A CERTIFICATION SYSTEM FOR STATISTICS KNOWLEDGE AND SKILLS BY JAPANESE STATISTICAL SOCIETY

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In 2011 the Japan Statistical Society (JSS) started a set of examinations, called the JSS Certificate (JSSC), for students and professional statisticians or interviewers working in various fields related to statistics. The exams consist of four levels for students and two levels for professional survey workers and researchers. The exams try to assess not only statistical knowledge and skills, but also statistical reasoning and thinking. Recently the national curriculum of Japan has changed, expanding the amount of statistics content. In this paper we focus on the lower level student exams, which target students who graduated from high school (level 3) and junior high school (level 4). We show the properties of the exams during two years and some results. The results indicate some problems with statistics education in Japan.

INTRODUCTION

Japan is undergoing a demographic shift, with an aging population and a diminishing number of children. In particular, the decrease in the 18-year-old population affects Japanese universities. An increasing proportion of students have the opportunity to study at university, but instructors feel a lowering of academic quality. Recently, most universities have begun to consider how to ensure quality education for students graduating from university. As one of the methods of assessing this situation, we statistics instructors discussed ideal students who graduate university and how to assure their achievement level in each research area. However, there are no undergraduate statistics major courses in Japan. Statistics professors teach only students who have major areas other than statistics, so we don't have any standing official meeting to discuss the quality of statistical education. We worried about falling behind other areas. The six Japanese academic societies related to statistics, including the Japan Statistical Society (JSS), cooperated and constructed a special meeting group in which we discussed guidelines for statistical education for some special areas. But at that time, we did not have any method to evaluate the goals of statistics education.

In 2008 and 2009, the Japanese government revised the guidelines for school curriculum, as part of the revision process that has occurred roughly every decade. The recent revision was affected by results of the Programme for International Student Assessment (PISA). The assessment found that 15-year-olds in Japan take less pleasure in learning mathematics and have less interest and motivation in doing so than the average student across OECD countries. The recent revision of the guidelines specially focused on the effective use of content that students study at school. The amount of statistical education was expanded in grades 7-12. This was a big change of direction, because statistical content almost vanished from mathematics in the prior revision. Until 2002, Japanese primary and secondary students attended school six days per week. Saturday schooling was eliminated to let students have a variety of activities and experiences outside of school. In order to drop Saturday schooling, we had to eliminate some content in mathematics, including much of the statistics. A lot of that content returned in 2008 and 2009.

In Japan, entrance examinations for high school and university have an important role. School teachers felt that it was difficult to assess statistical content, and teachers wondered how to present the new content. Academic society needs to offer assistance to the school curriculum and also provide examples for the entrance examination. To accomplish these two goals, we built the JSS Certificate (JSSC) program. JSSC is designed not only to assess ability in statistics, but also show the material to school teachers.

JAPANESE STATISTICAL SOCIETY CERTIFICATE (JSSC)

The Japan Statistical Society created a set of examinations, called the JSS Certificate (JSSC), for students, professional statisticians, and interviewers working in various fields related to statistics. The exams for students have 4 levels. Level 1 is the highest level, which targets graduate students who take the statistics major. Level 2 targets students who finish the basic course of statistics in university. Level 3 targets high school graduates, while level 4 targets students who graduate junior high school. At first, we planned to check the ability of only university students, due to the demographic shift. However, the school curriculum revision led us to add exams for levels 3 and 4.

JSSC exams have been administered once a year in six major cities across the country, as part of an organized exam system. JSSC exams for levels 2-4 have been carried out since 2011. The Level 1 exam started one year later. Levels 2-4 use multiple choice problems, while level 1 uses descriptive free-response questions. Test questions evaluate not only statistical literacy, but also statistical reasoning and thinking. We distinguish the three concepts according to the book by Ben-Zvi and Garfield (2004). Questions for statistical literacy check understanding of the basic concepts of statistical terms; those for statistical reasoning check ways of reasoning with statistical terms. It can be difficult to check the quality of statistical thinking, but we try to produce such questions, such as how to collect data and what statisticians need to collect in order to check hypotheses.

Table 1 shows the range of content for levels 3 and 4. For level 4, we evaluate basic ability in descriptive statistics. Graphical expressions, understanding the distribution of a variable, and contingency tables are included. Probability is treated in simple situations. For the higher level 3, descriptive statistics are extended to include quartiles and boxplots, plus standard deviation and variance as indices of variation. Basic ideas of sampling surveys, including random sampling, are included. Probability content is extended to independent events and conditional probability.

Table 1: Contents of JSSC exams

Level 4	Level 3 (Level 4 plus the following)
Graphs (bar plot, line graph, pie chart, etc.)	Sampling and Surveys (population, sample,
Types of data	census, random sampling, size of sample,
Distributions (including frequency table,	random numbers, etc.)
histogram, mean, median, mode, range)	Quartiles and interquartile range
Contingency tables	Standard deviation, variance
Basic aspects of time series	Boxplot, scatterplot, correlation
Basics of probability	Probability of independent events
	Conditional probability

Analysis of the Results of JSSC

In the first year, level 4 had 23 examinees and level 3 had 197. The number of examinees increased substantially in 2012, to 62 and 658, respectively. Interestingly, although the level 3 and 4 exams target high school and junior high school students, most examinees in 2011 and 2012 were over 20 years old. The success proportion for level 4 in 2011 was about 70%, and for level 3 it was about 64%. Passing percentages in 2012 were similar to those in 2011. For this paper, we analyzed the results of the first JSSC exams from 2011.

