out. We now had six wristbands completed and delivered and another nine completed and ready for delivery.

The next day started with a discussion of our schedule. Things seemed to be backing up at the planning and cutting centers. Although the students were willing to work overtime to catch up, they also realized that many customers were buying wristbands for Christmas presents and that their orders had to be completed before Christmas vacation. Therefore, the students agreed to stop taking orders until after

Christmas or at least until we had finished the orders we already had.

Production continued for several days. Halfway through one period, the snap center ran out of a certain type of snap and the dye center needed a new supply of two dye colors. Everyone agreed that we should use our current profits of $32 to buy more supplies since we still had orders totaling $42.

On another day we had very little leather left and twenty more orders to fill. The students were able to cut twenty bands from the available leather, but at the end of the period we found a mistake on one of the bands. That meant getting more leather, and I decided to get only enough for a few more bands.

Two students counted the money and reported that we had $72.52 and that $3.23 in bills had already been paid but that we also owed some money to the school for paying some of our bills. When the students heard how much money we had, they began making suggestions for spending it--buying ice cream, paying salaries, going on a field trip, and buying a Christmas tree. One girl said that we shouldn't make plans until all wristbands had been sold and paid for.

The next day we finished all the wristbands. Since we had only twenty-five snaps, but needed thirty, we remeasured the remaining customers and made the last batch of bands with one snap on each side. Just as we were finishing, the cafeteria clerk came in to ask about two wristbands she had ordered that we hadn't written down. I happened to have a long strip of leather that I was going to use to make a belt, but I agreed to sell it to the class for $2.00. The leather-strip was 1-3/4" wide, the exact width of a wristband, and so only the length had to be cut. We completed the last wristbands out of the belt leather.

The next day the treasurer gave another report, including one last-minute order for another wristband for the cafeteria clerk. His figures were as follows:

Cash on hand	$ 94.73	
Cash to be earned from finished orders	9.45	
Cash to be earned from one last-minute order	+1.05	
TOTAL	$105.23	
Bills to be paid	-25.77	($11.81 already paid)
TOTAL PROFIT	$ 79.46	

Someone mentioned that taxes had to be paid, so one student went over each receipt and added up the tax, which came to about $6.00.

The next problem was what to do with the money over the vacation. Someone said I should take it home, but I didn't want the responsibility. Therefore, the class agreed that we should open a savings account. The next day I asked the class to think of a name for the savings account; the class voted to call themselves "Cowhouse 5." However, one boy protested because he said the name didn't really indicate that we were a leather company. This led to an argument about whether we were a company or a shop. Although some students thought we were similar to a factory, most agreed that we didn't have machinery like a factory and we were smaller than most factories. Therefore, they decided we must be a shop. They settled on the name "Cowhouse 5 Leather Shop."

Over the vacation, I put $80.05 of the class' $100.05 in a savings account. When classes resumed, I asked the students if they knew why I had kept $20.00 in cash. Their responses were (1) to pay the bills, (2) to get more supplies, and (3) to have some change for customers.

Our next topic of conversation was whether or not to continue manufacturing wristbands. A few students said they had been asked by other students when we would be ready to take orders again. Another student mentioned that many fourth graders had not had an opportunity to place orders because their recess didn't coincide with ours. These arguments convinced the class to resume production.

During the next five months, we continued manufacturing wristbands and eventually switched to leather key chains.

The chart below shows improvements that were suggested by the class and tells whether or not they were implemented.

Improvements	Implemented
Buying leather belt strips at $2.00 apiece rather than using free leather scraps. Students felt that the loss of profit--25¢ per wristband--was worth the savings in labor.	Yes
Improving business through advertising--posters, signs, written ads for the school bulletin, commercials to be acted out.	Yes
Completing orders according to the date they were taken because some customers were upset about having to wait too long for their bands.	Yes
Organizing two shifts so that students who were bored could change jobs.	Shifts were organized, but there was too much confusion when one shift took over from the other and it was too noisy for students who were studying. Therefore, the class went back to the previous system of working together.
Surveying students in the school to determine the number of prospective customers in order to decide how much more leather, snaps, and dye to buy.	Survey was started but data was ignored. Instead students estimated amount of materials to buy and decided to use any extra materials for making other leather goods in the future.
When supplies ran low again, students decided to set a final date for order-taking so that they could determine exactly what supplies to buy.	Yes
Designing an inventory chart to keep track of "Supplies on hand" and "Supplies needed."	Chart was designed but it wasn't kept up-to-date.
Designing forms to keep track of finances.	Yes
Graphing number of orders filled per month, amount of sales per month, and expenses per month.	Yes
Branching out into the manufacturing of leather key chains--ready-made and made to order.	Yes
Designing a catalogue showing styles, designs, and colors of key chains available.	Yes
Using advertising gimmicks to promote key chains, e.g., offering discounts at certain times of year; giving free key chains if a certain number of wristbands were purchased; having a drawing for a free prize, for customers only.	Students were enthusiastic about these ideas but there wasn't enough time at the end of the year to implement them.

3. LOG ON MANUFACTURING

by Barbara Dahlberg*
Lyndale School, Grade 6
Minneapolis, Minnesota
(November 1972–March 1973)

ABSTRACT

The challenge to make some piece of clothing in quantity arose in this sixth-grade class while the students were working on Designing for Human Proportions. Students decided to make Design Lab aprons both for themselves and for sale to other students. After deciding which measurements were needed, they devised and carried out a survey in each grade. The data was tallied on bar graphs and scatter graphs, and the students were able to compare different measurements to determine the relationships between the measurements. Five sizes of aprons were recommended and patterns were made. After comparative shopping for materials, the class began production and found that they needed to solve problems concerning frayed edges, folding and cutting the material, and selecting tie strings. Stations were set up for division of labor and an inspection committee was formed for quality control. A second survey was conducted to determine the sizes and quantities of aprons prospective customers would buy. A sale price was established and a finance group was chosen to take care of money matters. The class sold aprons in the school store and later held an evaluation of their production and sales.

The desire to manufacture aprons arose when my class was working on the Designing for Human Proportions challenge. Initially the children were involved in measuring the heights of everyone in the class to prove that the drinking fountain and the mirrors in their area were too low. Using graphs of their data, they convinced the principal to raise the mirrors.

Then I mentioned the fact that the problems they had worked on were relatively simple compared to designing clothes, and I challenged the class to think of some piece of clothing that they could make. Suggestions included socks, belts, scarves, mittens, and aprons; the class voted to produce aprons. When I asked the children what we should do first, they suggested measuring, and then realized that they didn't know what to measure. One girl suggested designing an apron first and then figuring out what measurements were needed.

*Edited by USMES staff

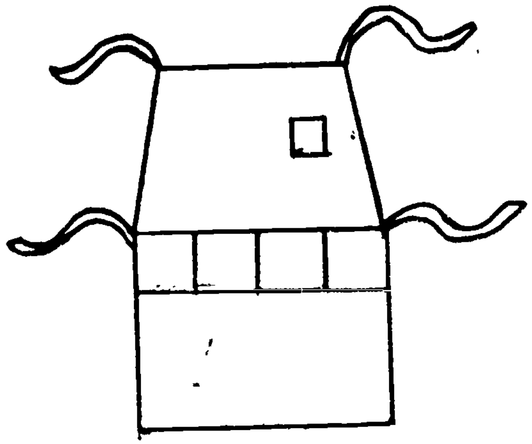


Figure C3-1

grade_____ age_____ sex_____

__________chest width

__________waist to collar bone

__________waist

__________knee to waist

Figure C3-2

The following day, a committee went over the apron designs that had been submitted and chose four. The class voted on the four designs, with the winning pattern shown in Figure C3-1.

A discussion was held the next day on what measurements were needed, and the following list was compiled:

1. length from collarbone to waist
2. chest width
3. waist
4. length from knees to waist
5. hip width
6. length of ties at waist
7. length of ties at neck

One student asked if the class could sell the aprons to other students, a prospect that excited the whole class. Another student then wanted to measure the whole school to see how many sizes they would need to make, but she was reminded that there were 800 students in the school. It was suggested that one class per grade level be measured.

A few days later the class was ready to measure students in each grade. After the children divided into groups, information charts, like the one in Figure C3-2, were distributed by the committee that had designed them. Then the children dispersed to measure the students in their assigned classrooms.

During the next session, a committee of students divided into groups to organize and make graphs of the data collected in the classrooms. This was a problem because the children were not sure how to organize the information. One girl suggested that they find out how many students had the same measurement. The class agreed and this was done by tallying on sheets like the one in Figure C3-3. This activity took a long time because 180 students had been measured.

Next, students were assigned to make bar graphs of the four measurements listed on the information chart and to prepare a report for the class on what their graph showed. While some students made graphs, the rest of the class compiled a list of things they wanted to find out from the graphs:

1. What are the highest and lowest measurements?
2. What is the most frequent measurement?
3. How many sizes would be needed to accommodate all measurements?
4. Is there a pattern formed by the measurements?
5. Is more information needed?

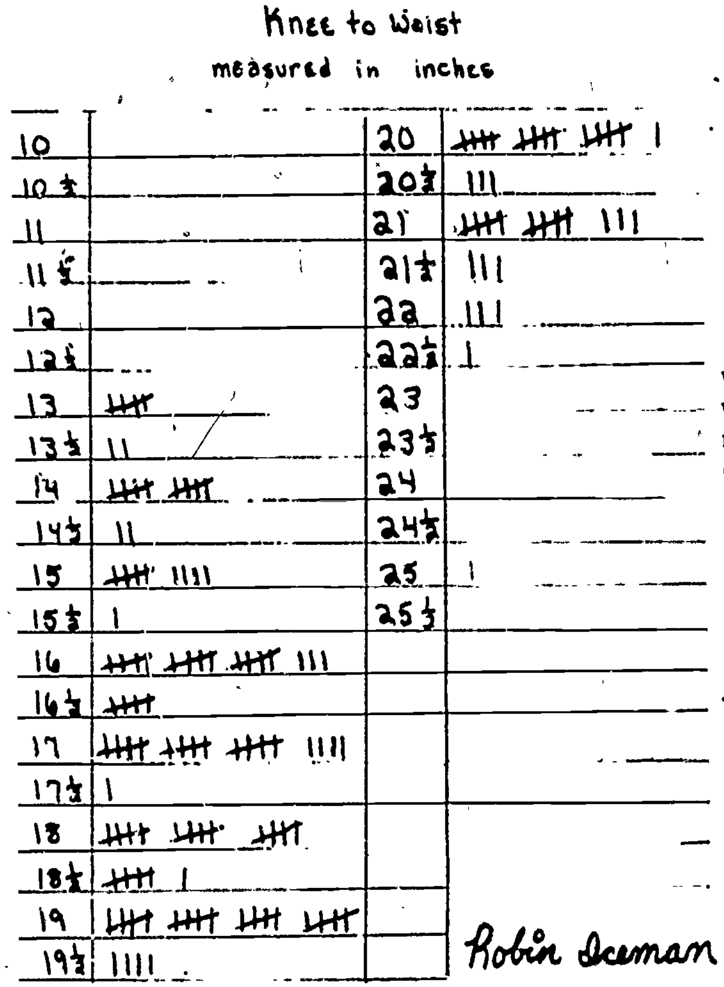


Figure C3-3

For the next four sessions, the groups gave their reports. For example, the group investigating chest width explained their graph (shown in Figure C3-4) as follows:*

1. The range was 6" to 13".
2. The most frequent measurement was 8".
3. Two-thirds of all students measured had chest widths of 7" to 9".
4. Three sizes were recommended,** as follows:

   small: 7" (for 6" to 7½")
   medium: 8½" (for 8" to 9½")
   large: 11½" (for 10" to 13")

5. A comparison of chest width and distance from collarbone to waist was recommended.

After all the reports were given, one student asked how we knew the parts would fit together properly; that is, would a customer necessarily take a medium size in all four measurements? The class groaned as they realized that some comparison of measurements had to be done.#

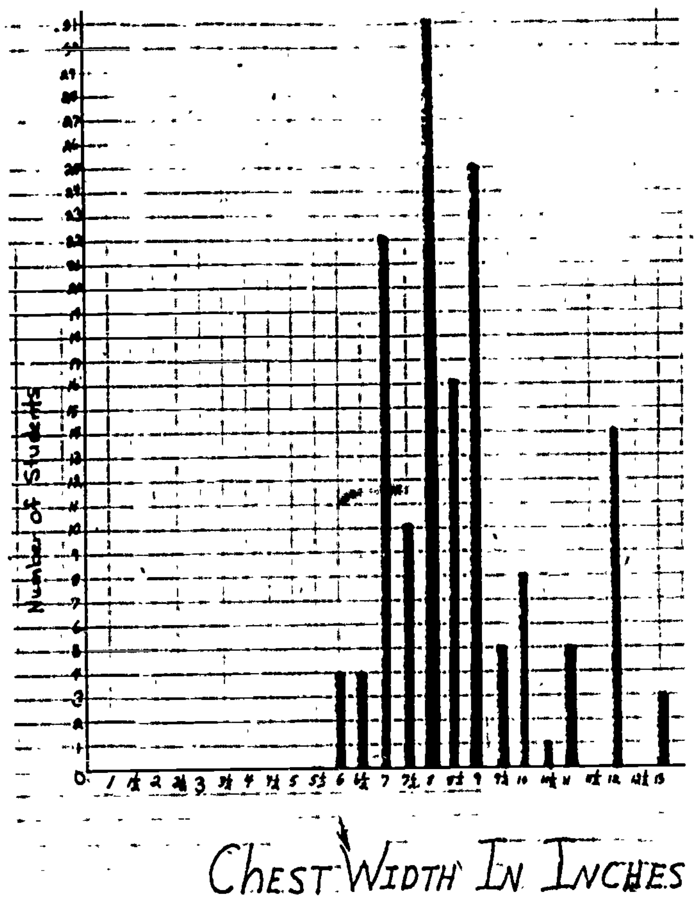
The following day, groups were established to make scatter graphs comparing the following measurements:

Group 1: collarbone-to-waist vs. chest (width)
Group 2: waist vs. waist-to-knee
Group 3: collarbone-to-waist vs. waist-to-knee

*The children might discuss the fact that the bars at each one-half mark (i.e., 6½, 7½) are consistently shorter. They might decide to make a 1" range for each bar rather than a ½" range.--ED.

**The children might be asked to figure out the number and amount of the misfits with each of these three sizes. A misfit might be defined as one inch (or more) too large or too small. Histograms might be constructed on a pegboard; blocks placed on pegs in appropriate holes would represent misfits. The children could then try to reduce the number of misfits by changing the three sizes.--ED.

#An interesting mathematical analysis would be the number of separate sizes required if all the above choices were needed independently. If there were only three sizes in each of the four categories, then there would be $3x3x3x3 = 3^4 = 81$ separate sizes.--ED.



