ASPECTS OF CRITICAL THINKING IN STATISTICAL EDUCATION
-RESEARCH SURVEY ON A SIXTH-GRADE ELEMENTARY SCHOOL-

OHTA Naoki[1]
Fukuyama City University, Japan

TERAGUCHI Ken[2]
Kuchita higashi Elementary School , Japan

LERNING OBJECTIVES

1. To develop a test to assess the level of critical thinking .
2. To clarify aspect of critical thinking with regard to sixth-grade elementary school.

BACKGROUND AND PURPOSE

In recent years, the need for statistical education has increased, for which the development of statistical thinking abilities has become fundamental. As a background to the introduction of critical thinking in statistical education, when collecting and reading statistical data and graphs surrounding daily life and society, Matsumoto (2017) stated that we should not immediately assume the correctness of these data. He argued that it has become important to think critically. Moreover, Matsumoto (2018) put forth the following statement as a definition of critical thinking in statistical education: "Critical thinking in statistical education is problem-solving (problems, plans, data, etc.) using statistical data performed by others or oneself. It is a way of thinking that interprets and reflects on the analysis / conclusion while having a multifaceted, objective, and logical thinking attitude." Therefore, he divided critical thinking into four elements: "objective," "multifaceted," "logical," and "introspective."

In 2017, although statistical education in Japan was extended to the elementary school curriculum guidelines, content related to critical thinking for the sixth grade was limited to "a critical analysis on the validity of the conclusions." In addition, Tatsuzaki (2017) and Takayama (2018) conducted research on critical thinking in children from the fourth and fifth grades of elementary school, respectively. However, given that their studies were mainly focused on the organization of the lessons and methods followed therein, a clear description of a critical thinking development was not reported. Moreover, tests for assessing critical thinking have not been developed in previous studies, and the critical thinking abilities of children are not known.

Therefore, the purpose of this study is to develop a test to assess the level of critical thinking and to clarify this aspect with regard to sixth-grade elementary school children.

METHOD

In December 2020, a survey questionnaire on the four aforementioned elements of critical thinking, namely "objective," "multifaceted," "logical," and "introspective," was filled out by 222 students of the sixth grade. A total of eight questions were asked, with two for each element. We asked the students to choose the wrong answer of the four options and explain their opinions based on the graph data. The aim was to assess and analyze the students' critical thinking abilities. For the analysis, the one-way analysis of variance (ANOVA) and Tukey's multiple comparison methods were used to obtain the average value of each element. Furthermore, the answers of the students were categorized into "right" and "wrong" and analyzed further.

RESULT

The analysis was performed by assigning a maximum of four points for each question (element). However, there was an error in question 3 ① ("logical"); hence, the score of question 3 ② was doubled. The average value, standard deviation, and scoring rate of each question are shown in Table 1, while the score distribution of each question is shown in a boxplot in Fig. 1. Table 1 shows that the average value and score rate corresponding to the "multifaceted" questions are 3.32 points and 83.0%, respectively, while those corresponding to the "objective" questions are 3.13 points and 78.3%, respectively. This implies a very high level of comprehension of the "objective" and "multifaceted" elements. The average value and the score rate corresponding to the "logical" questions are 2.79 points and 69.8%, respectively. Furthermore, Table 1 and Fig. 1 show that, in this case, the standard deviation is 1.34, the interquartile range is wider than that of other elements, and the difference between students who provided the right answers and those who did not is significant. The average value and the score rate corresponding to the "introspective" questions are 2.36 points and 59.0%, respectively—the lowest among the four elements. In this case, the interquartile range is between 2 and 3 points, and many students provided wrong answers.

To analyze the level of understanding of the elements, a one-way ANOVA method was performed. The result showed $F(4,222) = 45.59$, $p < .05$, and a significant difference among the elements. The results of Tukey's multiple comparison test showed a significant difference between "objective" and "introspective" and between "multifaceted" and "introspective" elements. Therefore, the "objective" and "multifaceted" levels are higher than the "introspective" level, as implied from Table 1.

In the case of the "objective" element, many students properly interpreted the bar and linear graphs. The analysis results of the incorrect answers indicated that, in some cases, the students used a subjective approach based on life experiences rather than on data, and they therefore did not correctly interpret the graphs. In the case of the "multifaceted" element, only about 30–40% of the answers were correct, which is not sufficient. Meanwhile, the analysis results of the incorrect answers indicated that the right data could not be selected because we did not understand the necessary conditions for the comparison. In the case of the "logical" element, some students understood the questions through objective interpretation of the data and consideration of future uncertain events. For example, they pointed out that it was wrong to conclude that something "always happens". About 30% of the answers were correct, while there were many semi-correct answers with insufficient explanations. The analysis of the incorrect answers showed that the students used a subjective approach instead of logically explaining the errors. Therefore, it is crucial to increase the opportunities in math learning and everyday life for logical assertions to be made based on objective reasoning. In the case of the "introspective" element, many unreasonable and meaninglessness explanations were provided in both the correct and incorrect answer cases. The analysis of the incorrect answers indicated that the students faced difficulties in reading while paying attention to the scales of the graph axes, understanding the consequences of a subjective interpretation, and noticing the relevant points of the graphs representing a ratio.

Table 1: Average value, standard deviation, score rate of students answer

	Q1 : objective	Q2 : multifaceted	Q3 : logical	Q4 : introspective
average value	3.32	3.13	2.79	2.36
standard deviation	0.86	1.12	1.34	1.10
score rate	83.0%	78.3%	69.8%	59.0%

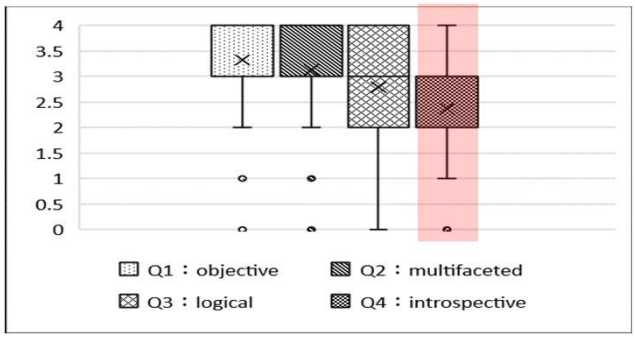

Fig. 1: Score distribution for each element

CONCLUSIONS

In this study, a survey was conducted among sixth-grade students to assess their level of understanding of four elements of critical thinking in statistical education. The results indicate that "logic" and "introspection" were the elements least understood by the students. We therefore believe that, in the future, elementary school students should be taught how to interpret statistical data, such as graphs and tabulated data. Moreover, the results of this research can be used for organizing lessons that encourage critical thinking within statistical education, and to analyze the practical effects of this approach. Finally, lessons aimed at raising critical thinking abilities and verifying the effects thereof should be conducted.

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