ON STATISTICAL EDUCATION IN SECONDARY MATHEMATICS EDUCATION IN JAPAN

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In recent years, the scope of statistical education in Japan has rapidly expanded. we review past circumstances and discuss future directions for the further development of statistical education. We reviewed the history of the course of study of statistics in upper secondary schools and found that many opportunities to change how statistics are taught in Japan have been missed. We describe why these opportunities were missed, based on the experiences of teachers. Finally, we discuss the hopes and concerns for the forthcoming courses of study and the roles played by statisticians and other people involved in statistics education.

INTRODUCTION

The "Course of Study for Senior High Schools" (hereafter simply referred to as Course of Study) stipulates the content to be taught under each subject in senior high schools and acts as a standard when textbooks are being prepared. The textbooks so compiled, based on the Course of Study, are authorized by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT); hence the quality of content is maintained at a certain level. Therefore, the standard course content taught at Japanese senior high schools can be understood by examining the Course of Study. Systems such as those currently used in the senior high schools were launched and adopted completely in 1951; hence, by considering only the Course of Study versions issued after 1951,

(1) Statistics education imparted as part of Japanese senior high schools' mathematics education is introduced and described summarily;

(2) Bearing (1) in mind, the course content for the future statistics education is proposed. The aim mentioned in the introduction to each Course of Study includes only the parts related to statistics and they have sometimes been rewritten by the present author.

METHOD

Firstly, the research reported here is based on the following methodology.

(1) The parts related to statistics education were selected from the standard mathematics courses learnt by high school students based on the Course of Study for Senior High Schools issued after 1955 by MEXT (former Ministry of Education).

(2) Based on the Course of Study and the educational experience in senior high schools, the current situation of statistics education is elucidated by a brief commentary.

Furthermore, along with details of the present state of statistics education and the future plans currently available, a realistic proposal is made regarding the future shape of statistics education in Japan.

TRANSITION

Hereinafter, statistics education as part of mathematics education in Japanese senior high schools shall be referred to simply as statistics education.

Firstly, for those not familiar with educational administration in Japan, a brief introduction is provided of the material used, namely, the Course of Study for Senior High Schools. Subsequently, the study content for the Course of Study for Senior High Schools is introduced in the order of issuing year and, at the same time, commentary is provided regarding the usual teaching situations based on experience. The main discussion would be around those periods when statistics education was not valued. Finally, we discuss the recent trends.

Course of Study for Senior High Schools

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Course of Study stipulates the content taught in each subject at senior high schools and is used as a standard when compiling textbooks. Textbooks compiled based on Course of Study are authorized by MEXT; hence the quality of the study content is maintained at a certain level. Hence it is possible to know the standard content being taught at Japanese senior schools by examining the Course of Study. Systems such as those currently used in the senior high schools were launched and moved over to it completely in 1951; hence the Course of Study issued after 1951 only are considered here. Furthermore, the aims mentioned in the introduction to each Course of Study includes only the parts related to statistics and they have sometimes been rewritten by the author.

Course of Study, 1951 and 1956 versions

Content related to statistics education shown in the Course of Study 1951 version is briefly introduced. This course of study led to many arguments after its announcement, and five years later in 1951, a new Course of Study had to be announced. Although this background is interesting from the viewpoint of mathematics education, further discussion of it shall be omitted here as the focus of this report is on statistics education.

Based on this 1956 Course of Study, there were four courses - General Mathematics, Analysis I, Analysis II and Geometry - of which at least one had to be taken. Statistics education is covered in two courses - General Mathematics and Analysis II, and although the teaching content in General Mathematics was not systematic and was constituted of life experiences, both General Mathematics and Analysis II used descriptive statistics.