Ruth Lacy

Figure C3-4.

That afternoon, each of the three groups presented their graphs, two of which are shown in Figures C3-5 and C3-6.

Group 1

The graph comparing collarbone-to-waist with chest width showed definitely that as one measurement increased, the other increased. The students grouped the dots on their scatter graph into five groups. For each group the following measurements were recommended:

	A	B	C	D	E
Chest width	7"	8"	8"	9"	11"
Collarbone-to-waist	9"	11"	13"	15"	17"

Group 2

The group comparing waist with waist-to-knee measurements found their scatter graph very confusing because the dots were spread all over the page. Their recommendation was that the graph have no part in determining the sizes since the waist measurement on an apron is not vital.

Group 3

The collarbone-to-waist vs. waist-to-knee graph showed that the two measurements were only slightly related. However, as the distance from collarbone to waist increased, so did the distance from waist to knee. The group had decided that the distance from the collarbone to the waist was more crucial than the distance from the waist to the knee because the hem could be lengthened or shortened. Keeping this in mind, the group recommended five waist-to-knee sizes that correlated with the five sizes given by the chest width vs. collarbone-to-waist group.

The next day the class indicated that they were satisfied with all the data collected and wished to establish the sizes before Christmas vacation. All the graphs were posted in front of the room so that everyone could see them. We decided to use the sizes recommended by the collarbone-to-waist vs. chest width group. To these measurements we added the measurements for the length from waist to knee recommended by the collarbone-to-waist vs. waist-to-knee group. Using the results of the waist vs. waist-to-knee graph, we concluded that the waist varied throughout the rest of the measurements. Therefore, the class decided to make the width of the aprons 20"-23" with long tie strings to accommodate all size waists.

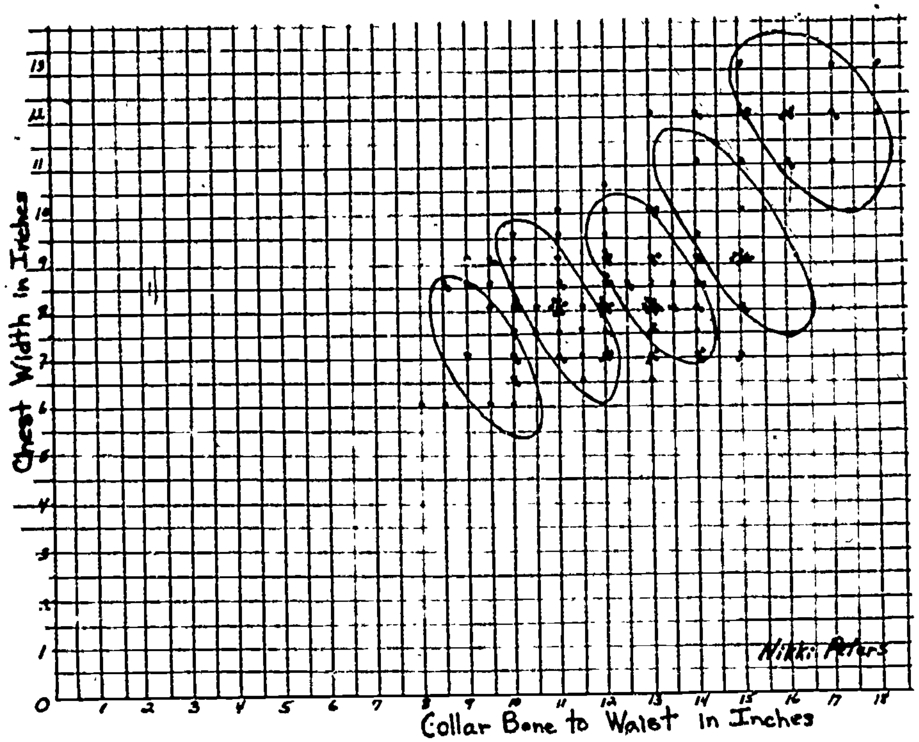


Figure C3-5

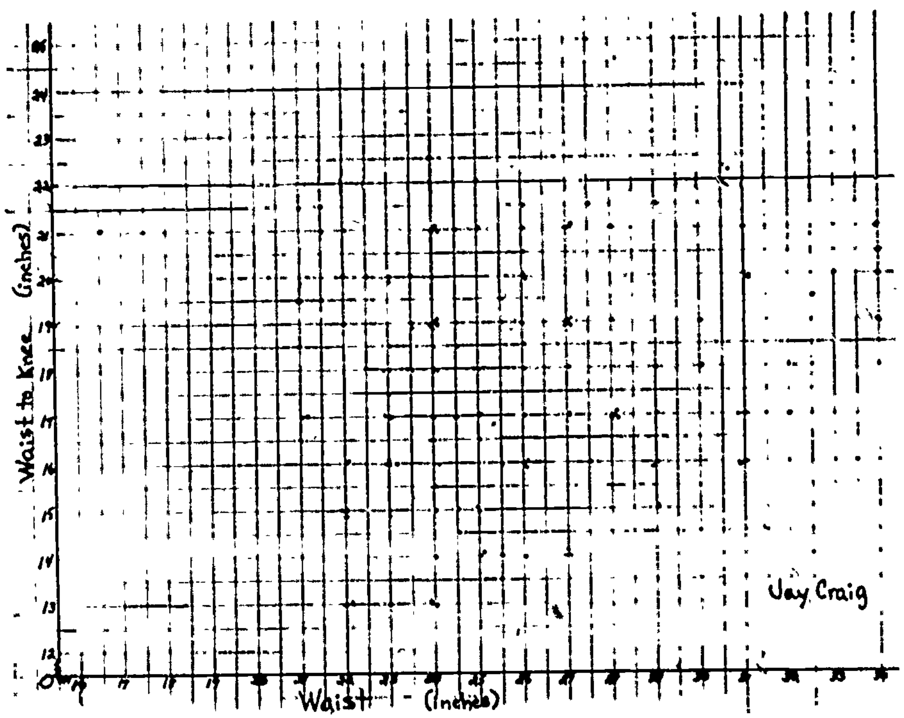


Figure C3-6

From the graphs the class established the following five sizes and measurements:

	A	B	C	D	E
Chest Width	7"	8"	8"	9"	11"
Collarbone-to-Waist	9"	11"	13"	15"	17"
Waist-to-Knee	18"	19"	19"	20"	21"
Width of Apron	20"	21"	21"	22"	23"

One student commented that sizes B and C could be combined since they varied at only one point, but the class disagreed since that was the measurement they considered the most crucial.*

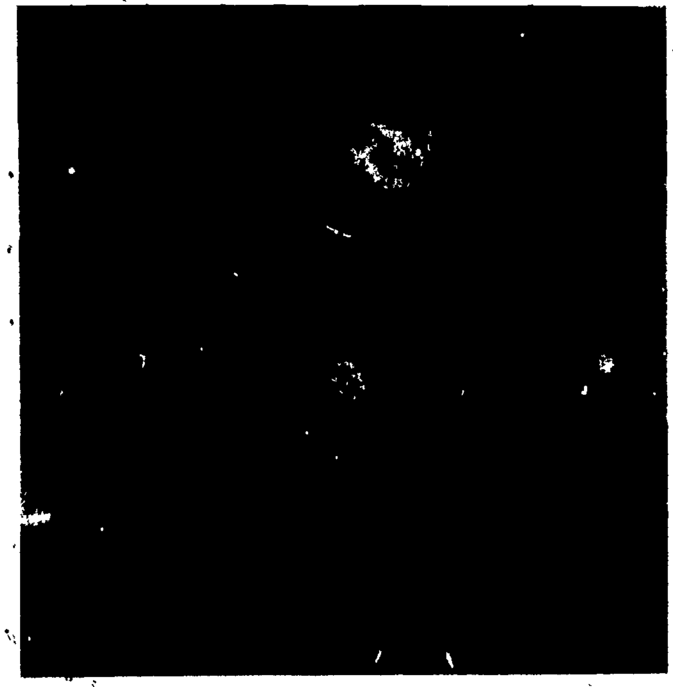
After Christmas vacation the class chose five students to go shopping with me to buy the fabric. After going to three department stores, they decided that J.C. Penny offered the best buy. Material was judged by feel and price, and the students chose the medium-priced heavy cotton at $1.59 per yard. This fabric came in many colors, so they decided to buy five different colors so that they could have contrasting pockets. It did not occur to the students to buy a variety of fabrics to see which one would work best. They liked the feel of their fabric and that settled it.

During the next session, work began on the aprons with each student making his or her own apron from start to finish. Students did work in pairs, however, to pin and cut the patterns because the material came folded. This made it more efficient to cut two aprons at a time.

While pinning the patterns, students made several discoveries. First, they noticed that too many pins bunched up the material, while too few pins didn't hold it down enough. They also realized that the material had to be refolded to make the largest size. Their first impulse was to cut the pattern down to fit the material, but fortunately one student realized that this defeated all their prior work in measuring.

Students began to notice that the edges of the aprons tended to fray, so the class considered three possible solutions: glue the edges, fold over the edges and staple, fold over the edges and sew them with a sewing machine. The

*The children could verify this premise by checking the number of misfits that would result from this combination of sizes. (See second footnote on page 75.)--ED.



Pinning the apron edge.

class voted to use the last suggestion, and those who were ready began folding and pinning the edges, while the others continued cutting. When it was time to use the four available sewing machines, one mother volunteered to help by showing the students in groups of four how to run the machines.

Four sessions after they began making the aprons, the class decided to eliminate some of the general confusion in the room by setting up stations for pinning and cutting out patterns, pinning edges, and using sewing machines. This change not only made things more organized but also motivated students to help each other.

During the next two sessions, problems arose for those making apron ties. The original method involved figuring out three different lengths of ties by experimenting with various lengths of yarn, cutting thin strips of material, and sewing the edges. When it became apparent that this method was very frustrating, the students suggested using ribbon, string, or yarn. The class voted on the three choices with ribbon getting the most votes. Three students then bought a sample of cotton ribbon (at 17¢ per yard) to show to the class. After receiving the approval of the class, fifteen yards of the cotton ribbon were purchased.

The next day, the class discussed the following sewing tips they had discovered:

- The material is easier to cut out if it is pinned neatly.
- The edges are easier to fold if the material is cut straight.
- When pinning the edges keep the pins going in the same direction which makes it easier to sew on the machines.
- Make sure the edges are folded over neatly so that they do not pull out after sewing.
- Don't hurry at the sewing machines.
- Wash your hands, especially when working with the white material.
- Measure the ribbon carefully so that we don't waste any.

Sewing an apron.

When several students had finished their first aprons, another problem had to be solved. They noticed that the pockets had a tendency to come loose at the top, and they agreed that further reinforcements were needed at these points. During the course of the discussion it was also suggested that each student make sure all threads were tied and cut off before turning the apron in as complete. One student suggested that an inspection committee be formed to check that the aprons were well-constructed. Consequently, four students were elected as an inspection committee.

As the proposed sale got closer, the students' enthusiasm grew. Students were ironing their completed aprons, and several girls began labeling the aprons by size. With eleven aprons completed, the class was divided about whether to open the store and take orders or to wait for more aprons to be finished. The class decided to postpone the sale but to think of ways to speed up production. One of the longest tasks was the pinning of the edges. One student suggested that the best sewers stay at the sewing machines, while the remaining class members cut and pinned edges. As a result, three girls and one boy stayed at the machines. After this change, several students could see the value of working together and noticed that the final product was often better than before.

During a discussion several days later, one boy suggested setting up a system for working together. An assembly line with one table for cutting, two tables for pinning edges, an area for sewing, and an area for pocket design was discussed and agreed on. Seven people opted to work alone, and the rest joined the assembly line. (Later, all but one student joined the line.)

The next day, students discovered that they had used all their material and had made twenty-two aprons. One boy reported that he had taken a quick survey in their section of the school and that more than twenty-two students wanted to buy aprons. Since the class had spent the $25.00 sent by USMES, they decided to set up a finance committee to investigate the possibility of a loan. The committee members presented me with the following reasons why I wouldn't have to worry about being paid back on a loan:

1. Adults' enthusiasm to buy the aprons.
2. Students' interest in buying aprons.
3. Mother's Day was coming up.
4. Obviously, anyone investing would get their money back.
5. I would get a free apron.

After this presentation, a committee member requested a $50.00 loan. With an offer like that, who could refuse?

A group of students were chosen to accompany me to the store, and a request was made that a wider variety of colors and designs be purchased. After school we went to the store where each student picked out two bolts of material. Several yards were purchased from each bolt. The students seemed to be more aware of the cost per yard this time, and they commented that the heavier material, which was out of their price range, would probably last longer. I was hoping they would experiment with fabrics, but they ended up purchasing twenty yards of the same material in various colors and designs and thirty yards of ribbon.

The students were elated over the new material and were eager to get to work. They reorganized their assembly line so that six students were cutting, ten were pinning, four were working at the sewing machines, four were designing pockets; the rest were working alone. The students were now aware that sloppy work was a waste of money and they began policing each other's work. As a result, the assembly line technique became smoother. At that point, some students expressed a concern about having enough aprons in the most popular sizes. Combining their visual observations of the sizes of people in the halls and the data collected on their graphs, the class agreed to make more aprons of sizes A, B, and C.*

The following day, one student came up with a new idea. She asked whether she could use the scraps to make an apron for her baby brother. A few students, who were impatient with the length of time necessary to make a large apron, decided to make small aprons to be sold at half the regular price. One boy came up with the idea of using some of the small aprons for advertising purposes.

At that time, an inventory report showed thirty aprons completed. The financial committee also gave a report in which they suggested a sale price of $2.00 for a large apron and $1.00 for a small apron, based on the cost of materials and the goal of seventy completed aprons.

Production continued and the class decided that a formal inspection committee should be formed to examine the aprons for the following problems:

---

*The students might be asked how they could get a more accurate idea of the number of each size apron that might be sold. See Background Paper, *PS4 Design of Surveys and Samples*.--ED.

Hemming an apron.

1. Are edges sewn well?
2. Are the strings secure?
3. Are all loose threads tied?
4. Are all pockets sewn on and secured at the top?

As a result of this careful inspection, many aprons were returned for repair or finishing touches, and the students began working more slowly and carefully.

The assembly line techniques were also refined. Laying out and cutting were done by four girls who had mastered these steps. The most-disliked job, pinning the edges, was done by fifteen students. Several students designed pockets and attached them; the same four students were still using the sewing machines. Anyone who got tired of his or her job could work on posters to advertise the sale.

Since the date for the sale had been set for March 15, five students started setting up the store area. A display of aprons and a sign asking for a $2.00 donation were posted on the wall behind the store area. A work schedule was created, and one boy was given the responsibility of making sure the money collected each day correlated with the number of aprons sold.

