Secondary teachers' pedagogical content knowledge to promote students' data-based decision-making ability: The cases of Japan and Thailand

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Introduction

Statistics has become very important at all levels of citizenry in today's society. Thus, to be part of modern society in a competent and critical way requires citizens to be able to interpret such data in a broad sense, in order to make informed decisions. In the educational context, many statistics educators, curriculum developers and international agencies around the world agree on the increasing importance for students to gain competence in using, handling and interpreting data to inform decision-making at personal, professional, and societal levels (Garfield & Ben-Zvi, 2008).

Recent reforms to the mathematics curriculum in many countries echo these ideas, with Japan and Thailand being two exemplary cases. In fact, in the case of Japan, in the particular case of secondary school level, the latest Japanese Course of Study emphasizes—in the mathematical domains "Practical Use of Data" at junior high school, and "Analysis of Data" at senior high school—nurturing the attitude and ability to purposely process daily-life data, capture its trends and features, and make decisions based on such analysis (MEXT, 2008, 2009). A similar situation can be seen in the case of Thailand, in its latest Basic Education Core Curriculum (MOE, 2008). In the strand "Data Analysis and Probability" at both junior and senior high school levels, one indicator of students' quality learning is the ability to apply statistical knowledge and the use of data and information for decision-making in various real-life situations. Thus, because of the significant place held by fostering decision-making skills in the Japanese and Thai secondary school mathematics curricula, teachers must be able to properly carry out data-based decision-making, as well as to design instruction aimed to develop students' decision-making skills. Knowledge about the latter involves being able to choose which type of tasks is more appropriate to implement with students for promoting particular abilities, which is central to the work of teaching and a skill related to pedagogical content knowledge, or PCK (Ball, Thames, & Phelps, 2008, p. 401).

Despite the attention given to students' development of decision-making skills and attitude in the latest Japanese and Thai mathematics curricula, what decision-making is and how to promote the skills related to it are not defined in those official documents. Therefore, teachers are left to determine by themselves how decision-making could be promoted in their students, which raises particular concern, due to the reported need for appropriate training in statistics education in the preparation of future mathematics teachers (Isoda & González, 2012; González, 2014).

The aforementioned facts point to the importance of doing research on how Japanese and Thai mathematics teachers conceptualize the promotion of decision-making in their students. To shed light on this issue, the present study addresses the following research questions: (1) what kind of tasks do Japanese and Thai secondary school mathematics

teachers regard as having the potential to promote decision-making? (2) What knowledge and skills do Japanese and Thai secondary school mathematics teachers believe to be associated with the promotion of decision-making?

Theoretical background

What is a decision?

A decision is defined as "the broader process within which a choice among specific options will be made" (Brown, 2005, p. 1). Through this process, the decision-maker is ultimately able to determine what action to take (Brown, 2005, pp. 1, 236-237).

Decision-making situations demand from the decision-maker to engage in the many phases of the decision-making process (Gal, 2004, p. 43; Arvai, Campbell, Baird & Rivers, 2004; Edelson, Tarnoff, Schwille, Bruozas & Switzer, 2006):

Definition: here decision-makers define the specific decision that has to be made, as well as a broad set of end objectives in the context of the impending decision.

Planning: during this phase, the identification, design, and choice of an optimal way to use resources—i.e., means to achieve ends objectives—is determined. The choices must be a set of appealing and purposeful alternatives from the objectives previously defined.

Data: the "Planning" phase tends to be followed by a recalling and seeking of information, as well as by collecting statistical data relevant to the achievement of end-objectives.

Evaluation: during this phase, decision-makers must assess the implications of different choices for the decision.

Weighing impact: during this phase, decision-makers weigh the impacts of the different options on stakeholders based on their own values. Thus, in this stage decision-makers bring in their values and see how different values can lead to different decisions.

Making and justifying a decision: during this phase, decision-makers select the course of action that better addresses their objectives, in the light of the decision-makers' constraints, considerations, assumptions, value systems, judgment of probabilities, stakeholder impact, etc., and provide an informed justification for such a decision.

What types of decisions are there?

In the present study, decisions will be classified in four types: three of them—i.e., personal, professional and civic—were identified by Brown (2005, pp. 5-7), while the last type—i.e., object-related—is proposed by the authors.

