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## STAT-MAPS

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### 1. Introduction

STAT-MAPS, "Statistics-Materials and Activities for Problem Solving", is a four year project (1991-94) in the Department of Mathematical Sciences, Appalachian State University, USA. Funded by the National Science Foundation, the STAT-MAPS project is developing curriculum and materials for students in grades 9-12 (ages 15-17). The STAT-MAPS curriculum is giving attention to students with a broad range of abilities and interests, not just the college bound ones or the advanced students who have a special interest in science or mathematics.

The goals of STAT-MAPS are to: (1) describe a flexible curriculum for various secondary level settings, (2) develop effective instructional strategies for presenting this curriculum, and (3) provide materials for implementing the instructional strategies and curriculum. The project is based on the recommendations of The Curriculum Standards of the National Council of Teachers of Mathematics (1989) and builds on the previous work of the Quantitative Literacy Project (Scheaffer, 1986)

### 2. Foundations

#### *General criteria*

STAT-MAPS is developing materials that not only include topics, concepts and problems at levels appropriate for the secondary curriculum, but also include contexts for problems which are of interest to the secondary learner and relate to other areas of the curriculum. Instructional designs and strategies present statistics so that it is appropriate by the secondary student. Ideas are presented in a unified fashion so as to present a coherent picture of statistics.

#### *Teaching and learning styles*

Observers of instructional styles consistently report an increase in

the use of lecture format and an accompanying decrease in small group or individual activity-based learning as the grade level increases. Formalization of procedures increases with grade level.

Learning theory research, however, suggests that the learning styles of most secondary students require exploratory activities with concrete realizations of ideas before abstract formalization of general concepts can be understood. STAT-MAPS is employing careful use of statistical problem-solving activities as a bridge across the concretion-abstraction gap suggested by current learning theory. STAT-MAPS activities encourage "intuitive" problem solving through a wide variety of real world problems. These concrete problems lend themselves to active, exploratory participation by the learner and may be used to nurture higher levels of reasoning.

### 3. The nature of the materials

The materials being developed by STAT-MAPS include:

- 1) Student text and activity manual;
- 2) Teacher manual.

**DATA:** to investigate our question about head sizes, we took measurements on 125 students (males and females) in five different classes. We measured head circumference (in millimeters) as described in the Eddie Bauer catalog.

**ANALYSIS:** the analysis uses stem-and-leaf and introduces the grouped frequency and relative frequency table and histograms.

**INTERPRETATION:** the pattern of head sizes and hence the shape of the histogram provide an answer to the question, and varying intervals is relevant to idea of a hat size.

**COMMUNICATION:** results are presented with tables, graphs, and written summary.

#### *Example C*

Problem type: Interpreting bivariate data  
 Levels: 2, 3  
 Title: Detectives, footprints and stature

Introduction: "Yes," he reported, after a short examination of the grass bed, "a number-twelve shoe, I should say. If he was all on the same scale as his foot he must certainly have been a giant". Sherlock Holmes, in *The Adventure of Wisteria Lodge*. Police officers often do not have accurate estimates for the height of a suspect in a criminal investigation. Footprints, either of the bare foot or more commonly as shoeprints, provide a possible way for estimating the height of a person. As suggested by inspector Sherlock Holmes, it is reasonable to expect that large persons have large feet. A lesser footprint would suggest a person of smaller stature.

QUESTION: is foot length a useful predictor of height?

DATA: to investigate the relationship between height and foot length, we took measurements on 121 students (male and female). Height and right foot length were measured with the subject standing barefooted.

ANALYSIS: visual analysis of scatterplots for trend is used. Fitting a line by the mean-mean method is introduced graphically and then the equation of the line is developed. Prediction error is described from the graph and the equation.

INTERPRETATION: the line is used for prediction, and prediction error is assessed.

COMMUNICATION: results are presented with tables, graphs, and written summary.