A few days before the sale, the class began their advertising campaign. They had already made posters telling other students to "Keep Clean, Wear an Apron!" and giving the prices and the date and time of the sale. The posters were placed in various parts of the school. To advertise further, three students wearing aprons visited each classroom to announce the sale.

On March 15 the sale began with fifty-six aprons available in the following sizes:

AA	--	5 (baby aprons)
A	--	9
B	--	11
C	--	12
D	--	4
E	--	3
Aprons on Reserve	--	12
		56

DATE	Expenses Purchase	Cost
Jan Something	material	$ 25.00
Jan. 20, 1973	Rybon	$ 4.76
FEB. 25. 1973	material	$ 27.89
FeB. 26. 1973	Rybon	$ 14.25
march. 10. 1973	Rybon	$ 3.66
march. 17. 1973	Rybon	$ 6.08

$81.64

Figure C3-7

DATE	Sales Amount
Thrusday march. 15. 1973	26 aprons $52.00
Friday march. 16. 1973	12 aprons $24.00
monday march. 1973	9 aprons +1 baby $17.00
Wednesday 21. 1973	5 aprons $10.00+$4.00

$107.00

The Great Profit
$25.36
3/21/73

Figure C3-8

The store was open before school and during recess, and twenty-six aprons were sold the first day for a total of $52.00. In their spare time, students sewed and kept a close watch on the money drawer. After a week, the last of the aprons had been completed. Of the sixty-nine aprons for sale, fifty-four regular aprons and one baby apron had been sold. The sheets on which the finance group kept track of expenses and sales are shown in Figures C3-7 and C3-8. When the financial report was given, one student noticed a miscalculation--the sales amounted to $109.00 rather than $107.00, raising "the great profit" to $27.36.

Near the end of the sale, the class analyzed what had happened. They noticed that their aprons were a popular item, that people preferred patterns over solid colors, and that people chose smaller sizes than expected (customers bought aprons that measured approximately 5" above the knee and 2"-3" below the collar bone). The students agreed that if they sold aprons again, they would make smaller sizes and choose materials with bright colors and patterns.

Next, we had to start thinking about what to do with the money from the sale. At that point, we had $109.00 in total sales, $81.64 total expenses, and $27.36 profit. First I asked the class what we could do for the two teachers who had loaned their sewing machines. Suggestions included flowers, candy, perfume, aprons, and a party; they agreed on perfume. While shopping for the gifts, several girls decided to give one teacher perfume and an apron and to give the other one perfume and powder since she had already bought an apron. A total of $4.76 was spent. Suggestions on how to spend the rest of the money included the following:

pencils	tape recorder	more fabric
books	sports equipment	roller skating
split money	waterbed	Como Zoo
aquarium	records	

By the time the sale was over, $126.00 worth of aprons had been sold, giving us a profit of $44.36. The children gave a party for $9.60 and donated the remaining $30.00 to the library. Our final financial statement was as follows:

1 apron to one of the teachers who loaned them a sewing machine
1 apron for me
1 apron mailed to USMES
3 unsellable aprons (due to sewing mistakes beyond repair)
68 aprons sold (10 were baby aprons).

Total amount sold	$126.00
Expenses (cost of fabric & ribbon)	- 81.64
Profit	44.36
Gifts	- 4.76
	39.60
Party	- 9.60
	30.00
Library Donation	- 30.00
	0.00

In the final analysis, the students were very pleased with their work, but they did come up with the following list of changes they would make if they were to start all over again.

1. We should do a style survey.
2. Organize more sewing after school.
3. Work into an assembly line earlier.
4. Try to get a department store to carry the apron.
5. Start during the first weeks of school.
6. Have two styles of aprons.
7. Cut out three or four aprons at a time.
8. See if there is something cheaper than ribbon for the straps.
9. Cut costs by buying material on sale.
10. All pockets should be large.
11. Keep store open only before and after school hours.
12. No charging of aprons--too difficult to collect.

4. LOG ON MANUFACTURING

by Pamela Johnson and
Stanley Myk*
Hannah Middle School, Grades 6-7
East Lansing, Michigan
(December 1973-January 1974)

ABSTRACT

When a need for more three-dimensional "tic-tac-toe" games arose in this combination sixth- and seventh-grade class, a group of twenty-five students decided to manufacture one game per student and approximately ten extras for sale. The class worked for an hour a day, four times a week for four weeks. They began by selecting wood for the base and then formed groups to carry out cost comparison of materials, to devise an order form, to make scale drawings of the game, and to raise money for supplies through a bake sale. While the prototype was being constructed, the students recorded the time necessary for each step. They then revised their original assembly line process in terms of production time and job distribution. Group supervisors checked for quality control. After they completed production, the students established a price and selected the ten best games to sell. Other students were polled to establish prospective customers. Because of the demand, all of the games were sold. An informal student evaluation of their manufacturing process was held. Finally, the group discussed what to do with the profit and eventually voted to pay each person who had worked on the games.

Working together, the industrial arts teacher and I began by asking the students to write a brief definition of the word manufacturing. I then asked the class, "What do you think of when I say the word manufacturing?"

We made a list and categorized the ideas under different areas of manufacturing, e.g., designing, producing, and selling. We also discussed why, how, and what people manufacture. The class was then presented with a hypothetical problem: "If you worked in a factory and you were told that you had five weeks to manufacture 100 yo-yos, what would you do?"

The class realized that a design would have to be made, materials bought, workers found and trained, expenses cal-

*Edited by USMES staff

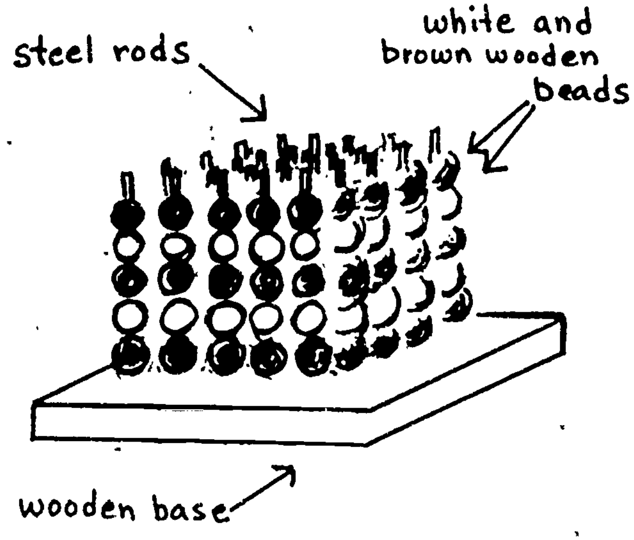


Figure C4-1

culated and a price set, and the yo-yos would have to be boxed, advertised, and sold.

The class was then challenged to think of a product they needed that could be manufactured in four weeks. The next day, the students discussed possible products and developed a list of forty-five items.

The class spent the next two sessions discussing and voting on possible products to manufacture, keeping in mind the time limit, the materials available, and the skills necessary to make each item. After eliminating all but six items (candle holders, leather key chains, book ends, three-dimensional tic-tac-toe games, chess- and checkerboards, wine holders) the class discussed which item would be the most attractive to sell and the easiest to make. The class then voted to produce three-dimensional tic-tac-toe games. A sketch of the final product is shown in Figure C4-1.

The need for these games had developed in the class approximately one month before the challenge was introduced.* I had brought in one game for the entire class of 110 students, and everyone wanted to use the game at the same time. There were many complaints about who should play next, how long a game should be, and why there couldn't be more games available. Thus, there was a real need for the students to manufacture more games.

At the next session, the class brainstormed to figure out a tentative plan for production. As a start they decided to design one complete game as a prototype. The number of games to be produced was also discussed; the class decided to make one game per student and an undetermined number to be sold.

For the next two days we met in the Design Lab where we chose the type of wood to use for the base and devised the following list of production operations and the tools needed to carry out each procedure:

1. cutting with a band saw
2. rough sanding with a disc sander
3. final sanding with a hand sander
4. finishing (oiling)
5. drilling holes with a drill press
6. cutting pegs with a hack saw
7. pounding pegs with a hammer

*The challenge might be issued as soon as the need for a product becomes apparent.--ED.

Dec. 18 (Tues.)

Order Form for Peg Committee

Length of pegs

7 cm 7 mm - peg
1 cm 5 mm - pounded in
5 mm - extra at top
8 cm 17 mm
9 cm 7 mm length of peg

no. of pegs

25 pegs
x 36 games
150
75
900 - total no. of pegs

lenghth of pipe needed -
9000 cm = 90 m of
3 mm or 1/8" pipe

[illegible]

Figure C4-2

While two previous industrial arts students demonstrated the tools needed to produce the game, others observed and asked questions. Safety procedures in the lab were also discussed. Then each student tentatively stated what type of job he or she wanted to perform.

Next, we gathered as a group so that students could decide if they were ready to start. The consensus was that the following items had to be taken care of before production could begin:

1. elect a chairman
2. appoint a safety engineer and a general supervisor
3. make a template to show the locations of pegs on the base
4. assign jobs to individual students
5. make copies of production procedures for all workers

In the remaining time, the class took care of the first item by electing a chairman and a vice-chairman.

The next day the class decided to form committees to decide on the sizes and amounts of wood, wooden beads, and steel pegs necessary to produce the games. (See Figure C4-1.) Before committees could start planning, the class had to make a firm decision about the number of games to produce. They agreed on thirty-six; one for each student and teacher working on the unit and ten extras.

Those in charge of beads decided to call local vendors and compare costs, while the other committees spent time preparing order forms to submit to the industrial arts teacher. Student calculations and order forms are shown in Figures C4-2 and C4-3.

For the next two days, students worked in committees and then met as a group to discuss their findings. Since the wood committee could not decide between a 5" x 5" and a 6" x 6" base, they brought the issue up in the group meeting. The 6" x 6" base was chosen unanimously because the class agreed that it was easier to figure out the positions of the steel pegs on this size After the vote was taken, students proceeded to make scale drawings for templates to be used to indicate the location of pegs on the base. One scale drawing is shown in Figure C4-4. A money-making committee was also formed; they planned to have a bake sale to raise money for the purchase of beads.

At the beginning of the next period, the group analyzed the order forms for materials submitted by each committee,

Wood Comm.

wood	cherry
boardft.	9½
no. of games	36 plus exas
games per boardft	4
Demmonetions	6x6 x 3/4
cost	$5.90

Bead Committee.

Bead: circumference 19 mm
hole 1/8 inch
white and black

Quanity: 4500 beads
125 beads per game
36 beads per pack.
125 packs.

Price: $128.75 total with tax
$4.95 1/5 per game
.36 beads 99¢

Figure C4-3

checking to see that the forms were complete and accurate. The group then decided which scale drawing to use to make the template. Then we asked, "What do we do next?" Suggestions included starting production, assigning jobs, and making a sample game. At that point, we led a discussion about the advantages of making a prototype, and the class decided to make one at the next session. They also had a hearty debate about whether or not to have an assembly line. Some students preferred having each person make a complete game. Others suggested that groups of three or four students work together. However, there was a core of students who insisted on mass production in order to get the most work accomplished in the least amount of time. After much discussion, this was generally accepted as the best idea.

After vacation, we made plans for and began work on a prototype of the three-dimensional tic-tac-toe game. Those students with previous industrial arts experience were assigned jobs; the rest of the class acted as observers, inspectors, and timers. The data recorded by the timers is shown in Figure C4-5. When the students realized how long it took to cut the steel pegs, they came up with a new procedure: they cut a steel tube the desired length and clamped it with a vise, then put the peg inside and cut it off with metal snippers. After two sessions of work, the prototype was completed.

The next day, the head timer reported on the time for each step in the production of the prototype. Below is a list of jobs and the time required for each one:*

Job	Time Required
marking wood	55 sec.
cutting wood	55 sec.
disc sanding	50 sec.
hand sanding	3 min. 14 sec.
facing	40 sec.
setting holes	1 min. 25 sec.

*The students might look over the list of jobs to see whether several could be done at the same time. Each job could then be tried and the total time to make one three-dimensional tic-tac-toe game calculated; only the longest of concurrent jobs would be included in this total.--ED.

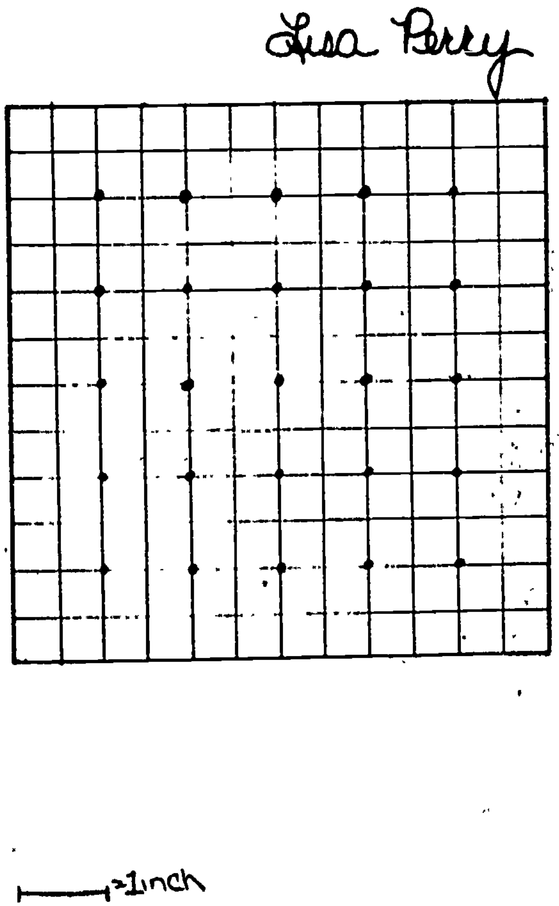


Figure C4-4

Job	Time Required
drilling holes	6 min.
sanding	10 sec.
finishing	1 min. 35 sec.
peg cutting	2 min. 35 sec.
peg pounding	4 min. 10 sec.
peg filing	2 min. 35 sec.

Before job assignments were made, one student suggested that "production time" should be the key factor in determining the number of workers per job. The class agreed and began estimating the number of people needed for each job without considering the number of students in the class. As a result, they came up with thirty-two positions and only twenty-four available workers. When they finally realized that they had a worker shortage, the job distributions were revised as follows:

Job	No. of Workers
measuring and cutting wood squares with band saw	3
disc sanding	1
hand sanding	4
marking holes with a template on wood base	4
marking holes for pegs with an electric drill	4
finishing wood base with linseed oil	2
cutting pegs	2
filing one end of pegs	2
pounding pegs in wood base	2

The chairman next asked for volunteers for each job. Committee chairmen were appointed as supervisors to watch for errors in production, and a general supervisor was also elected.

When it was announced near the end of the session that the total production time would be 22 minutes and 44 seconds per game,* the students strongly protested that this was the

*A check of the total on the students' data sheet shows that the actual total production time was 28 minutes and 4 seconds, including the 3 minutes allowed for the product to be passed from one worker to the next. The discrepancy is due to the students' use of the decimal system of addition when adding the seconds to the minutes.--ED.