- General Mathematics
  Aims: Develop the habit of thinking about the accuracy of numerical values and the limitations thereof when carrying out quantitative processes. In particular, deepen the understanding regarding statistical methods of documentation, organization and interpretation, while cultivating an attitude favorable to correctly using the statistical way of thinking and the ability to capture things without errors and to communicate accurately.
  Terms: mode, median, standard deviation, correlation, cartogram
- Analysis II
  Aim: Understand statistical method of documentation, teach organization skills and interpretation, and cultivate the ability to capture things without errors and to communicate them accurately. Cultivate an attitude favorable for correctly using a statistical way of thinking in day-to-day life.
  Terms: frequency, frequency distribution, class, variable, range, deviation, standard deviation, correlation, correlation table, representative value, arithmetic mean, weighted average, mode, median, sample survey

The teaching content that we have now was developed on the basis of this Course of Study implemented in 1956.

According to the Course of Study 1956 version, it was decided to teach Mathematics I (for the first grade) for 6 or 9 hours per week by schools, and in cases where 6 hours was the time selected, many schools did not include statistics in the curriculum. Therefore, it is thought that not many students learnt it.

- Mathematics I
  Aims: To use the fundamentals of descriptive statistics as a method for mathematically expressing statistical phenomena in a social or natural phenomena and make clear their role.
  Terms: variable, frequency, distribution, class, range, histogram, representative value, arithmetic mean, mode, median, deviation, standard deviation, correlation, correlation table, scatter diagram, correlation coefficient

After learning Mathematics I, Mathematics II (course for the second grade) will be learnt and grade progression will happen; if the choice is made to move onto Mathematics III (course for the third grade), the following content would be learnt, but there is hardly any record to say that these were actively taught.

- Mathematics III
  Aims: Clarify the concept of probability and add the concept of probability to topics taken from" Mathematics I" from a descriptive statistics perspective and deepen the understanding of statistics.

Terms: sample, population, sample survey, sample mean, sampling

The content in Mathematics I is similar to that being covered at senior high schools at the moment. However, the majority is pulled out of the curriculum being learnt by high school students in a revision afterwards. Although the need for statistics education is on the verge of being recognized, it is apparent from the internal notes for Mathematics I or Mathematics III, "no complex calculations are carried out," "correlation coefficient on a descriptive level," or "at a level of knowing the meaning through actual examples of practical training," statistics had been treated differently to subjects which were systematically organized such as algebra or geometrics. Hence statistics has been treated as a heterogeneous subject within mathematics and has been avoided for many years by mathematics teachers.

Course of Study 1963 version

Japan at that time was known to be in period of high economic growth and revisions were carried out to match the progress in science and technology. Content relating to statistics education described in the revised Course of Study 1963 version is as below.

- Mathematics IIA (course for the second grade, taken mainly by students undergoing vocational training)
  Aims: Clarify the concept of probability as well as deepening the understanding of descriptive statistics. Moreover, make students understand the basic concepts in inferential statistics and cultivate a statistical way of viewing and thinking.
  Terms: standard deviation, population, sample, sample survey
- Mathematics III (course for the third grade, taken by many students aiming to progress to universities for majors in maths and sciences)
  Aims: As well as clarifying the concept of probability, deepen thoughts and views regarding statistics using probabilistic ways of thinking.
  Terms: variable, standard deviation, expected value, binomial distribution, normal distribution, sample, population, sample survey, sampling inspection, quality control

Looking at this curriculum, it seems that statistics education in Japan is not dissimilar to that in other countries. However, Mathematics IIA and Mathematics IIB (courses for the second grade) are elective courses and many senior high schools opted for Mathematics IIB so there would have been no opportunity to learn statistics unless one opted for Mathematics III. Also, there was a course in place known as Applied Mathematics (course for second grade or higher), which could be taken after taking Mathematics I for mainly vocational education subjects, but as only a few students were suited to the course, it shall not be discussed here.

The major differences from the previous period's Course of Study are that some of the descriptive statistics such as histogram or scatter diagram are no longer used and the fact that random number tables are used now in sample surveys. Histograms and scatter diagrams were to be taught at junior high schools and they were no longer used at senior high schools.

Course of Study 1973 and 1983 versions

The main reason behind the issue of Course of Study 1973 version is the influence of the movement to modernize the education content in the United States due to the Sputnik crisis. The initiative for modernizing mathematics education impacted Japan too. Details relating to statistics education described in Course of Study 1973 version are as follows.