#### *Example D*

Problem type: Interpreting time series

Levels: 2, 3

Title: Murder rates in North Carolina

Introduction: there is great concern about the crimes rates in cities and regions of the United States. Many reports claim that the crime rate continues to rise. Most disturbing is the upward trend in violent crimes such as murder, rape, robbery, and assault. Many officials warn that we do not have enough policemen or jails to deal with the problems, and suggest that the criminal justice system needs additional support.

QUESTIONS: has the number of murders increased in North Carolina over the past ten years?

Can we predict what the number of murders will be next year?

DATA: uniform crime reports from the state of North Carolina Department of Justice provide data on several categories of crime, including the number of murders recorded monthly over the past ten years.

#### *The teacher manual*

STAT-MAPS is giving special attention to the teacher because statistics is a new subject in the U.S. curriculum. The limits of the teacher's knowledge about subject matter or about ways in which young people learn place predictable limits on what the teacher can offer and accomplish in the classroom. The teachers' beliefs about the nature of statistics are equally important influences on their students.

The STAT-MAPS Teacher Manual will include:

- (1) an annotated version of the text to clarify objectives, provide supplementary discussion of statistical ideas and issues, and provide teaching ideas;
- (2) a presentation and discussion of the various STAT-MAPS curriculum uses including class implementation schedules;
- (3) a bibliography of teaching resources and references;
- (4) suggestions on how to integrate other materials or resources such as videos into the STAT-MAPS curriculum.

#### *Computing*

STAT-MAPS is developing a curriculum for the future which employs computing resources. We are collaborating with Data Descriptions, Inc. to develop a special version of the DATA DESK software for school use.

#### 4. The curriculum and instructional design

We agree with the statement of purpose for the textbook Introduction to the Practice of Statistics (Moore and McCabe, 1993): "We share the emerging consensus among statisticians that statistical education should focus on data and on statistical reasoning rather than on either the presentation of as many methods as possible or the mathematical theory of inference. Understanding statistical reasoning should be the most important objective". For secondary students, this may mean that sophisticated statistics are not used but what is used will be understood.

*Curriculum levels*

The STAT-MAPS curriculum is developed in four levels, roughly corresponding to grade levels 9-12. The materials are organized in a corresponding fashion. This organization provides flexibility so that they could be used in a curriculum which does statistics at each grade level, levels 1-2 could be combined within one year (grade 10), or levels 3-4 could be combined within one year (grade 11 or 12). The materials could be used in smaller pieces also.

*Problem types / interpretation and inference*

Ideas or activities are always presented through problem scenarios which may be classified according to several categories of interpretation and inference:

- A. Fundamentals/Tables and Graphs
- B. Interpreting Univariate Data
- C. Interpreting Bivariate Data
- D. Interpreting Designed Experiments
- E. Interpreting Time Series
- F. Estimating Population Values from Samples
- G. Model Fitting
- H. Statistical Decision Making

*Statistics as a problem solving process*

Statistics begins with the notion that we use data to answer questions. A statistics "problem" typically contains the four components:

- (1) question
- (2) data
- (3) analysis, and
- (4) interpretation and inference, in some order; and
- (5) communication of results.

What makes a problem a statistical problem is the way we ask the question, the role and nature of the data, the peculiar ways that we look at the data, and the types of interpretations and inferences we make. STAT-MAPS uses this five point framework as a foundation for all of its text and activities.

Question formulation is an important part of any problem solving process. How we ask the question determines what kind of answer is attainable, and conversely, we must know what kind of answer is possible before we ask the question. The heart of the subject is data. Data is not just

a set of numbers; data consists of a set of measurements. This distinction and the issues of measurement must be a major objective of statistical education. Understanding the role of data collection design must also be a major objective of statistical education. Statistical analysis, to a great extent, focuses attention on the variation of measurements and the pattern of variation in data is its typical starting point. Statistical education should develop an appreciation for this peculiar way that we look at data. The interpretation of the analysis and resulting inferences may lead to an answer for our question. Inference from data, whether formal or informal, is the final stage of the problem.