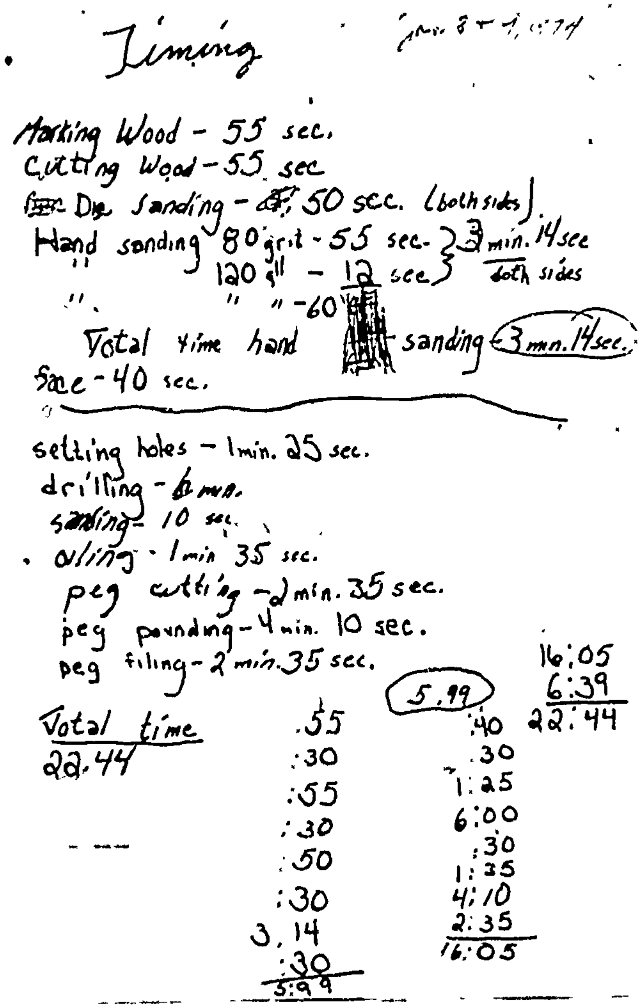


Figure C4-5

time needed for making the prototype. They argued that the actual production time would be less than the time necessary to make the prototype, for the following reasons:

1. Their skills would improve.
2. They would become more familiar with the jobs and tools.
3. When an assembly line was organized, there would be more workers per job.

That afternoon a bake sale was held after school and $17.42 was raised. The money was to be used toward the purchase of the beads. Because the amount of money raised was insufficient to purchase all of the beads needed, the money-making group planned to have another bake sale the next week.

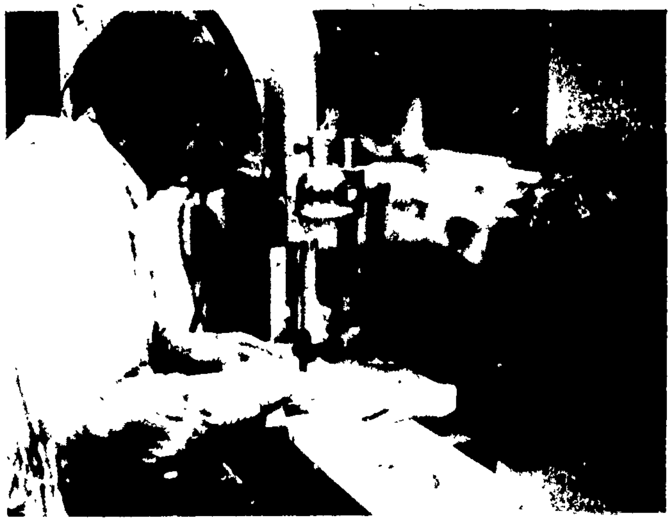
The next day was the first day of production. The class held a brief meeting and decided that the prototype did not need modification. During the remainder of the period, thirteen games were started and one was completed. Since some of the students at the end of the assembly line didn't have much to do at first, they moved up the line and worked where they were needed.

For the next four days, production continued as students set up and worked on their own with no adult supervision except for technical assistance. Because of high student interest, there were no discipline problems whatsoever.

Students took their work very seriously and quickly gained in proficiency. When asked how they liked their jobs, most students, especially the peg filers and hand sanders, responded that the work was boring or tiresome. Yet the students' daily overall reaction indicated that they were enthusiastic and interested in the unit. Although they did express some discontent with their jobs, the students never initiated any changes in the original job assignments. On the other hand, when one area needed help or "bottlenecks" occurred, students filled in where they were needed. As for quality control, some of the girls were good inspectors and constantly demanded high quality.

On the fourth day of production the last game was completed as the students cheered. Thirty-nine games had been completed in five sessions, approximately 3 hours and 45 minutes.* Since two games were given to the school and one to USMES, there were ten games for sale as planned.

*This works out to 5 minutes and 46 seconds per game, much less time than for the prototype. See footnote on page 89. --ED.



Cutting the base.

At the next session, we discussed the price of the ten games to be sold. After figuring out that the cost of the materials needed to make each game was $3.17, the students voted to make $1.82 profit per game. This put the sale price at $4.99. The class decided to poll neighbors and students at school for prospective buyers.

For the school polls, an advertisement committee was formed and met after school. They set up one sample game in the school display case and prepared an announcement that asked prospective buyers to sign up for a game the next day at the ticket booth. To poll neighbors, the class decided that each student should try to find at least one prospective buyer and bring the name to school the following day.

At the next session, the students divided into groups to select the ten best games which were to be sold. Their selection was based on the following factors:

1. squareness of base
2. quality of sanding operation
3. alignment of holes
4. equal length of all pegs
5. general appearance of game

The students were very critical of the games. One student commented that choosing the best games wouldn't have been so difficult if quality control had been better.

The advertisement committee then reported that a total of fourteen people expressed willingness to buy the games. During this session, I asked the students to fill out an evaluation of the unit. Student responses to four of the open-ended questions are recorded below:

1. I think the manufacturing unit was

   8 fun, interesting.
   4 fun, because we could see what it was like to work in a factory.
   2 fun in most cases, but it got to be boring sometimes.
   2 fun because we got to work together in the lab.
   2 fun and educational.
   1 really fun, and I wish we could do it again.

Sanding the base.

2. The thing(s) I liked best were

   9 the actual production; working in the Design Lab.
   4 working as a team.
   3 having everything done; the end result.
   2 the brainstorming sessions.
   1 no comment.

3. The thing(s) I liked least were

   7 hand sanding and filing pegs.
   6 planning sessions.
   2 doing the same job over and over.
   1 people bossing others around.
   1 having another class in the Design lab at the same time.
   2 no comment.

4. If I had my way, we would

   5 do another manufacturing unit.
   4 have had better quality control.
   2 do it the same way.
   2 have been able to rotate jobs.
   1 have coordinated the sizes of the beads and pegs better.
   1 have had more sanders.
   4 no comment.

After the games went on sale and people became aware of the quality of the product, the demand increased greatly. As a result, we sold all thirty-six of the games, including those that were imperfect.

At our last session, we discussed how we should distribute the profit. The class suggested that the money could be used for--

1. camping funds for our class
2. camping funds for the whole school
3. paying each worker $4.75
4. paying those workers who bought a game $4.75, and those who did not buy a game $1.25; left-over money to go to the camping fund
5. paying half to the workers and giving the other half to the camping fund for the school

6. paying half to the workers and giving the other half to camping fund for the class
7. eating out at a restaurant
8. paying only those workers who bought games

The class then voted on these suggestions with the outcome that each worker received $4.75.

Drilling holes for pegs.

D. References

1. LIST OF "HOW TO" CARDS

Below are listed the current "How To" Card titles that students working on the Manufacturing challenge might find useful. A complete listing of both the "How To" Cards and the Design Lab "How To" Cards is contained in the USMES Guide. In addition, the Design Lab Manual contains the list of Design Lab "How To" Cards.

GRAPHING

- GR 1 - How to Make a Bar Graph Picture of Your Data
- GR 2 How to Show the Differences in Many Measurements or Counts of the Same Thing by Making a Histogram
- GR 3 How to Make a Line Graph Picture of Your Data
- GR 4 How to Decide Whether to Make a Bar Graph Picture or a Line Graph Picture of Your Data
- GR 5 How to Find Out If There is Any Relationship Between Two Things by Making a Scatter Graph
- GR 6 How to Make Predictions by Using a Scatter Graph
- GR 7 How to Show Several Sets of Data on One Graph

MEASUREMENT

- M 1 How to Use a Stopwatch
- M 2 How to Measure Distances
- M 9 How to Make a Conversion Graph to Use in Changing Measurements from One Unit to Another Unit
- M 10 How to Use a Conversion Graph to Change Any Measurement in One Unit to Another Unit

PROBABILITY AND STATISTICS

- PS 2 How to Record Data by Tallying
- PS 3 How to Describe Your Set of Data by Finding the Average
- PS 4 How to Describe Your Set of Data by Using the Middle Piece (Median)
- PS 5 How to Find the Median of a Set of Data from a Histogram

RATIOS, PROPORTIONS, AND SCALING

- R 1 How to Compare Fractions or Ratios by Making a Triangle* Diagram
- R 2 How to Make a Drawing to Scale
- R 3 How to Make Scale Drawings Bigger or Smaller

*Presently called slope diagram.

New titles to be added in 1976:

How to Round Off Data
How to Compare Two Sets of Data by Making a Q-Q Graph
How to Design and Analyze a Survey
How to Choose a Sample
How to Compare Two Sets of Data by Using Interquartile Ranges
How to Design an Experiment
How to Make and Use a Cumulative Distribution Graph

A cartoon-style set of "How To" Cards for primary grades is being developed from the present complete set. In most cases titles are different and contents have been rearranged among the various titles. It is planned that this additional set will be available early in 1977.

2. LIST OF BACKGROUND PAPERS

As students work on USMES challenges, teachers may need background information that is not readily accessible elsewhere. The Background Papers fulfill this need and often include descriptions of activities and investigations that students might carry out.

Below are listed titles of current Background Papers that teachers may find pertinent to Manufacturing. The papers are grouped in the categories shown, but in some cases the categories overlap. For example, some papers about graphing also deal with probability and statistics.

The Background Papers are being revised, reorganized, and rewritten. As a result, many of the titles will change.

DESIGN PROBLEMS

DP 13 People and Space by Gorman Gilbert

GRAPHING

GR 3 Using Graphs to Understand Data by Earle Lomon

GR 4 Representing Several Sets of Data on One Graph by Betty Beck

GR 6 Using Scatter Graphs to Spot Trends by Earle Lomon

GR 7 Data Gathering and Generating Graphs at the Same Time (or Stack 'Em and Graph 'Em at One Fell Swoop!) by Edward Liddle

GROUP DYNAMICS

GD 2 A Voting Procedure Comparison That May Arise in USMES Activities by Earle Lomon

MEASUREMENT

M 1 Gulliver's Travels Activity by Abraham Flexer

M 3 Determining the Best Instrument to Use for a Certain Measurement by USMES Staff

PROBABILITY AND STATISTICS

PS 4 Design of Surveys and Samples by Susan J. Devlin and Anne E. Freeny

PS 5 Examining One and Two Sets of Data Part I: A General Strategy and One-Sample Methods by Lorraine Denby and James Landwehr

PS 6 Examining One and Two Sets of Data Part II: A Graphical Method for Comparing Two Samples by Lorraine Denby and James Landwehr

RATIOS, PROPORTIONS, AND SCALING

R 1 *Graphic Comparison of Fractions* by Merrill Goldberg
R 2 *Geometric Comparison of Ratios* by Earle Lomon
R 3 *Making and Using a Scale Drawing* by Earle Lomon

3. BIBLIOGRAPHY OF NON-USMES MATERIALS

The following books are references that may be of some use during work on Manufacturing. Publishers' prices may have changed. A list of references on general mathematics and science topics can be found in the *USMES Guide*.

A. Comparative Shopping and Product Testing

Consumer Education Materials Project. *Elementary Level Consumer Education*. Mount Vernon: Consumers Union of the U.S., Inc., 1972. ($3.00. Order from Consumers Union, Education Services Division, Orangeburg, N.Y. 10962.)

Case studies from various school districts and communities demonstrate various approaches to teaching consumer education. Includes computation of unit prices, comparative shopping, product testing, and use of scrap materials in making things. For teachers.

Gay, Kathryn. *Be A Smart Shopper*. New York: Simon and Schuster, Inc., 1974.

Explains comparative shopping, advises reader on how to be a more responsible shopper. For children.

See also BIBLIOGRAPHY in the Consumer Research Teacher Resource Book.

B. Mass Production and the Assembly Line

Grant, Neil. *The Industrial Revolution*. New York: Franklin Watts, Inc., 1973.

Historical background to mass production. Suitable for teachers and upper elementary children.

Lazarus, Harry. *Let's Go To A Clothing Factory*. New York: G.P. Putnam's Sons, 1961.

The process of manufacturing a boy's sport shirt is described step by step. A flow diagram of the sewing room at the factory is shown and quality control is discussed. For children.

Sullivan, George. *How Do They Make It?* Philadelphia: Westminster Press, 1965.

Descriptions of the various processes used in the manufacture of twenty everyday food and household products such as soap, soft drinks, and batteries. For children and teachers.

C. Ideas and Directions for Making Things

Carrey, Mary. *Step-by-Step Candlemaking.* New York: Golden Press, 1972.

Corrigan, Barbara. *Of Course You Can Sew! Basics of Sewing for the Young Beginner.* Garden City: Doubleday and Co., Inc., 1971.

Howard, Sylvia. *Tin-Can Crafting.* New York: Sterling Publishing Company, Inc., 1959.

Mattil, Edward. *Meaning in Crafts.* Englewood Cliffs: Prentice Hall, Inc., 1959.

Villiard, Paul. *Jewelrymaking.* Garden City: Doubleday and Co., Inc., 1973.

Weiss, Harvey. *How To Make Your Own Books.* New York: Thomas Y. Crowell Co., 1975.

Young, Jean. *Woodstock Kids' Crafts.* New York: Bobbs-Merrill, 1974.

The above references are only a few examples of the many excellent crafts books available. The children's use of crafts books will depend on their choice of an item to be produced.

D. Books for Children

Merrill, Jean. *The Toothpaste Millionaire.* Boston: Houghton Mifflin Company, 1972.

Excellent book describing comparative shopping, production methods and setting up a company.

4. GLOSSARY

The following definitions may be helpful to a teacher whose class is investigating a Manufacturing challenge. Some of the words are included to give the teacher an understanding of technical terms; other are included because they are commonly used throughout the resource book.

These terms may be used when they are appropriate for the children's work. For example, a teacher may tell the children that when they conduct surveys, they are collecting *data*. It is not necessary for the teacher or students to learn the definitions nor to use all of these terms while working on their challenge. Rather, the children will begin to use the words and understand the meanings as they become involved in their investigations.