- Mathematics IIA
  Aims: Deepen understanding regarding the concept of probability as well as passing on understanding about the concept of statistical inference or probability distributions.
  Terms: random number table, probability distribution
- Mathematics III
  (1) Probability distribution
  Aims: Clarify the concept of population and samples as well as the meaning of probability distributions and enable understanding regarding binomial distribution and normal distribution.
  Terms: random number table, variance, probability distribution, random variable, binomial distribution, normal distribution
  (2) Statistical inference

Aims: To gain an understanding regarding basic thinking around statistical inference.
Terms: estimation, hypothesis test

The key point is that the terms "estimation, hypothesis test" were added. It is appropriate to view this stage as having reached an international level. However, most of the students of Mathematics III are candidates for universities with majors in maths and science; as less than half of all the students take the course, even if one graduated from a senior high school, the level learnt never went beyond junior high school. Furthermore, courses known as General Mathematics and Applied Mathematics were provide in this Course of Study, but since there were not many learners, these courses were usually omitted.

As there was a lot in the content of study in the Course of Study 1973 version, there was a move toward narrowing the range of content, which led to the creation of the Course of Study 1983 version. According to this, the content relating to statistics education is as below.

- Mathematics II
  Aims: Includes probability and the fundamentals of statistics so refer to the aims below.
  Terms: expected value, standard deviation
- Probability and Statistics (course for the second grade or third grade)
  Aims: As well as deepening the understanding of basic concepts and laws of probability, gain an understanding of the concept of probability distribution and extend the ability relating to statistical viewing and thinking.
  Terms: expected value, estimation, hypothesis test

Other topics were being reduced but hardly any topics relating to statistics education were reduced. As a separate course called Probability and Statistics was established, this opportunity could not be taken to enrich statistics education. Several of the main reasons shall be described in the next section.

Course of Study 1994 and 2003 version

Course of Study 1994 version had a shift toward education that made students think, reducing the content of study significantly and statistics education regressed with it. The major changes were that hypothesis test was no longer included and utilization of computers became clearly stated.

- Mathematics B (course for the second grade)
  Aims: Enable understanding of probability distributions as more advanced content than probability covered in Mathematics Ⅰ and aim for the acquisition of basic knowledge and proficiency of skills and extend the ability to mathematically examine and process phenomena.
  Terms: conditional probability, mean, standard deviation
- Mathematics C (course for the second grade or third grade)
  Aims: Utilize computers from the perspective of applied mathematics in order to understand about statistical processing and extend the ability to mathematically examine and process phenomena in order to gain knowledge and proficiency in skills.
  Terms: variance, standard deviation, correlation coefficient, estimation

Both Mathematics B and Mathematics C have unit options within the course and statistics is not taken in most senior high schools.

Items handled in Course of Study 2003 version were influenced by the fact that statistics was no longer learnt at junior high schools and basics of descriptive statistics - frequency table, scatter diagram, representative value - were to be incorporated.

- Mathematics B
  Aims: Understand the basic concepts in statistics and organize and analyze familiar materials using spreadsheet software, etc. to be able to capture the trends in materials accurately.
  Terms: frequency table, scatter diagram, representative value, variance, standard deviation, correlation coefficient
- Mathematics C
  (1) Probability distributions

Aims: Deepen understanding regarding probabilistic calculations as well as random variables and their distribution and developing the ability to examine uncertain phenomena mathematically, become able to utilize them.
Terms: conditional probability, mean, variance, standard deviation
(2) Statistical processing
Aims: Understand continuous probability distributions and statistical inference and enrich statistical views and thinking as well as become able to utilize them in statistical inference.
Terms: estimation

As with the earlier Course of Study, both Mathematics B and Mathematics C require units to be selected within the courses and most senior high schools do not take up statistics. There is another serious issue. Statistics was being learnt in junior high schools until Course of Study 1994 version. However, high school students following Course of Study 2003 version do not learn statistics at junior high schools. Hence Course of Study 2003 version includes a course called Basic Mathematics, in which elementary descriptive statistics is included. However, as there were not many students of taking this option, its introduction shall be omitted in this discussion.