Understanding the nature and limitations of statistical inferences must be an important objective of statistical education. The communication of statistical findings in the form of graphical or tabular presentations as well as succinct written summaries should be emphasized. In each of the problem components, statistical reasoning must be employed. This "statistical reasoning" must be developed over time and the curriculum for high school students must continually cultivate and exercise this form of reasoning.

#### *Student skills*

STAT-MAPS categorizes student skills by concepts and techniques which are organized according to:

- (1) Data Collection;
- (2) Data Tabulation and Representation;
- (3) Data Reduction, and
- (4) Probability.

#### **5. Example units**

STAT-MAPS materials are organized by problem type and level. The presentation of ideas in the student text and the student activities are given in the framework of the problem solving process, with skills developed as needed for the given problem. This distinguishes the STAT-MAPS materials from most traditional textbook presentations which are organized essentially on the basis of techniques and methodology. By emphasizing statistics as problem solving, the development of statistical reasoning is quite natural because it is integral to the problem solving focus. The following are abstracts of STAT-MAPS units to illustrate how this is accomplished.

*Example A*

Problem type: Interpreting univariate data  
Levels: 1, 2  
Title: Reading Level

Introduction: magazines and newspapers are written for a wide variety of readers. The reading levels of publications vary. Some are written for persons who may have a limited education while others are designed for college graduates. The reading level may vary within a newspaper. An article on the sports page may not be at the same level as an article on the editorial page. There are several possible indicators of reading level that we can describe and analyze with statistics. Long words would indicate a high reading level, whereas use of short words would suggest a lower reading level. Other measures of reading level would include the lengths of sentences, the size of paragraphs, or the number of adjectives used.

We will compare the reading level of two newspaper articles by comparing the word lengths used in the articles. One article is by George Will, a political writer whose articles appear in different newspapers throughout the United States. An article about Whitney Houston is from *The Star*, a magazine which features stories on people in entertainment.

**QUESTION:** is there a difference between the word lengths used in the George Will article and the word lengths used in the article from *The Star*?

**DATA:** we examine and tally the word lengths for each of the three articles.

**ANALYSIS:** the analysis uses the ideas of max, min, median, mode, mean. It introduces frequency and relative frequency tables and bar charts as other ways of looking at the data which are relevant to the question.

**INTERPRETATION:** a comparison of word lengths is based on tables, bar charts, mean, median, and mode.

**COMMUNICATION:** the results are presented through the tables, graphs, and a written summary.

*Example B*

Problem type: Interpreting univariate data

Levels: 2

Title: Hat Sizes

Introduction: hats are made in a variety of styles and sizes. A merchant must decide what styles to keep in stock and how many hats of each size should be ordered. Are some hat sizes more common than others? If so, the merchant would want to order larger quantities of the more popular sizes. Hat size is apparently determined by head size. There are several possible measurements of the human head that might be used to describe head size. Mail order catalogs ask you to measure your head to determine your hat size. Here is the description from the Eddie Bauer catalogue (1992): "Hold tape level and firm. Measure circumference around the head, across temples and above eyebrow ridges".

QUESTION: are some head sizes more common than others?

ANALYSIS: visual analysis of time series plots and prediction from linear trends are used. Prediction based on non-linear trends is introduced.

INTERPRETATION: the notion that this type of prediction depends on assumptions about future trends is emphasized. A line may be fitted to a portion of the series, and the portion used affects the prediction.

COMMUNICATION: results are presented with tables, graphs, and a written summary.

## 6. Project status

Class Testing of materials was conducted at two sites during the spring of 1993. Two classes at Garinger High School in Charlotte, an urban environment, used STAT-MAPS units. One class in the rural community of Yanceyville also participated in testing. These will be expanded to four sites during 1994. The design and development of the DATA DESK software just began during the summer of 1993. It is anticipated that the project work will be completed during the spring of 1995.

The principal persons in the STAT-MAPS project are: Mike Perry,



Project Director; Gary Kader of Appalachian State University, Associate Project Director; Peter Holmes of the University of Sheffield, England, consultant.

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