Accounts Payable — A current liability representing obligations to pay a creditor, usually a supplier.

Accounts Receivable — A current asset representing obligations owed to a company, usually by its customers.

Assembly Line — An arrangement of machines, equipment, and workers in which work passes from operation to operation in direct line until the product is assembled.

Asset — Anything owned that is measurable in terms of money.

Average — The numerical value obtained by dividing the sum of the elements of a set of data by the number of elements in that set. Also called the mean.

Barter — To exchange one piece of merchandise for another.

Bookkeeping — A system for recording business transactions.

Comparative Shopping — A method for determining the best buy(s) by comparing the costs, quantities, and qualities of different brands of products.

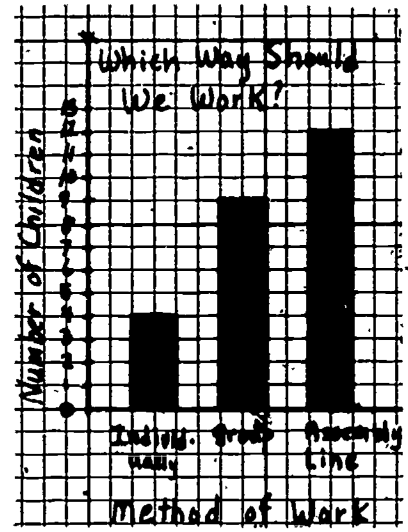
Consumer — A person who buys or uses goods or services.

Conversion	A change from one form to another. Generally associated in mathematics and science with the change from one unit of measure to another or the change from one form of energy to another.
Correlation	A relationship between two sets of data.
Cost	The amount of money needed to produce or to purchase goods or services.
Cost Accounting	That form of accounting designed to provide management with cost information.
Data	Any facts, quantitative information, or statistics.
Discount	A reduction in the price of products or services, often stated as a percentage of price. This is done (1) for customers who buy in large quantities or (2) in order to generate a greater volume of sales.
Distribution	The spread of data over the range of possible results.
Dividend	Payment in either cash or stock to the holders of a company's stock.
Division of Labor	The process by which a complicated task is reduced to a series of simple tasks. Each task is normally performed repetitively by the same worker.
Economics	A social science concerned chiefly with description and analysis of the production, distribution, and consumption of goods and services.
Event	A happening; an occurrence; something that takes place. Example: A step in the production process.
Force	A push or a pull.
Frequency	The number of times a certain event occurs in a given unit of time or in a given total number of events.
Friction, Sliding	A force between two rubbing surfaces that opposes their relative motion.
Graph	A drawing or a picture of one or several sets of data.

Bar Graph

A graph of a set of measures or counts whose sizes are represented by the vertical (or horizontal) lengths of bars of equal widths. Example: the number of children who wanted to work individually, in groups, or on an assembly line.

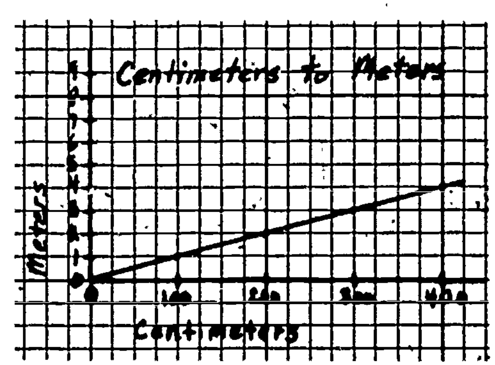
Method of Work	Number of Children
Individually	4
In Groups	9
On Assembly Line	12



Conversion Graph

A line graph that is used to change one unit of measurement to another. For example, changing centimeters to meters, and vice versa.

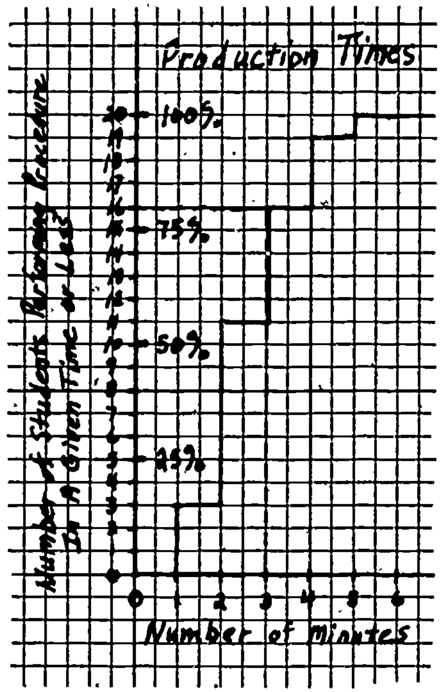
Centimeters	Meters
100	1
200	2
300	3
400	4



Cumulative Distribution Graph

A graph that can be constructed from a histogram by computing running totals from the histogram data. The first running total is the first value in the histogram data (see table of values). The second running total is the sum of the first and second values of the histogram, the third is the sum of the first, second, and third values, and so on. The horizontal scale on the graph is the same as the histogram; the vertical scale goes from 0 to the total number of events observed or samples taken (in the example, the total number of students who performed the same production procedure). Each vertical distance on the graph shows the running totals for the values shown on the horizontal scale. Thus, the graph below indicates that sixteen students (or 80% of the students) performed the production procedure in 3 minutes or less.

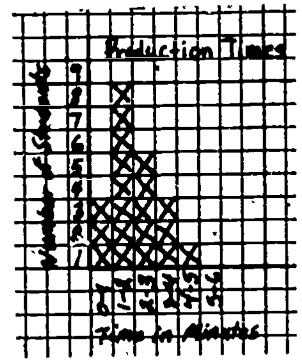
Number of Minutes	Running Total Number of Students
1 or less	3
2 or less	11
3 or less	16
4 or less	19
5 or less	20



Histogram

A type of bar graph that shows the distribution of the number of times that different measures or counts of the same event have occurred. A histogram always shows ordered numerical data on the horizontal axis. Example: Different numbers of children who performed the same production procedure in different lengths of time.

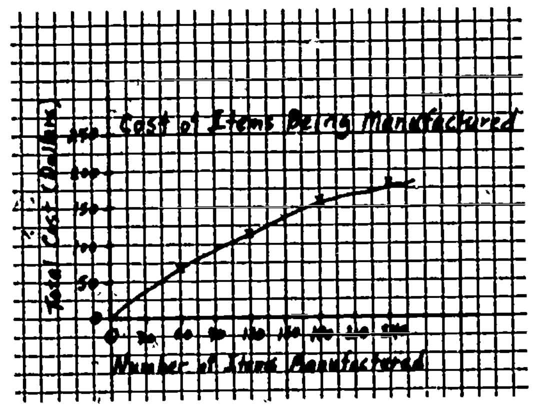
Time in Minutes	Number of Students
0-1	3
1-2	8
2-3	5
3-4	3
4-5	1



Line Chart

A bar graph that is represented by circles, triangles, or crosses with lines connecting them so that it has the appearance of a line graph. (See *Line Graph*.) This is a useful representation when there is a need for interpolation or when two or more sets of data are shown on the same graph. Example A: The number of items manufactured versus their total cost.

Number of Items Manufactured	Total Cost in Dollars
60	$ 72.00
120	$ 120.00
180	$ 156.00
240	$ 180.00

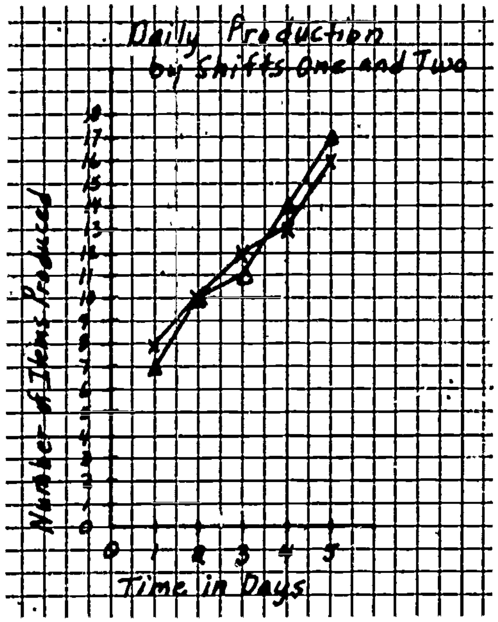


Prediction: It will cost about $100.00 to make 100 items.

Line Chart (cont.)

Example B: The number of items produced per day by the first shift of workers and by the second shift of workers.

Time (in Days)	Number of Items Produced	
	First Shift-Δ	Second Shift-x
1	7	8
2	10	10
3	11	12
4	14	13
5	17	16



Line Graph

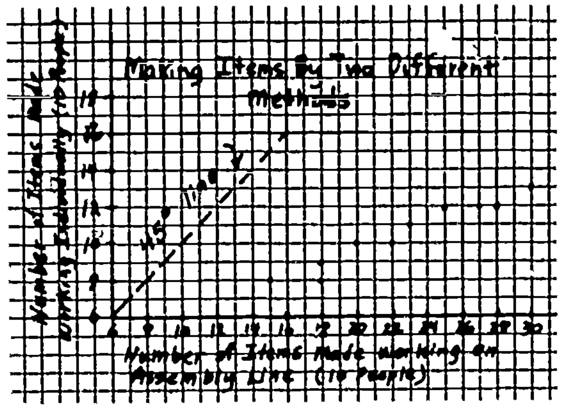
A graph in which a smooth line or line segments pass through or near points representing members of a set of data. Since the line represents an infinity of points, the variable on the horizontal axis must be continuous. If the spaces between the markings on the horizontal axis have no meaning, then the graph is not a line graph, but a line chart (see *Line Chart*).

Q-Q Graph

A graph that shows the comparison between the same type of data collected from two groups of people,....from two different situations,....from two brands of a product. Example: number of items manufactured in a certain amount of time by two different groups, one group working individually and the other on an assembly line. The data for each set is ordered and the smallest measurement of one set plotted against the smallest of the other set, the second smallest against the second smallest, and so on. The scatter of points is compared to a reference line, a dashed 45^{o} line that represents the data from two identical sets.

Number of Items Made in 3 Hours

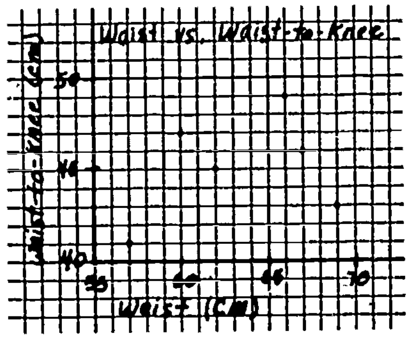
Working on Assembly Line	Working Individually
15	8
18	8
18	9
20	10
22	10
23	11
25	12
27	12
28	12
30	13



Scatter Graph

A graph showing a scatter of points, each of which represents two characteristics of the same thing. For example, in the graph below, each point represents a student; the position of the point indicates the waist measurement of the student and the waist-to-knee measurement of the student.

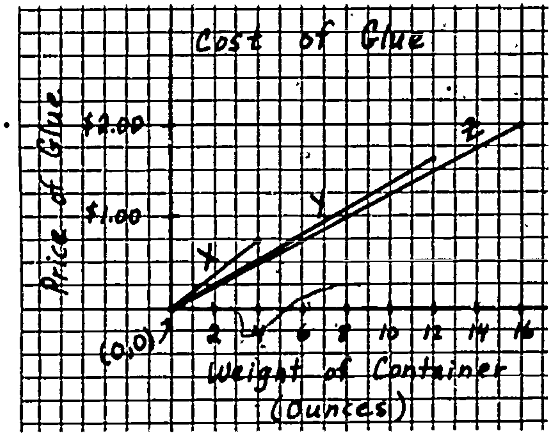
Name	Waist (cm)	Waist-to-Knee (cm)
Jose	69	43
Denise	60	47
Gary	62	45
Sue	57	41
Natasha	66	49
Billy	67	46



*Slope Diagram**

A graphical means of comparing fractions or ratios. To represent the ratio a/b, plot the point (b,a) and draw a line from (b,a) to the origin, (0,0). The slope of this line represents the ratio a/b. By comparing slopes of several lines, different ratios can be compared; the less steep the line, the smaller the ratio. For example, in the diagram showing the ratio of price to weight for different brands of glue, the ratio of price to weight for Brand Z is smaller than that for Brands X and Y, and therefore Brand X costs the least per ounce.

Brand	Price	Weight
X	$ .75	4 ounces
Y	$1.62	12 ounces
Z	$2.00	16 ounces



Gross Profit

See *Profit*.

Histogram

See *Graph*.

Hypothesis

A tentative conclusion made in order to test its implications or consequences.

Inference

An assumption derived from facts or information considered to be valid and accurate.

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*Formerly called triangle diagram.

Interest	A charge for borrowing money; generally a percentage of the amount borrowed.
Inventory	The quantity of goods or materials on hand.
Investment	The outlay of money for a future financial return.
Liability	A debt or obligation.
Marketing	The study or implementation of the most profitable and efficient method of directing goods from manufacturer to consumer.
Market Research	The compilation of statistical information concerning consumers or purchasers.
Mass Production	The process of making something in quantity.
Mean	See *Average*.
Median	The middle value of a set of data in which the elements have been ordered from smallest to largest. The median value has as many elements above it as below it.
Merchandising	Identifying and meeting market needs in terms of products and subsequently stimulating a demand for products through advertising, promotion, and selling.
Mode	The element or elements in a set of data that occur most often.
Net Income	Profit for a given period.
Ordered Set	A set of data arranged from smallest to largest.
Per Cent	Literally per hundred. A ratio in which the denominator is always 100, e.g., 72 per cent = 72/100 = 0.72 = 72% , where the symbol % represents 1/100.
Percentage	A part of a whole expressed in hundredths.
Population	Any group of objects (e.g., people, animals, items) or events from which samples are taken for statistical measurement.

Profit — The excess of monetary returns over expenditures; the excess of the selling price of goods over their cost. (Often called net income.)

Gross Profit — The profit reported before deduction of the indirect costs of doing business.

Profit Margin — Profit expressed as a percentage of total sales revenue.

Proportion — A statement of equality of two ratios, i.e., the first term divided by the second term equals the third term divided by the fourth term, e.g., 5/10 = 1/2. Also a synonym for ratio: when two quantities are in direct proportion, their ratios are the same.

Quartile

First — The first quartile is the value of the quarter-way piece of data in an ordered set of data.

Third — The third quartile is the value of the three-quarter-way piece of data in an ordered set of data.

Interquartile Range — The range or length of the middle 50% of an ordered set of data; the difference between the first and third quartile.

Range — Mathematical: the difference between the smallest and the largest values in a set of data.

Rank — To order the members of a set according to some criterion, such as size or importance. Example: to put pieces of data from smallest to largest.