Personal decisions: those that decision-makers make on their own behalf.

Professional decisions: those that decision-makers, as professionals and specialist decision aiders, make on behalf of others in a work capacity—e.g., in medical practice.

Civic decisions: these are decisions made on a public issue, such as when decision-makers, as citizens, take a private position on someone else's—e.g., government's—choice, for which they have no direct responsibility.

Object-related decisions: those that decision-makers make about parameters or particular features of statistical objects—i.e., decisions regarding language situations, concepts, propositions, procedures and arguments—involved in a given statistical problem.

Knowledge of content and teaching

According to Ball et al. (2008), one of the three cognitive domains of the PCK is comprised of knowledge of the design of mathematics instruction, which they called "knowledge of content and teaching", or KCT. This domain includes knowledge about choosing which examples to start the lesson with; about which examples to use to take students deeper into the content to be taught; and about the instructional advantages and disadvantages of different representations, methods and procedures used to teach a specific idea (ibid., pp. 401–402).

Methodology

Data-collection instrument and participants

In order to address the research questions of this empirical study, an assignment-like survey was designed, asking respondents the following open questions:

1. From a textbook, teacher's guide, student workbook, internet, academic journal, or other type of source, choose a task or activity that, in your opinion, would promote decision-making skills in your students in secondary school mathematics when you teach contents in the mathematical domains "Practical Use of Data" or "Analysis of Data" (for the case of Japan), or "Data Analysis and Probability" (for the case of Thailand). You may also develop a task or activity by yourself.
2. Attach a copied or printed version of the chosen task or activity, and write down its source.
3. Briefly explain why, in your opinion, the chosen task or activity has the potential to promote decision-making skills.

In this paper it is reported a preliminary analysis of the data gathered from purposeful samples of twelve Japanese and twelve Thai secondary school mathematics teachers, who voluntarily responded and mailed back the survey booklets. In the case of Japan, six of the respondents were working at junior high school, while the rest were working at senior high school. Japanese respondents—who will be identified as J1 to J12—were between 24 and 63 years old, and they had between two and forty-one years of teaching experience—with seven of them with at least 13. In the case of the Thai participants—who will be identified as T1 to T12—, seven of the respondents were working at junior high school, three at senior high school, and the rest were working at both levels. Thai respondents were between 24 and 43 years old, and they had between one and fifteen years of teaching experience—with seven of them with at least 10.

Data analysis

During the initial phase all the questionnaire, a "bottom up" approach to coding was initially used to analyze the tasks' features and the participant's reasons for choosing such tasks. The authors reviewed all the given answers to the three questions and identified answers that occurred frequently in the data. Such answers appearing to contain similar content were initially given the same code by the authors, and each code

was further analyzed to find true meanings within their text. A process of reduction and clustering of categories, followed resulting in clusters of themes sharing common meaning.

Results

Tasks' features – What kinds of tasks are thought to promote decision-making?

From the qualitative analysis performed on the collected data, several task features were identified. The result of sorting and clustering such task-based features is shown in Tables 1 and 2.

It seems that almost all the Japanese and Thai teachers in this study agree that a task intended to promote decision-making should engage students in statistical investigations, should connect different statistical concepts, should be set in a real-life context, and should have more than one way to be solved. This is in line with the findings of many previous studies—e.g., Arvai et al., 2004; Edelson et al., 2006; Edwards & Chelst, 2007; Garfield & Ben-Zvi, 2008; Pfannkuch & Ben-Zvi, 2011.

The vast majority of participants from both countries seem to think that promoting decision-making should be done exclusively within the limits of the mathematics classroom. Consequently, students might miss the opportunity to extend their knowledge beyond the limits of the classroom, into the real world, which is needed in order to be statistically literate—cf. Garfield & Ben-Zvi, 2008.

Nine Japanese and seven Thai participants shared the idea that a task with the potential to promote decision-making must explicitly ask students to provide arguments justifying their decisions, which is actually one of the phases of decision-making.

There is not an overwhelming majority of opinion among the respondents as to which type of decisions should be requested in a problem intended to promote decision-making. In this regard, specialists say that, although decision-making skills are not specific to any particular type of decision, developing such skills has been done mainly in the context of personal and civic decisions, to which students can most immediately relate (cf. Brown, 2005, p. 155; Edelson et al., 2006).