Changes in statistics education

The Course of Study versions looked at in the previous section have provided an opportunity for statistics education to be received by all high school students, but the reality is that most students are not receiving it. It can be said that there was practically no statistics education in senior high schools for about 60 years from 1951 to 2011. This was changed in a major way by the Course of Study 2012 version.

Course of Study 2012 version

Course of Study 2012 version was announced which led to all high school students receiving statistics education for the first time since the senior high schools that exist now were first established. The content is as below.

- Mathematics I (compulsory for everyone in a unit called "Data Analysis")
  Aims: Understand basic ideas in statistics as well as become able to grasp the trends in data by organizing and analyzing them.
  Terms: box plot, interquartile range, quartile deviation, variance, standard deviation, scatter diagram, correlation coefficient
- Mathematics B
  Aims: Understand random variables, their distributions and statistical inferences and become able to utilize them in the examination of uncertain phenomena.
  Terms: random variable, probability distribution, mean, variance, standard deviation, binomial distribution, normal distribution, population, sample, sample survey, inference

Box plots which were not used in the past were newly added. Descriptive statistics was made compulsory for all but unfortunately inferential statistics is in the same situation as before. The actual state of lessons will be discussed in next chapter.

RESULTS

We have been looking at the changes in statistics education within Japan's education system, but the question seems to be, why has statistics education been continually neglected in Japan despite there being such extensive and regular curriculum planning and upgradation? We want to first consider it based on actual experience as a means of reflection. Subsequent to that, I would like to propose my idea of the future before ending this report.

Reflection

Let us recapitulate the problems in statistics education in Japan.

(1) It is treated as a unit within Mathematics hence the learning time even within the current course of study is only about 10 hours and so the absolute time available for learning statistics is short. There are not many hours for analyzing data, and often the time is used up with just the calculation of mean, variance and correlation coefficients.

(2) As the criterion for teaching a subject or not is down to whether it is necessary for the university entrance examination or not, if any subject is excluded from the entrance exam coverage, the lessons will not be conducted. Even universities representing Japan such as the University of Tokyo or Kyoto University do not include statistics out of Mathematics B in their exams. There will be no changes in the classroom as long as this current situation is not changed.
(3) As there is no data science included in the university curriculum required to become a Mathematics teacher, many teachers have only ever learnt mathematical statistics. Furthermore, there are teachers who have not learnt in their high school days, and hence do not know what they should teach in statistics. Ideally, statisticians or data scientists should be giving hold lectures relating to data science at universities where mathematics teachers may be trained; whereas for practicing teachers, at the very least workshops should be organized dealing with what should be taught at high schools, so that teachers who are expert mathematicians do not struggle in teaching statistics. However, although it has been six years since statistics education was rolled out to all high school students, there has not been that much actual implementation hence there has been not many changes in the classroom since then. If the next Course of Study is implemented as is, it would not be hard to imagine that the school curriculum may involve, for example, hypothesis tests ending with just the calculation of test statistics and comparison with the critical region.

A proposal for statistics education for the future

Since it has become apparent that statistics would become compulsory in senior high schools in 2012, 'statistics' is included in the proposals. The main reasons behind this are as follows.
(1) Mathematics teachers haven't studied subjects relating to data science until graduating from university. There are not many teachers who are interested.
(2) As long as it is incorporated within mathematics, it is handled mainly as part of mathematics, and there is the risk that the essence of statistics, which is to construct a hypothesis from data and test it, will not be learnt by the high school student.
(3) Statistics has a practical aspect of being an information processing skill hence a comprehensive course of learning spanning multiple subjects not fitting into the framework of mathematics is required.

It would be difficult to increase the number of subjects in the average school curriculum; hence both theory and practice of statistics can be learnt together by first learning statistics as a mathematics subject, and then actually experiencing the process of organizing, analyzing and considering actual data as subject 'information'. After acquiring these basic skills, ideally things that can be done within the framework of existing subject should be proposed such as utilizing them in the Period for Integrated Studies proposed within the next Course of Study.

In order to nurture young people who will be taking Japan forward into the 2030s and beyond, data science education that further develops statistics education within mathematics is important and we are now in an era that thinks of such things as even beyond the framework of mathematics.

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