Ratio — The quotient of two denominate numbers or values indicating the relationship in quantity, size, or amount between two different things. For example, the ratio of the number of children working on the assembly line to the number of items completed by them might be $\frac{12 \text{ children}}{17 \text{ items}}$ or

12 children:17 items

Recycle — To process a discarded item for reuse, either for its original purpose or for a new purpose.

Retail Price — The price level of goods sold in small quantity to the consumer.

Sample	A representative fraction of a population studied to gain information about the whole population.
Sample Size	The number of elements in a sample.
Scale	A direct proportion between two sets of dimensions (as between the dimensions in a drawing of a lab and the actual lab).
Scale Drawing	A drawing whose dimensions are in direct proportion to the object drawn.
Scale Model	A three-dimensional representation constructed to scale.
Set	A collection of characteristics, persons, or objects. Each thing in a set is called a member or an element.
Slope Diagram	See *Graph*.
Statistics	The science of drawing conclusions or making predictions using a collection of quantitative data.
Stock	A share in a company's assets and earnings.
Subcontractor	A company or a person who accepts part of a total contract or project from a general contractor or from a company that cannot do all the required work.
Tally	A visible record used to keep a count of some set of data, especially a record of the number of times one or more events occur. Example: A tally of survey results on customer preferences for three different designs of a product.
Template	A pattern used in making large quantities of some item.
Wholesale Price	The price level of goods sold in large quantity to a merchant for resale.
Work	Work is done when a force is exerted through a distance. Work is the product of the force exerted and the distance moved.

E. Skills, Processes, and Areas of Study Utilized in Manufacturing

The unique aspect of USMES is the degree to which it provides experience in the process of solving real problems. Many would agree that this aspect of learning is so important as to deserve a regular place in the school program even if it means decreasing to some extent the time spent in other important areas. Fortunately, real problem solving is also an effective way of learning many of the skills, processes, and concepts in a wide range of school subjects.

On the following pages are five charts and an extensive, illustrative list of skills, processes, and areas of study that are utilized in USMES. The charts rate Manufacturing according to its potential for learning in various categories of each of five subject areas--real problem solving, mathematics, science, social science, and language arts. The rating system is based on the amount that each skill, process, or area of study within the subject areas is used--extensive (1), moderate (2), some (3), little or no use (-). (The USMES Guide contains a chart that rates all USMES units in a similar way.)

The chart for real problem solving presents the many aspects of the problem-solving process that students generally use while working on an USMES challenge. A number of the steps in the process are used many times and in different orders, and many of the steps can be performed concurrently by separate groups of students. Each aspect listed in the chart applies not only to the major problem stated in the unit challenge but also to many of the tasks each small group undertakes while working on a solution to the major problem. Consequently, USMES students gain extensive experience with the problem-solving process.

The charts for mathematics, science, social science, and language arts identify the specific skills, processes, and areas of study that may be learned by students as they respond to a Manufacturing challenge and become involved with certain activities. Because the students initiate the activities, it is impossible to state unequivocally which activities will take place. It is possible, however, to document activities that have taken place in USMES classes and identify those skills and processes that have been used by the students.

Knowing in advance which skills and processes are likely to be utilized in Manufacturing and knowing the extent that they will be used, teachers can postpone the teaching of those skills in the traditional manner until late in the year. If the students have not learned them during their USMES activities by that time, they can study them in the usual way. Further, the charts enable a teacher to integrate USMES more readily with other areas of classroom work. For example, teachers may teach fractions during math period when fractions are also being learned and utilized in the students' USMES activities. Teachers who have used USMES for several successive years have found that students are more motivated to learn basic skills when they have determined a need for them in their USMES activities. During an USMES session the teacher may allow the students to learn the skills entirely on their own or from other students, or the teacher may conduct a skill session as the need for a particular skill arises.

Because different USMES units have differing emphases on the various aspects of problem solving and varying amounts of possible work in the various subject areas, teachers each year might select several possible challenges, based on their students' previous work in USMES, for their class to consider. This choice should provide students with as extensive a range of problems and as wide a variety of skills, processes, and areas of study as possible during their years in school. The charts and lists on the following pages can also help teachers with this type of planning.

Some USMES teachers have used a chart similar to the one given here for real problem solving as a record-keeping tool, noting each child's exposure to the various aspects of the process. Such a chart might be kept current by succeeding teachers and passed on as part of a student's permanent record. Each year some attempt could be made to vary a student's learning not only by introducing different types of challenges but also by altering the specific activities in which each student takes part. For example, children who have done mostly construction work in one unit may be encouraged to take part in the data collection and data analysis in their next unit.

Following the rating charts are the lists of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in Manufacturing. Like the charts, these lists are based on documentation of activities that have taken place in USMES classes. The greater detail of the lists allows teachers to see exactly how the various basic skills, processes, and areas of study listed in the charts may arise in Manufacturing.

The number of examples in the real problem solving list have been limited because the list itself would be unreasonably long if all the examples were listed for some of the categories. It should also be noted that the example(s) in the first category--*Identifying and Defining Problems*--have been limited to the major problem that is the focus of the unit. During the course of their work, the students will encounter and solve many other, secondary problems, such as the problem of how to display their data or how to draw a scale layout.

Breaking down an interdisciplinary curriculum like USMES into its various subject area components is a difficult and highly inexact procedure. Within USMES the various subject areas overlap significantly, and any subdivision must be to some extent arbitrary. For example, where does measuring as a mathematical skill end and measurement as science and social science process begin? How does one distinguish between the processes of real problem solving, of science, and of social science? Even within one subject area, the problem still remains--what is the difference between graphing as a skill and graphing as an area of study? This problem has been partially solved by judicious choice of examples and extensive cross-referencing.

Because of this overlap of subject areas, there are clearly other outlines that are equally valid. The scheme presented here was developed with much care and thought by members of the USMES staff with help from others knowledgeable in the fields of mathematics, science, social science, and language arts. It represents one method of examining comprehensively the scope of USMES and in no way denies the existence of other methods.

REAL PROBLEM SOLVING	Overall Rating
Identifying and defining problem.	1
Deciding on information and investigations needed.	1
Determining what needs to be done first, setting priorities.	1
Deciding on best ways to obtain information needed.	1
Working cooperatively in groups on tasks.	1
Making decisions as needed.	1
Utilizing and appreciating basic skills and processes.	1
Carrying out data collection procedures--observing, surveying, researching, measuring, classifying, experimenting, constructing.	1
Asking questions, inferring.	1
Distinguishing fact from opinion, relevant from irrelevant data, reliable from unreliable sources.	1
Evaluating procedures used for data collection and analysis. Detecting flaws in process or errors in data.	1

REAL PROBLEM SOLVING	Overall Rating
Organizing and processing data or information.	1
Analyzing and interpreting data or information.	1
Predicting, formulating hypotheses, suggesting possible solutions based on data collected.	1
Evaluating proposed solutions in terms of practicality, social values, efficacy, aesthetic values.	1
Trying out various solutions and evaluating the results, testing hypotheses.	1
Communicating and displaying data or information.	1
Working to implement solution(s) chosen by the class.	1
Making generalizations that might hold true under similar circumstances; applying problem-solving process to other real problems.	1

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use

MATHEMATICS	Overall Rating
Basic Skills	
Classifying/Categorizing	2
Counting	1
Computation Using Operations	
Addition/Subtraction	1
Multiplication/Division	1
Fractions/Ratios/Percentages	1
Business and Consumer Mathematics/ Money and Finance	1
Measuring	1
Comparing	2
Estimating/Approximating/Rounding Off	1
Organizing Data	1
Statistical Analysis	1
Opinion Surveys/Sampling Techniques	1
Graphing	3
Spatial Visualization/Geometry	2
Areas of Study	
Numeration Systems	1
Number Systems and Properties	1
Denominate Numbers/Dimensions	1
Scaling	-
Symmetry/Similarity/Congruence	2
Accuracy/Measurement Error/ Estimation/Approximation	1
Statistics/Random Processes/Probability	1
Graphing/Functions	3
Fraction/Ratio	1
Maximum and Minimum Values	3
Equivalence/Inequality/Equations	2
Money/Finance	1
Set Theory	3

SCIENCE	Overall Rating
Processes	
Observing/Describing	1
Classifying	2
Identifying Variables	2
Defining Variables Operationally	2
Manipulating, Controlling Variables/ Experimenting	2
Designing and Constructing Measuring Devices and Equipment	1
Inferring/Predicting/Formulating, Testing Hypotheses/Modeling	1
Measuring/Collecting, Recording Data	1
Organizing, Processing Data	1
Analyzing, Interpreting Data	1
Communicating, Displaying Data	1
Generalizing/Applying Process to New Problems	1
Areas of Study	
Measurement	1
Motion	3
Force	3
Mechanical Work and Energy	3
Solids, Liquids, and Gases	1
Electricity	-
Heat	-
Light	3
Sound	3
Animal and Plant Classification	-
Ecology/Environment	-
Nutrition/Growth	-
Genetics/Heredity/Propagation	-
Animal and Plant Behavior	-
Anatomy/Physiology	3

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use

SOCIAL SCIENCE	Overall Rating
Process	
Observing/Describing/Classifying	2
Identifying Problems, Variables	1
Manipulating, Controlling Variables/ Experimenting	2
Inferring/Predicting/Formulating, Testing Hypotheses	1
Collecting, Recording Data/Measuring	2
Organizing, Processing Data	2
Analyzing, Interpreting Data	2
Communicating, Displaying Data	2
Generalizing/Applying Process to Daily Life	1
Attitudes/Values	
Accepting responsibility for actions and results	1
Developing interest and involvement in human affairs	1
Recognizing the importance of individual and group contributions to society	1
Developing inquisitiveness, self-reliance, and initiative	1
Recognizing the values of cooperation, group work, and division of labor	1
Understanding modes of inquiry used in the sciences, appreciating their power and precision	1
Respecting the views, thoughts, and feelings of others	1
Being open to new ideas and information	1
Learning the importance and influence of values in decision making	1
Areas of Study	
Anthropology	-
Economics	1
Geography/Physical Environment	-
Political Science/Government Systems	3
Recent Local History	-
Social Psychology/Individual and Group Behavior	3
Sociology/Social Systems	3

LANGUAGE ARTS	Overall Rating
Basic Skills	
Reading	
Literal Comprehension: Decoding Words, Sentences, Paragraphs	2
Critical Reading: Comprehending Meanings, Interpretation	3
Oral Language	
Speaking	1
Listening	1
Memorizing	-
Written Language	
Spelling	3
Grammar: Punctuation, Syntax, Usage	3
Composition	3
Study Skills	
Outlining/Organizing	3
Using References and Resources	3
Attitudes/Values	
Appreciating the value of expressing ideas through speaking and writing	1
Appreciating the value of written resources	3
Developing an interest in reading and writing	3
Making judgments concerning what is read	3
Appreciating the value of different forms of writing, different forms of communication	1

KEY: 1 = extensive use, 2 = moderate use,
3 = some use, - = little or no use

REAL PROBLEM SOLVING IN MANUFACTURING

Identifying and Defining Problems	• Students identify a need for an item in their classroom and decide to make the item in quantity. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables.*
Deciding on Information and Investigations Needed	• After a discussion, students decide that they need information on materials and tools available and that they need to collect data on whether other students also need the item.
Determining What Needs to Be Done First, Setting Priorities	• Students list tasks to be done and decide that investigating materials and tools needed and deciding on a design are things that should be done first.
Deciding on Best Ways to Obtain Information Needed	• Students telephone several merchants to obtain information on costs and availability of materials. • Students decide to conduct an opinion survey in one class from each grade to determine if others also need the item.
Working Cooperatively in Groups on Tasks	• Students form groups to survey other students, investigate materials and tools, and to build a sample of the item.
Making Decisions as Needed	• After looking at many possible designs, students decide that a certain design is best. • After tallying data from an opinion survey, students decide that they should make a certain number of extra items to sell to others. • After testing possible materials to use in making their item, students choose the strongest material that they can afford to buy.
Utilizing and Appreciating Basic Skills and Processes	• Students measure and mark their materials to construct prototype. • Students multiply the amount of material needed for one item in order to find out how much material they need for a large number of items.

Utilizing and Appreciating Basic Skills and Processes (cont.)

- Students learn that they have to set up a system of quality control in order to produce good products.
- Students give an oral presentation to the PTA asking for a loan to make the item.
- Students prepare cost analysis of materials needed for presentation to the PTA.
- See also MATHEMATICS, SCIENCE, SOCIAL SCIENCE, LANGUAGE ARTS lists.

Carrying Out Data Collection Procedures--Opinion Surveying, Researching, Measuring, Classifying, Experimenting, Constructing

- Students conduct opinion survey to determine price that others are willing to pay for the product.
- Students obtain samples of materials and test them for strength and durability.
- Students measure children in different grades to determine whether they need different sizes for their item.
- Students construct a prototype of the product and time each step in the process.
- See also MATHEMATICS list: *Classifying/Categorizing; Measuring.*
- See also SCIENCE list: *Observing/Describing; Classifying; Manipulating, Controlling Variables/Experimenting; Designing and Constructing Measuring Devices and Equipment; Measuring/Collecting, Recording Data.*
- See also SOCIAL SCIENCE list: *Observing/Describing/Classifying; Manipulating, Controlling Variables/Experimenting; Collecting, Recording Data/Measuring.*

Asking Questions, Inferring

- Students ask whether working individually, in groups, or on an assembly line is best and after timing each method, infer that the assembly line method is the best because it was the fastest method.
- See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.*
- See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*

Distinguishing Fact from Opinion, Relevant from Irrelevant Data, Reliable from Unreliable Sources

- Students recognize that the merchants are reliable sources of information on prices of materials.