Reasons for choice – What competence aspects are associated with decision-making?

From a grounded analysis of the reasons given by teachers about why their chosen tasks have the potential to promote decision-making, six category clusters of competence aspects were identified (cf. Tables 3 and 4).

Ten out of 12 Japanese and Thai participants associated decision-making with skills related to mathematical and statistical literacy, by using expressions such as "mathematical grounds", "knowledge about statistical ideas", "ability to read data properly", "ability to grasp data trends", and "practical use of multiple statistical representations". This is in agreement with what many statistics educators have previously reported on this matter (e.g., Gal, 2004; Pfannkuch & Ben-Zvi, 2011).

Only 4 participants—3 Japanese and one Thai—expressed that decision-making requires the enactment of personal or societal values, such as social fairness. Most of these teachers also selected tasks requesting either a personal or a civic decision.

J3's task

Mr. Tōru's school received 600 packs of the powdered sport drink "Pocarius". He distributed them between the clubs having activities during summer. The number of members and activity days of the summer clubs are shown in the table below:

Club	N° of members	N° of activity days
Basketball	20	14
Soccer	50	12
Tennis	30	18

Club	N° of members	N° of activity days
Badminton	15	8
Chorus	25	24
Science	10	24

If it were you, how many packs would you give to each club? Please explain your reasoning.

J4's task

PROBLEM

The numbers below are the results achieved by certain class on a mathematics test (100 points maximum), ordered by student's number in the class attendance sheet. I am the only one who got 33 points. Only by what this score tells, I will be scolded by my family. I wonder, what should I do to avoid this difficult situation?

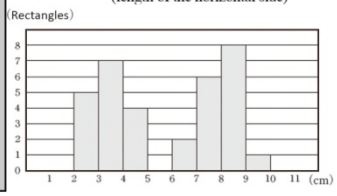
25 28 45 44 41 28 58 88 100 21 28
16 50 50 45 **33** 21 22 24 25 26 28
30 45 28 23 25 22 77 100 26 58 26
14 12 69 28 18 53 100

J8's task

Mai and Koharu decided to investigate what kind of rectangles their classmates consider beautiful. Then, they distributed among their 33 classmates a survey sheet with a 5 cm segment already drawn, as it is shown below, and asked them to draw rectangles using the given segment as one side. Figure 1 summarizes the obtained results. From this histogram, it can be seen that, for example, there were drawn 5 rectangles which lengths of the horizontal side were larger than or equal to 2 cm, but smaller than 3 cm.

Survey request
Please draw a rectangle that you would consider beautiful, using the segment below as one its sides

FIGURE 1: Distribution of the rectangles (length of the horizontal side)



Look at the histogram and, working in groups, express whatever you realize from the figure.

J10's task

Prepare a worksheet consisting of rows of one-digit numerals (a matrix-like arrangement of random 1-digit numbers written on a A4-size paper sheet)→

1 2 5 7 5 8 7 9 2 1 3 4 2 1 5 6 9 7 3 5
8 3 2 1 7 6 4 9 2 2 4 4 6 8 5 7 2 6 8 5
⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮ ⋮

During 1 minute, let students add adjacent numbers, and then write the digit corresponding to the ones place of the answer between the added numbers→ All the students will check the number of digits they were able to write during 1 minute, record it in the blackboard, and then obtain statistics→ Deliver the lesson based on the statistics obtained by the class, such as arithmetic mean, median, quartile deviation and boxplots→ Let students think, among other things, about the significance of knowing about each of such values.

T3's task

Students' homework assignment:

Collect data about the lifetime of cars' tires (tire brand: Bridgestone, Michelin or Goodyear) for pick-up, compact car (1600 cc) or mid-size car (1800 cc).

Find the range, coefficient of quartile deviation, coefficient of median deviation and coefficient of variation.

According to the obtained results, which brand do you think is the most worthwhile?

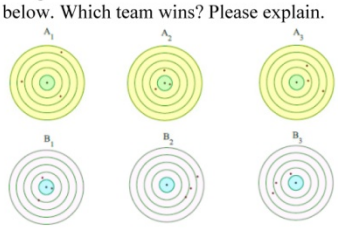
T4's task

There are 3 bags of fruit. The first bag has oranges only; the second bag has mangosteens only; and the last bag has both oranges and mangosteens. All of bags are labeled, but the label incorrectly matches with the fruits inside the bag. Let us find a method and explain, how you could change the labels to correctly match the content of each bag, if you can pick up only 1 fruit at a time from each bag?

