TEACHING DESIGN OF CROSS-CURRICULAR STATISTICAL EDUCATION AT HIGH SCHOOL IN JAPAN

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In Japan, most of the people who teach statistics at junior and senior high school are math teachers. And while teaching license of mathematics can be acquired in various departments and faculties in university, features of each department and faculty are reflected in the teacher's training curricula and syllabuses. This study was conducted to establish a case to take advantage of the features of various subjects (Mathematics, ICT, Civics, Chemistry, etc.) in secondary school, playing the central role to train skillful statistics teachers. In this study, the contents of cross-curricular statistical education at secondary school in Japan were investigated and categorized to gain some implications for creating a good curricula and syllabus.

INTRODUCTION

Japan's course of study for senior high schools (Ministry of Education, Culture, Sports, Science and Technology in Japan 2009), implemented in 2012, prioritizes the development of practical skills, and schools and teachers are required to involve problem-solving or exploratory activities in every subject. In mathematics, "the cultivation of sound critical thinking, intuition, insight, logical reasoning, imagination, and independence" is required. To encourage statistical thinking, statistics curricular content was made compulsory for the first time in secondary schools. However, statistics education is not solely considered in mathematics. Nakanishi et al. (2011) reported that the data analysis of Mathematics I does not entirely comprise calculation methods, showing the importance of the relations between data analysis and other subjects. Many subjects other than mathematics require statistical tools; however, there are only a limited number of examples of statistics concepts that are taught across subjects. This lack of continuity across subjects involving statistical content may be due to the diverse spread of academic subjects or possibly due to a limited awareness of statistical concepts that appear in many subjects.

A considerable percentage of teaching staff in schools has no experience with studying statistics. When the key concepts are unclear to some instructors, they may plan their lessons that incorporate statistical material in less depth, while instructors more familiar with mathematics may cover statistical content more extensively. More research is required before all schools can implement unified statistics education. These two points are believed to be the pressing issues for the pursuing statistics education in the future.

This paper reviews statistics curricula in which concepts have been presented in a fragmented fashion across subjects. Then, the study surveys the tools of Statistical Thinking that should be focused upon in each subject. In particular, mathematics classes impart theoretical knowledge, whereas information technology classes nurture practical analytical skills using real data and train students on the use of appropriate software. Furthermore, in social studies classes, the ability to interpret the required data from various resources and tables is essential. Science classes nurture error-analysis skills and experimental design through practice in observation and experiments. In other subjects, abilities corresponding to various situations need to be nurtured. This paper discusses and identifies a sustainable form of statistics education, which uses the characteristics of each subject in a form clearly realizable within the framework of ordinary lessons at high schools in a multi-disciplinary fashion at different levels. Ultimately, this study proposes a statistics education curriculum that aims to nurture Statistical Thinking skills across the whole of high schools.

METHOD

Statistical Thinking

The Cabinet Office Economic and Social Statistical Development Promotion Committee (2005) states that "statistics is a 'mirror' that reflects the state of the nation or society by objectively grasping the aggregate condition of population, economy, society and can also be a

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'compass' for navigating to the future." Watanabe (2011) states that statistical thinking "supports decision-making in all kinds of fields, such as academics, administration, and management." Watanabe also mentions the following 7 tasks as specific examples of Statistical Thinking (Watanabe 2008):

Choosing the topic
Formulating the problem
Data collection
Data description and analysis
Statistical interpretation of results
Linking the interpretations to the original topic and communicating to others
Discovering new theories or performing estimation based on the results

Statistics education in Japan's high schools

Academic instruction requirements (Ministry of Education, Culture, Sports, Science and Technology 2009) point out the need for statistics education in the following subjects. The main content items are listed below.

Geography B: Systematic geographical consideration of the modern world (modeling)
Natural environment, resources, industry, population, distributions in our life and culture, and survey
Contemporary Society: Objective thinking about social phenomena (modeling)
Distribution of statistical documents, surveys, reading and understanding problems, and analysis
Mathematics I: Data analysis (methodology)
Representative values: Mean, median, mode, and comparisons for different distributions
Dispersion: Range, quartiles, box and whisker plot, variance, and standard deviation
Correlation: Scatterplot, correlations, correlation table, and coefficient of correlation
Basics of Science/Science: Experimental design and exploratory activities (modeling)
Physics / Chemistry / Biology / Geography experiments:
Hypothesis setting, verification, and experimental data analysis/interpretation
Information Study for Participating Community: Use of information and representation (method)
Representation and communication: Data organization, analysis, and representation methods
Information Study by Scientific Approach: Aggregate processing of information (modeling)
Data analysis using table calculation software: Collection, organization, and analysis
Modeling and simulation: Analysis of real data
Problem-solving assessment and improvement: optimization and solution consideration