Evaluating Procedures Used for Data Collection and Analysis, Detecting Flaws in Process or Errors in Data

- Students discuss methods of testing materials for strength and decide that they should standardize their tests in some way.
- Students decide that in timing the steps in the production process they would obtain more accurate results if they used a stopwatch rather than the clock in the classroom.
- See also MATHEMATICS list: *Estimating/Approximating/ Rounding Off.*

Organizing and Processing Data

- Students organize test results and prices for various types of materials in order to decide which material is best for their purposes.
- To draw histograms, students order and group the prices others are willing to pay and the number of students who are willing to pay each price.
- See also MATHEMATICS list: *Organizing Data.*
- See also SCIENCE and SOCIAL SCIENCE lists: *Organizing, Processing Data.*

Analyzing and Interpreting Data

- Students decide that the price of material should be one determining factor in choosing material and then rank the test results in order of decreasing importance so that they can pick the best material for their purposes.
- Students find median price others are willing to pay.
- See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values.*
- See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data.*

Predicting, Formulating Hypotheses, Suggesting Possible Solutions Based on Data Collected

- As a result of survey data, students predict the number of items they will be able to sell.
- Students hypothesize that they can produce more items in a period if they set up an assembly line.
- After pricing and testing various materials, students recommend one as best suited for their item.
- On the basis of survey data and cost analysis of making product, students recommend a selling price for their product.
- See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.*
- See also SOCIAL SCIENCE list: *Inferring/Predicting/ Formulating, Testing Hypotheses.*

Evaluating Proposed Solutions in Terms of Practicality, Social Values, Efficacy, Aesthetic Value	• Students assess assembly line manufacturing vs. individual manufacturing. • Students assess manufacture of their product in terms of cost, use, design appeal, and size. • Students discuss whether to use more expensive materials which are stronger and more durable, and whether others will pay more for a better product.
Trying Out Various Solutions and Evaluating the Results, Testing Hypotheses	• Students try out different assembly lines and compare the number of items produced in a time period. • Students find that they could have sold more of the product than they predicted. • On the basis of a survey of customers, students list and implement suggestions for improving the product and find that most customers are still satisfied with the product. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Communicating and Displaying Data or Information	• Students draw a flow diagram of assembly line. • Students draw histograms to show possible prices and number of students willing to pay each price. • Students make up a sample chart showing possible designs and colors of product. • See MATHEMATICS list: *Graphing.* • See SCIENCE and SOCIAL SCIENCE lists: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Working to Implement Solution(s) Chosen by the Class	• Students mass produce item chosen by class.
Making Generalizations That Might Hold True Under Similar Circumstances; Applying Problem-Solving Process to Other Real Problems	• Students find that working together gives better results than working individually. • Students find that sloppy workmanship results in an inferior product. • Students decide to manufacture another item. • Students working on Manufacturing apply skills acquired to work on Consumer Research.

Making Generalizations That Might Hold True Under Similar Circumstances; Applying Problem-Solving Process to Other Real Problems (cont.)

- See also SCIENCE list: *Generalizing/Applying Process to New Problems.*
- See also SOCIAL SCIENCE list: *Generalizing/Applying Process to Daily Life.*

ACTIVITIES IN MANUFACTURING UTILIZING MATHEMATICS

Basic Skills

Classifying/Categorizing

- Categorizing characteristics or properties of possible items to be manufactured, possible materials to be used in making item.
- Categorizing in more than one way characteristics of customers or materials needed to produce item.
- Distinguishing sets and subsets of quantitative survey data on design and color of the product.
- See also SCIENCE list: *Classifying*.
- See also SOCIAL SCIENCE list: *Observing/Describing/Classifying*.

Counting

- Counting votes to determine which item to manufacture, which design of item to use, which jobs on the assembly line students prefer.
- Counting survey data, questionnaire data on product preferences, design preferences.
- Counting number of seconds for each step in the production process, number of items manufactured, number of orders to be filled.
- Counting to read scales on rulers, meter sticks, tape measures, weighing scales.
- Counting by sets to find scale for graph axes.

Computation Using Operations: Addition/Subtraction

- Adding one-, two-, or three-digit whole numbers to find total tally of orders taken, total measurement of materials needed, or total number of items that can be made from materials available.
- Adding minutes and seconds when timing steps in production to calculate total production time.
- Subtracting to find differences between predicted and actual measurements of times of steps in the production process.
- Subtracting to find differences between predicted and actual counts of the number of items made or amounts of supplies needed per week.
- Subtracting one-, two-, or three-digit whole numbers to find ranges for graph axes or for measurement data.

Computation Using Operations: Multiplication/Division

- Multiplying whole numbers to find total measurement of material needed for large numbers of the product, total time of production for a large number of items.
- Multiplying or dividing to find scale for graph axes.
- Dividing or multiplying to find how many items can be made in an hour.
- Dividing to find how many items can be made from a certain amount of material.
- Dividing to find time it takes for one item to be made.
- Multiplying to convert from meters to centimeters or dividing to convert from centimeters to meters.
- Dividing to calculate average of wrist measurements for adjustable wristband or to calculate average production time for article.
- Dividing to calculate ratios, fractions, percentages of materials bought to materials used; of customers who prefer a particular color or design to total number of customers.

Computation Using Operations: Fractions/Ratios/Percentages

- Using mixed numbers to perform calculations, such as calculating number of items that can be made from a certain amount of material.
- Changing fractions to higher or lower terms (equivalent fractions) to perform operations such as multiplying to convert from one product size to another.
- Using ratios to convert from inches to centimeters.
- Using ratios to increase or decrease measurements for different sizes of the same item.
- Using fractions in measurement, graphing, graphic comparisons.
- Calculating ratios of numbers of different colors of item to make from survey data on customer color preferences.
- Calculating ratios for product sizes from survey data on body measurements of prospective customers.
- Using slope diagrams to compare ratios or fractions of waist size to waist-to-knee length when analyzing body measurement data.
- Calculating percentage of students willing to buy item, percentage of students who will pay a certain price for product, percentage of time spent on each step of assembly line, and percentage of items made incorrectly.

Computation Using Operations: Business and Consumer Mathematics/ Money and Finance	• Adding and subtracting dollars and cents to perform cost analysis on product being manufactured, on materials needed to make item, to figure profit or loss, to make change, to withdraw or deposit money in bank account. • Multiplying and dividing to perform cost analysis on product being manufactured, on materials needed to make item, and to figure profit or loss per item. • Dividing to find unit cost of materials needed to produce item. • Dividing to calculate average sales per week. • Calculating percentage of profit that each student should get for his work. • Using comparison when shopping for materials needed to produce item. • Gaining experience with finance: sources, uses, and limitations of revenues for manufacture of product. • Investigating costs of materials for product vs. use of materials and budget restrictions.
Measuring	• Converting from inches to centimeters. • Using arbitrary units (e.g., knotted string, children's fingers) to measure how many items can be cut from a certain amount of material. • Using different standard units of measure to make body measurements (inches, centimeters). • Using different measuring tools to measure length, width of materials. • Using a pattern to measure how many items can be cut from a piece of material. • Reading rulers, tape measures, yardsticks, meter sticks accurately. • Timing total production time for prototype using a watch or a clock. • See also SCIENCE list: *Measuring/Collecting, Recording Data*. • See also SOCIAL SCIENCE list: *Collecting, Recording Data/ Measuring*.
Comparing	• Using the concept of *greater than* and *less than* in making comparisons about size of product vs. size of customer, size of product vs. size of product package. • Comparing quantitative data (materials available vs. materials needed to fill orders) gathered from various sources.

Comparing (cont.)

- Comparing qualitative information on customer preferences gathered from various sources, such as opinion surveys and informal conversations.
- Comparing different methods of making the item--individually, in groups, on assembly line--and comparing times for each method.
- Comparing qualitative with quantitative data.
- Comparing estimated and actual (1) time needed to manufacture item, (2) costs of making item, (3) sales of item.
- Making graphic comparisons of orders taken and orders filled and of chest width vs. collarbone-to-waist length to determine sizes on a scatter graph.
- Making graphic comparisons of fractions and ratios on slope diagrams of weight vs. price of various materials.
- Comparing costs of various materials needed to make item.
- See also SCIENCE list: *Analyzing, Interpreting Data*.
- See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data*.

Estimating/Approximating/Rounding Off

- Estimating error in qualitative judgments on number of people who will buy the product when collecting survey data.
- Estimating the number of people who will wear a certain size, who will buy a product, who can work comfortably in a given area.
- Estimating size of product package, measurement of the amount of materials needed, or cost of the product.
- Estimating number of items that will be sold, time period needed to manufacture product before sale, number of patterns that can be cut from a certain amount of material.
- Determining when a measurement of waist size (or some other body measurement) is likely to be accurate enough to determine sizes of product.
- Using approximation in constructing prototype or sample of item.
- Rounding off measurements while taking body measurements.
- Rounding off data after measuring the times for each step in production process.

Organizing Data

- Organizing and classifying sets of materials to be used, information on sales and customers.
- Tallying votes to determine which item should be made.

Organizing Data (cont.)	• Tallying on bar graphs, histograms. • Ordering real numbers on number line or graph axis. • Tallying and ordering survey results on prices that students are willing to pay for product. • Ordering minutes and seconds. • Ordering waist sizes for boys and girls when making q-q graph. • Ordering data to find the median. • See also SCIENCE list: *Organizing, Processing Data*. • See also SOCIAL SCIENCE list: *Organizing, Processing Data*.
Statistical Analysis	• Finding the median in an ordered set of data on customer sizes or prices others are willing to pay. • Using the median measurement in various size ranges to determine sizes to make. • Assessing predictability of larger sample of customer sizes based on results from smaller sample of customer sizes. • Comparing medians and modes of data on customer sizes for various grade levels. • Determining range of data on customer measurements. • Interpretation of histograms, scatter graphs, q-q plots, cumulative distribution graphs. • See also SCIENCE list: *Analyzing, Interpreting Data*. • See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data*.
Opinion Surveys/Sampling Techniques	• Conducting surveys to determine quantity of product needed or price that others are willing to pay for product. • Defining data collection methods, makeup and size of sample. • Devising methods of obtaining quantitative information about subjective opinions of customer preferences and price customer is willing to pay. • See also SCIENCE list: *Analyzing, Interpreting Data*. • See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data*.
Graphing	• Using different methods to display data such as charts of possible designs and colors of product, order forms, flow diagrams of assembly line, and graphs.

Graphing (cont.)

- Making a graph form--dividing axes into parts, deciding on an appropriate scale.
- Obtaining information from graphs.
- Representing data on graphs.
  - Bar graph--plotting days of week vs. number of items made per day.
  - Conversion graph--plotting inches vs. feet to use when making price per unit comparisons of possible production materials; plotting inches vs. centimeters to change running board feet of wood to centimeters in making product.
  - Cumulative distribution graph--plotting number of items sold vs. time to determine when demand is easing.
  - Histogram--plotting possible prices (dollars and cents) vs. number of students willing to pay each price.
  - Line chart--plotting the number of student and adult preferences for each product design or color.
  - Q-Q graph--plotting waist sizes of boys vs. girls to determine if there is any difference.
  - Scatter graph--plotting chest width vs. collarbone-to-waist length to determine possible combinations of measurements.
  - Slope diagram--plotting costs vs. weights to determine unit cost of materials.
- See also SCIENCE list: *Communicating, Displaying Data*.
- See also SOCIAL SCIENCE list: *Communicating, Displaying Data*.

Spatial Visualization/Geometry

- Drawing possible designs for product.
- Drawing or constructing a design or model of item to be made in quantity.
- Constructing and using geometric figures, for example, triangles, squares, circles, etc., for product prototype, product packaging.
- Using geometric figures to understand and utilize relationships, such as area, volume, similarity, congruence, symmetry, etc.
- Using standard mensurational formulas such as area = length x width.
- Measuring and constructing patterns, product prototype or tools needed, using rulers, compasses, and protractors.

Spatial Visualization/Geometry

- Using spatial arrangements to convey information on layout of assembly line.
- Making a flow diagram of work area to organize assembly line.
- Using the congruence of pieces to cut more than one piece at a time or to make a template or pattern for the piece.
- Using similarity to make patterns for different sizes.
- Using symmetry in cutting patterns for clothing.

Areas of Study

Numeration Systems

- Using decimal system in making body measurements (metric system measurement).
- Using fractions in measuring amount of material needed for product (inches, fractions of inches—American system of measurement).
- Using decimal system in calculations involving money (cost analysis, etc.)

Number Systems and Properties

- See *Computation Using Operations*.

Denominate Numbers/Dimensions

- See *Measuring*.

Symmetry/Similarity/Congruence

- See *Spatial Visualization/Geometry*.

Accuracy/Measurement Error/ Estimation/Approximation

- See *Measuring* and *Estimating/Approximating/Rounding Off*.

Statistics/Random Processes/ Probability

- See *Statistical Analysis*.

Graphing/Functions

- See *Graphing*.

Fraction/Ratio

- See *Computation Using Operations: Fractions/Ratios/ Percentages*.

Maximum and Minimum Values	• Finding the shortest time to produce a product in quantity; finding the shortest time to produce a single item of the product. • Minimizing the assembly line time by finding jobs that can be done concurrently. • Maximizing the number of items that can be made by using the assembly line process, by rearranging the steps so that several can be done concurrently, by transporting the product efficiently between groups of workers, by improving skills in handling tools, by constructing a tool or a model. • Maximizing profit by considering both price and number that can be sold at a given price. • Using slope diagrams to find minimum costs of materials. • Getting maximum number of pieces from material available.
Equivalence/Inequality/Equations	• See *Comparing* and *Computation Using Operations.*
Money and Finance	• See *Computation Using Operations: Business and Consumer Mathematics/Money and Finance.*
Set Theory	• See *Classifying/Categorizing.*

ACTIVITIES IN MANUFACTURING UTILIZING SCIENCE

Process	
Observing/Describing	• Observing that there are several possible materials that could be used to make product; observing differences in these materials. • Describing steps in making the item. • Observing by timing with a stopwatch that some steps in making the item take longer than others. • See also SOCIAL SCIENCE list: *Observing/Describing/ Classifying*.
Classifying	• Determining which materials are best (strongest, most durable, cheapest) for producing the item. • Determining the sizes needed for the product. • See also MATHEMATICS list: *Classifying/Categorizing*. • See also SOCIAL SCIENCE list: *Observing/Describing/ Classifying*.
Identifying Variables	• Identifying the length of time and number of people engaged in each step of the manufacturing process as things to be measured or recorded to determine time spent on that step. • Identifying durability and cost as characteristics that must be investigated to determine which materials should be used in manufacturing the item. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables*.
Defining Variables Operationally	• Defining the time it takes to make one item as the length of a work session (in minutes) divided by the number of items completed in that session. • Defining durability of a fabric by the amount of stress needed to rip it.
Manipulating, Controlling Variables/ Experimenting	• Assigning more people to those steps in the manufacturing process that take longer.

Manipulating, Controlling Variables/ Experimenting (cont.)	• Making items by various methods--individually, in groups, on an assembly line. • See also SOCIAL SCIENCE list: *Manipulating, Controlling Variables/Experimenting.*
Designing and Constructing Measuring Devices and Equipment	• Constructing a device to measure the durability of various types of materials. • Constructing a pattern or template to replace several measurements. • Constructing a tool to make a step in the manufacturing process easier or faster.
Inferring/Predicting/Formulating, Testing Hypotheses/Modeling	• Inferring from tests and prices that a particular material is best suited for the product. • Predicting the number of items that will be sold, based on survey data. • Hypothesizing that the assembly line method is fastest, timing various methods of producing item (working individually, in groups, on assembly line) to test this prediction. • Making possible flow diagrams for the assembly line. • Making a prototype or sample of the item before producing item in quantity. • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Measuring/Collecting, Recording Data	• Measuring and marking materials to construct prototype. • Using stopwatches to time steps in the manufacturing process and recording the times on the chalkboard. • Testing and recording test results for various materials that might be used to make an item. • Taking body measurements of students of different ages to determine sizes for product. • See also MATHEMATICS list: *Measuring.* • See also SOCIAL SCIENCE list: *Collecting, Recording Data/Measuring.*
Organizing, Processing Data	• Ordering steps in the manufacturing process according to the order in which they must be done on the assembly line.