Results of Level 4

There were 28 questions on the level 4 exam. It included 6 testlets, which use the same situation for several questions. Since the JSSC emphasizes importance of the situation for data, each testlet described the situation in detail. The questions and the detailed descriptions were published in Japanese (Japan Statistical Society, 2012a).

For each question, we computed the proportion of correct answers. On 14 questions, more than 80% of test takers answered correctly. On 7 questions, less than 50% answered correctly, with 3 questions at less than 40%. Table 2 shows the average percentage for the three overall concepts of statistical literacy, reasoning, and thinking. The average percentages for statistical literacy and

statistical reasoning were 79.3% and 73.9%, respectively. For statistical thinking, test takers averaged 50.7%, lower than the other two areas. The questions for level 4 exams were not so difficult with respect to statistical literacy and reasoning. But some testlets and questions described situations in detail and asked about thinking and understanding the situations. The results of level 4 show that the ability of statistical thinking is not sufficient.

The question with the lowest percentage correct, about 26%, involves analyzing results of a survey of junior high school students about the genre of their favorite TV program. In the question, samples were randomly chosen from students by sex at different sampling rates. Frequencies for each genre and each sex are given by a two-way contingency table. The question was to choose the formula to estimate the proportion of most favorite genre among all high school students. Seventy percent of examinees chose the formula to calculate the frequency of the genre divided by the total frequency in the survey results. Most examinees did not consider the different sampling rates between boys and girls. It is unknown why they choose an incorrect answer, but their ability in reading the situation is not sufficient.

The question with the second lowest percentage, also around 26%, was related to histograms. In this question, the frequency table was given, but the range of one class was larger than other classes. Forty three percent of examinees chose a histogram with the same width for each class. Considering possible reasons, in addition to troubles differentiating between bar graphs and histograms, the curriculum in school mathematics treats only histograms which have classes with the same width. Additionally, most of the 2011 examinees were university students, who did not study the histogram before they entered university.

Table 2: Average percentage of correct answers for the three concepts in 2011

	Level 3	Level 4
Statistical Literacy	70.0%	79.3%
Statistical Reasoning	76.9%	73.9%
Statistical Thinking	75.5%	50.7%

Results of Level 3

There were 27 questions on the level 3 exam. It included 4 testlets, less than level 4. The questions and detailed descriptions were included in the same book as level 4 (Japan Statistical Society, 2012a). The percentages of correct answers for 10 questions were more than 80%. The number of questions with the percentages less than 50% was four, the two described below plus a question about using a table of random numbers and a question about time trends. No questions had less than 40% correct answers. The average percentage for statistical literacy was 70.0%, for statistical reasoning 76.9%, and for statistical thinking 75.5%. The questions for level 3 exams were not as hard overall as those for level 4. Questions with concrete information had high proportions of correct answers, but questions which need abstract thinking had low percentages.

The question with the lowest percentage correct was about the distribution of test scores. The question gave the mean and median of the score distribution. It asked students to explain the change if we added 5 points for all students or added 10% of their scores. Around 35% of examinees misunderstood the changes in the proportion of students scoring greater than or equal to 60 points. The question did not give the scores for each student, just mean and median, so we guessed that examinees felt the question was difficult. The scores in the two cases were different, but the proportion of students with more than 60 points was the same.

The question with the second lowest percentage was related to conditional probability in screening for gastric cancer. The question gave information about the proportion of positive results in the first screening, and the proportion of positive results in both the first screening and the second screening. The question asked for the conditional probability of a positive result in the second screening, given a positive first screening. In the question, 35% of examinees calculated the product of the probabilities of first positive result and both positive results. Only 44% of the examinees gave the correct answer.

CONCLUSIONS AND DISCUSSION

Results of the 2011 exams showed that most examinees gave correct answers for questions on basic knowledge. On the other hand, success proportions for questions which required understanding the background of data and engaging in statistical thinking are not high enough. Not engaging high level thinking is a typical characteristic of Japanese education. The results of the PISA questionnaire showed that Japanese students thought that the content they studied in school was not useful in their lives. They considered passing the entrance examinations as the goal of their study, so they studied simplified situations for the entrance exams. The contents were far from real life. The recent revision of the curriculum guidelines in Japan has challenged this viewpoint; it has focused on statistics and extended the context. Unfortunately, the improvement is limited. To show the usefulness of statistics, we have to consider context to design future effective instruction methods.

We analyzed results from the 2011 JSSC exams for level 3 and level 4. Since the JSSC exams had just started, the numbers of examinees for level 3 and level 4 were not high. Most examinees were university students, with just a few junior high school and high school students, even though the exams were designed for high school (level 3) and junior high school (level 4) curriculum. Despite being targets of these exams, the abilities of high school and junior high school students are not well known from these results. Things are changing. At present, many Japanese people are interested in the effective use of big data and many statistics books have been published. In fact, the number of examinees increased in 2012 and 2013. The JSS has decided to expand the JSSC to two administrations, in June and November 2014. We might consider how characteristics of the questions might need to change if the number of high school students and junior high school students increases.

This was the first time designing the exams. To create questions, 20 or more persons were assembled from various research areas. The committee met several times and discussed the questions. They found that there were varying opinions; different definitions are used for some basic statistics terms, caused by the wide range of areas that use statistics. Some definitions and practices of statistics vary between areas. In order to unify terms, we published standard textbooks for level 3 and 4 (Japan Statistical Society, 2012b; 2012c) Now test questions are based on these books.

The JSSC emphasizes not only statistical literacy, but also statistical reasoning and thinking. In creating questions, we found it easy to make questions for statistical literacy and reasoning, but hard to create questions for statistical thinking because past experiences were poor. In order to assess statistical thinking, we have to provide detailed information on the situations and offer some background knowledge for the data. We need to continue working on the challenges of this issue.

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