Statistical problem solving

To encourage Statistical Thinking, the curricular content should be divided into several parts. Students study decision theory, Statistical Thinking, and phenomena modeling. First, mathematics and information technology classes teach skills. Then each unit within social studies and science classes requires students to use these skills organically and continuously. This division of topics can be used to construct a statistics curriculum that can be implemented within the existing curriculum. In this regard, the problem, plan, data, analysis, and conclusion (PPDAC) cycle is used in New Zealand as the model statistical problem-solving process for planning lessons:

Problem (clarification of familiar topics)
Plan (survey/real experiment design)
Data (creation of data tables)
Analysis (data analysis)
Conclusion (conclusion related to the original topic)

LESSON PLAN

The number of hours: Mathematics I: 6 h, Information Study by Scientific Approach: 4 h
Basic Chemistry: 4 h, and Geography B: 3 h
Target: the Senior high school 10th Grade (age 15-16)

Mathematics I Lesson objective:

Understanding the characteristics of representative value, dispersion, and correlation and how to use them. Calculating each value with at least five data points. Estimating the changes to a plot caused by changing the values.

Information Study by Scientific Approach Lesson objective

Using table calculation software to perform calculations involving descriptive statistics. Creating tables and graphs from data. Choosing an appropriate graph and make decisions about presenting data. Using data to solve specific problems.

Problem

Table 1 Sales at 2 coffee shops (Unit: 1,000 yen)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	249	187	218	220	214	246	200	210	217	205	258	233	258	202	213	268	169	229	216	228
B	239	264	245	158	116	239	263	186	228	188	210	229	115	211	184	159	191	249	187	115

Practice 1: Calculate the total sales and average sales per day for the two shops

Practice 2: Analyze the data to compare the sales of the two shops

Practice 3: Which graphs would you use to give advice to the people running shops A or B from the point of view of an area manager?

Practice 4: What additional data and information would be required to give advice to the people running shops A and B from the point of view of an area manager?

Basic Chemistry Lesson objective:

Understanding the fundamentals of statistical methods for analytical chemistry. Estimating how an experiment's analytical precision can be improved and how the results would change.

Experiment 1: Neutralization titration (concentration determination)

Using neutralizing titration to determine the unknown concentrations of an acid (hydrochloric acid) and base (NaOH solution)

Experiment 2: Neutralization titration (creation of a titration curve)

Measuring the change in pH of a solution during neutralization titration, and create a titration plot from the data using Excel 2007.

Geography B Lesson objective:

Categorizing weather data and understanding its characteristics. Summarizing data into a hythergraph. Interpreting the characteristics of weather from data or graphs.

Practice problem 1

Creating hythergraphs for Beijing, Brisbane, San Francisco, and Perth, and compare the two different ways of summarizing them.

Practice problem 2

Making estimations for regions from the hythergraph, and narrow them down to the weather categories and regions.

RESULT AND DISCUSSION

This section evaluates the lesson objectives based on the pupils reports for each lesson.

Mathematics I

Many concepts were used in mathematics lessons, but there were several concepts that were distorted. Some pupils noticed that the representative value is not necessarily the mean, and many pupils were confused with the concepts of median and mode. One of the practice problems was "how do the values and distribution change if 100 is added to each of the five data points or if they are increased by 10%," and the pupils required a considerable amount of time to fully grasp the essence of this question. Gonzales et al. (2014) point out that "dispersion" has eight potential meanings. For mathematics instructions, they state that the distinction between "concepts concerning histograms (individual statistical concepts that change with the way in which the widths

are selected) and the related dispersion" and "dispersion in data and distributions (statistical problem solving)" must be made clear. Instructions tend to be superficial if only textbooks are used and end up relying upon simple calculation problems, and teachers must rather emphasize the meaning of each value.

Information Study by Scientific Approach

Many students sought representative values and levels of dispersion blindly, showing that future lesson plans will need to take into account the need for different strategies in order to calculate statistical values depending on practical circumstances. Pupils could create all kinds of graphs using Excel 2007; however, they struggled with appropriately interpreting and summarizing the data. Instructions are required to focus on expressing data analysis in the most useful manner and discouraging the inclusion of irrelevant plots. The sample problems included practical data analysis for individual shops as well as analysis of the comparison of two shops. More proposals were raised than expected. These questions had no specific correct answers but required imagination and communications skills. Interest and enthusiasm for data analysis should be encouraged by teachers working together with the pupils in these classes.

Basic Chemistry

Experiment 1: A neutralization reaction in which an acid and a base react with each other was carried out several times using the given solutions in order to determine the unknown concentrations of the acid and base. Experimental data, including outliers, were collected, and pH estimations were made without any difficulties. Furthermore, since the machine information operation had already been completed, data analysis was quick. Experiments and observations should be facilitated with attention to experimental rigor and careful error analysis.

Geography B

The representative values and the distribution of all kinds of data were discussed, and the advantages of the hythergraph were identified. Pupils examined the geographical differences and characteristics from several scatterplot hythergraphs, and the overall results were satisfactory. The pupils enjoyed "creating graphs that make data apparent at once." Some pupils requested lessons based on the estimation of economic variables and on civics.

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