Organizing, Processing Data (cont.)

- Ordering test results on various materials according to importance in order to decide which material is the best.
- See also MATHEMATICS list: *Organizing Data.*
- See also SOCIAL SCIENCE list: *Organizing, Processing Data.*

Analyzing, Interpreting Data

- Determining which material is best for product based on prices and test results.
- Determining number of items that can be made from available material.
- Calculating the total time to make one item from list of times for each step on chalkboard.
- See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values.*
- See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data.*

Communicating, Displaying Data

- Constructing a chart showing the steps and times for each step in the manufacturing process.
- Making a graph of number of items vs. amount of material needed to facilitate ordering of materials.
- Drawing a flow diagram of assembly line.
- See also MATHEMATICS list: *Graphing.*
- See also SOCIAL SCIENCE list: *Communicating, Displaying Data.*
- See also LANGUAGE ARTS list.

Generalizing/Applying Process to New Problems

- Applying skills acquired to mass produce another item.
- Applying techniques learned to production problems in Growing Plants, Soft Drink Design, School Supplies.
- Applying skills acquired in testing materials to work on Consumer Research challenge.
- See also SOCIAL SCIENCE list: *Generalizing/Applying Process to Daily Life.*

Areas of Study

Measurement

- Timing the steps in the manufacturing process using a stopwatch.

Measurement (cont.)

- Measuring and marking product to be made and materials using a ruler or meter stick.
- See also MATHEMATICS list: *Measuring*.

Motion

Speed/Velocity

- Observing that electrically-run machines (saber saws, duplicating machines, sewing machines, electric drills) are faster than hand machines.
- Observing that the speed of electrically-run machines such as sewing machines and saber saws can be varied by the operator.
- See also *Force*.

Force

- Observing that force must be exerted to cut material.
- Observing that more force must be exerted when several pieces of material are cut at one time.
- Observing that force must be exerted to pull apart two glued blocks when testing the strength of different types of glue.
- Observing that force must be exerted to hammer nails into wood, that the hammer increases the force exerted.
- Observing that differing amounts of force must be exerted to pound nails into different types of materials (plywood, pine, Tri-Wall) with a hammer.
- Observing that electrically-run tools require less effort to operate than hand tools and that electrically-run tools multiply the force exerted.

Friction

- Observing that the surfaces of some materials offer less resistance to motion (friction) than others.
- Observing that a piece of wood becomes warm as it is sanded because doing work against the force of friction generates heat.
- Observing that sanding a piece of wood results in a surface that is smoother and offers less resistance to motion.
- Observing that saws become warm as they are being used because doing work against the force of friction generates heat.

Mechanical Work and Energy	• Observing that work is done and energy is expended when nails are hammered into wood, leather or material is cut, or snaps and designs are put on leather or fabric. • Observing that making aprons with a sewing machine requires less time than sewing by hand and that electrical energy is transformed into mechanical energy. • Observing that wood blocks become warm when sanded vigorously as mechanical energy is transformed into heat energy. • See also *Motion* and *Force*.
Solids, Liquids, and Gases	
States of Matter	• Noting that glue is available in both solid and liquid form. • Observing that a solid stick of glue is turned into a hot liquid glue by heat in the hot glue gun.
Properties of Matter	• Testing materials such as leather, cloth, paper, or wood for strength, durability, flexibility. • Observing that different types of materials have different properties that make them useful for certain products. • Observing that the different types of materials available for making a product have different textures, densities, and colors (e.g., fabrics for aprons, leather for wristbands, wood for tic-tac-toe games). • Assessing suitability of different types of materials to use in making the product (types of leather, wood, clo , paper, beads, glue, string). • Observing, while mixing dyes or tempera paints, that the dry powder mixes uniformly with the water. • Observing that glues, lumber, paper, leather and other materials have particular odors.
Electricity	• Observing that electricity can be transformed into mechanical energy (saber saw, electric drill, sewing machine), into heat energy (glue gun, iron), into chemical energy (battery charger).
Heat/Temperature	• Observing that some machines (glue gun, electric iron) generate heat when turned on as electrical energy is transformed into heat energy.

Light	• Observing that different colors reflect light in different ways, changing the appearance of the product. • Observing that the side of the room near the windows is brighter than the rest of the room and that the intensity of illumination decreases as the distance from the light source increases.
Sound	• Observing that noise from power tools can sometimes be heard in adjacent rooms. • Observing that mechanical energy of tools can be transformed into sound. • Observing that sounds made by different tools (saber saws, drill, sewing machine) differ in tone, pitch, loudness and quality. • Observing that the sound of a power tool is less intense farther away from the sound.
Anatomy/Physiology	• Observing that several sizes of the product to be manufactured may be needed because children differ in size and body proportions. • Observing that some body measurements are related and some are not.

ACTIVITIES IN MANUFACTURING UTILIZING SOCIAL SCIENCE

Process

Observing/Describing/Classifying

- Observing and describing needs and preferences of other students for possible products.
- Observing and describing preferences of other students for design, color, size of product.
- Classifying potential customers according to age, sex, grade level.
- Observing, describing, organizing, and classifying good and bad aspects of working individually, in groups, on assembly line.
- Observing, describing, and classifying problems of students working on the assembly line, such as boredom, wasted materials, faulty workmanship.
- See also MATHEMATICS list: *Classifying, Categorizing.*
- See also SCIENCE list: *Observing/Describing; Classifying.*

Identifying Problems, Variables

- Identifying problems of students working on the assembly line.
- Establishing criteria for jobs on assembly line--difficulty, number of people needed, job popularity.
- Identifying age and sex as possible factors in design and color preferences.
- See also SCIENCE list: *Identifying Variables.*

Manipulating, Controlling Variables/Experimenting

- Conducting trial runs of assembly line process using different numbers and arrangements of workers.
- Conducting an opinion survey using a stratified sample.
- Surveying different groups of students (males and females, primary and intermediate) to determine differences in color and design preferences.
- See also SCIENCE list: *Manipulating, Controlling Variables/Experimenting.*

Inferring/Predicting/Formulating, Testing Hypotheses

- Predicting, on the basis of trial runs, best number and arrangement of workers for the steps on assembly line.
- Choosing color and design of product to be manufactured, based on opinion surveys.

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Inferring/Predicting/Formulating, Testing Hypotheses (cont.)	• Hypothesizing that a better-made product will result in more items being sold; listing number of items sold per day after improvements have been made. • Predicting that a quality control system will result in a better product, counting number of badly-made items produced after quality control is begun. • Recommending a selling price for the product, on the basis of survey data and cost analysis of production. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses*.
Collecting, Recording Data/ Measuring	• Using a voting procedure to determine final size, design, color of product. • Timing the trial runs of assembly line process. • See also MATHEMATICS list: *Counting; Measuring*. • See also SCIENCE list: *Measuring/Collecting, Recording Data*.
Organizing, Processing Data	• Preparing cost analysis of materials needed to produce item. • Tallying votes to determine preferred size, design, color of product. • Tallying survey data, questionnaire data on preference for color and design of item. • See also MATHEMATICS list: *Organizing Data*. • See also SCIENCE list: *Organizing, Processing Data*.
Analyzing, Interpreting Data	• Comparing survey results for males and females, primary and intermediate on color and design preferences. • Assessing predictability of larger sample of student preferences based on results from smaller sample of student preferences. • Evaluating the way that the opinion survey was administered, evaluating the size and makeup of the sample. • See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values*. • See also SCIENCE list: *Analyzing, Interpreting Data*.
Communicating, Displaying Data	• Representing survey data on color and design preferences on graphs or charts. • See also MATHEMATICS list: *Graphing*.

Communicating, Displaying Data (cont.)	• See also SCIENCE list: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Generalizing/Applying Process to Daily Life	• Using knowledge acquired from organizing production line to help in organizing classroom schedule. • Concluding that working together gives better results than working individually; that sloppy workmanship results in an inferior product. • Gaining insight into the operation of a factory assembly line; understanding more clearly what assembly line workers may do. • See also SCIENCE list: *Generalizing/Applying Process to New Problems.*

Attitudes/Values

Accepting Responsibility for Actions and Results	• Making sure that various tasks (e.g., getting needed materials and tools for product) are done. • Scheduling and giving presentations to persons in authority (principal, PTA) in order to obtain funds to manufacture product. • Making sure that jobs are done well on assembly line, that product is made well.
Developing Interest and Involvement in Human Affairs	• Producing an item that is needed by others in the school.
Recognizing the Importance of Individual and Group Contributions to Society	• Recognizing that manufacturing the product fulfills the needs of others in the school as well as themselves.
Developing Inquisitiveness, Self-Reliance, and Initiative	• Conducting group sessions with help from teacher. • Dealing with various merchants in obtaining materials and supplies to make product. • Finding their own solutions to problems of boredom and quality control on assembly line, in addition to main problem of challenge. • Choosing and developing best way of presenting a proposal for funds to make product to the principal or PTA. • Using the telephone to obtain information on materials available for making product.

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Recognizing the Values of Cooperation, Group Work, and Division of Labor	• Finding that manufacturing a product in quantity progresses more rapidly and smoothly when they work in groups or on an assembly line. • Eliminating needless overlap in work during mass production of their item. • Finding that work is more fun and proceeds more smoothly when people learn to cooperate during mass production.
Understanding Modes of Inquiry Used in the Sciences, Appreciating Their Power and Precision	• Using scientific modes of inquiry to investigate and solve the problem of choosing a color and design for the product that satisfies the most people. • Convincing others through the use of supporting data (opinion survey) and graphs that a suggested solution should be chosen. • Setting up several arrangements of the assembly line and timing each one before deciding on an assembly line arrangement. • See MATHEMATICS and SCIENCE lists.
Respecting the Views, Thoughts, and Feelings of Others	• Considering all suggestions and assessing their merit. • Considering the opinions of others when proposing a change, conducting opinion surveys to determine customer preferences for design and color of item to be produced.
Being Open to New Ideas and Information	• Considering several methods of producing an item in quantity. • Asking other people for information on possible materials to use and for ideas about better methods of making the product.
Learning the Importance and Influence of Values in Decision Making	• Realizing that cost effectiveness alone is not a sufficient criterion for choosing one method of production over another; effects on people must also be considered. • Realizing that preferences for various possible products and various possible designs and colors of the product reflect the values of each individual.

Economics

- Using concepts and terms, for example, cost, profit, production cost, retail price, when manufacturing and marketing a product in quantity.
- Gaining experience with finance: sources, uses, and limitations of revenues for purchase of materials to produce an item.
- Gaining experience in comparative shopping for materials, record keeping, analyzing manufacturing costs.
- Assessing preferences of possible customers through surveys and questionnaires.
- Analyzing variables affecting purchase of product.
- Investigating economics of production and marketing of item being manufactured.
- Investigating costs of materials for product vs. use of materials and budget restrictions.
- Assessing costs, benefits of inventory and record keeping, quantity purchasing, mass production, and quality control.

Political Science/Government Systems

- Determining need for rules and regulations to maintain quality of product and to ensure safety on the production line.
- Contacting and working with school authorities to obtain funds needed to manufacture product, to obtain permission to sell product.

Social Psychology/Individual and Group Behavior

- Developing a product that is appealing to most people.
- Assessing which workers are best suited to each job: recognizing differing capacities of individuals for various jobs on assembly line.
- Determining factors that motivate workers.
- Recognizing the need for leadership within small and large groups.

Sociology/Social Systems

- Devising a system of working cooperatively on an assembly line.
- Producing an item that will satisfy the needs of others in the school or community as well as themselves.

Sociology/Social Systems (cont.)

- Relating assignments or jobs on assembly line to jobs done at home.
- Recognizing importance of worker morale.
- Recognizing that there are many social groups and that one person belongs to more than one social group.

ACTIVITIES IN MANUFACTURING UTILIZING LANGUAGE ARTS

Basic Skills

Reading: Literal Comprehension--Decoding Words, Sentences, and Paragraphs	• Decoding words, sentences, and paragraphs while reading directions, patterns, and supply catalogs.
Reading: Critical Reading--Comprehending Meanings, Interpretation	• Obtaining factual information about materials and tools needed to manufacture product. • Understanding what is read about materials and tools needed to manufacture product. • Interpreting what is read, such as directions for making product.
Oral Language: Speaking	• Offering ideas, suggestions, and criticisms during discussions in small group work and class discussions on problems and proposed solutions. • Reporting to class on small group investigations of possible materials and designs for product. • Responding to criticisms of activities. • Preparing, practicing, and giving effective oral presentations to obtain funds needed for manufacture of product. • Using the telephone properly to obtain information on costs and availability of materials. • Conducting opinion surveys. • Using rules of grammar in speaking.
Oral Language: Listening	• Listening to group reports on small group activities. • Following spoken directions.
Written Language: Spelling	• Using correct spelling in writing.
Written Language: Grammar--Punctuation, Syntax, Usage	• Using rules of grammar in writing.

Written Language: Composition	• Writing to communicate effectively: • writing down opinion survey, devising questions to elicit desired information; judging whether a question is relevant and whether its meaning is clear. • preparing write-ups of directions for each step in the manufacturing process.
Study Skills: Outlining/Organizing	• Taking notes. • Developing opinion survey; ordering questions around central themes, such as customer preferences for design, color, and price of item. • Planning presentations. • Planning and preparing drafts, presentations for critical review by the class before final copy is written.
Study Skills: Using References and Resources	• Using the library to research information on various methods of making product. • Using indexes and tables of contents of books and catalogs to locate desired information. • Using "How To" Cards for information on slope diagrams.
Attitudes/Values	
Appreciating the Value of Expressing Ideas Through Speaking and Writing	• Finding that the PTA will lend money needed to make item when presented with an adequate (written or oral) proposal.
Appreciating the Value of Written Resources	• Finding that certain desired information can be found in books and catalogs (directions for making item).
Developing an Interest in Reading and Writing	• Willingly looking up information on how to make product. • Looking up further or more detailed information on methods of making products, materials needed.
Making Judgments Concerning What is Read	• Deciding whether what is read is applicable to the particular problem. • Deciding how reliable the information obtained from reading is.

Making Judgments Concerning What is Read (cont.)	• Deciding whether the written material is appropriate, whether it says what it is supposed to say, whether it may need improvement.
Appreciating the Value of Different Forms of Writing, Different Forms of Communication	• Finding that how information can be best conveyed is determined in part by the audience to whom it is directed. • Finding that certain data or information can be best conveyed by writing it down, preparing graphs or charts, etc. • Finding that certain data or information should be written down so that it can be referred to at a later time. • Finding that spoken instructions are sometimes better than written instructions and vice versa.