T6's task

From darts game:

There are 2 teams (A and B), and each one has 3 persons (A_1, A_2, A_3 and B_1, B_2, B_3). Each person throw a dart 3 times. The positions where the darts landed are shown in figure below. Which team wins? Please explain.



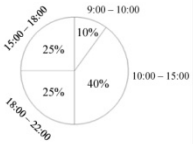
T8's task

Customers' favorite food at the school cafeteria:

Papaya salad: ♡ ♡ ♡ ♡ ♡
Fried chicken: ♡ ♡ ♡ ◡
Grilled fish: ♡ ♡ ♡ ♡
Noodles: ♡ ♡ ♡

♡= 10 customers

Arrival time for customers:



1. In which time period should this shop open? Why?
2. In which time period should a worker be hired? Why?
3. If think about "type of food" only, which "type" will you choose? Why?
4. If think about "type of food" only, which "type" you won't sell? Why?

Figure 1. Some tasks chosen by the Japanese (J) and Thai (T) participants in this study

Table 1. Features of a task with potential to promote decision-making, according to the information provided by the Japanese participants on the questionnaire

		TEACHER											
		J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12
FEATURES	Number of choices offered by the task	2	0	0	0	0	2	0	0	2	0	0, 2	2
	The task explicitly requests students to think of several possible solutions / to solve the problem in different ways	Y	Y	N	N	N	Y	Y	N	Y	Y	N	N
	The task invites students to engage in open inquiry and investigation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y&N	Y
	The task required to connect different statistical concepts	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	The task is a multi-step one, comprised of several mini-tasks	Y	N	N	N	N	Y	Y	Y	N	Y	Y	N
	The task explicitly demands from students to communicate and/or justify their procedures	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N
	Different types of statistical representations in the task	1	0	1	1	1	0	1	1	2	1	4	0
	The task includes the use of manipulatives	N	N	N	N	N	Y	N	N	N	Y	N	Y
	The task is set in a real-life context	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y&N	Y
	The task can be solved in several ways	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y&N	Y
	Type of decision requested by the task (Pe = personal; Pr = professional; C = civic; O = object-related)	O	C	C	Pe	C	Pe	O	O	Pe	O	O	Pe
	Environment in which the task is supposed to take place (I = indoors, O = outdoors)	I	I&O	I	I	I	I	I	I	I	I	I	I

Table 2. Features of a task with potential to promote decision-making, according to the information provided by the Thai participants on the questionnaire

		TEACHER											
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
FEATURES	Number of choices offered by the task	0	0	3	0	3	2	0	8	2	4	2	0
	The task explicitly requests students to think of several possible solutions / to solve the problem in different ways	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	N
	The task invites students to engage in open inquiry and investigation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	The task required to connect different statistical concepts	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	The task is a multi-step one, comprised of several mini-tasks	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	The task explicitly demands from students to communicate and/or justify their procedures	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	N
	Different types of statistical representations in the task	1	0	0	0	0	1	0	2	1	1	0	0
	The task includes the use of manipulatives	N	N	N	N	N	N	N	N	N	Y	N	N
	The task is set in a real-life context	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	The task can be solved in several ways	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
	Type of decision requested by the task (Pe = personal; Pr = professional; C = civic; O = object-related)	O	Pe	Pe	Pe	C	O	O	C	O	O	Pe	Pe
	Environment in which the task is supposed to take place (I = indoors, O = outdoors)	I	I	I&O	I	I	I	I	I	I	I	I	I

Table 3. Competence aspects associated with decision-making, according to the information provided by the Japanese participants on the questionnaire

		TEACHER											
		J1	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**J9**	**J10**	**J11**	**J12**
ASPECTS	Decision-making involves opportunity to build students' own decision criteria	✓	✓	✓	×	×	×	×	×	×	×	×	×
	Decision-making involves personal or societal values	✓	×	×	×	✓	×	×	×	✓	×	×	×
	Decision-making demands from students to make use of their own mathematical and statistical literacy skills	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×
	Decision-making involves engagement with different steps of the open-ended approach	✓	✓	×	✓	×	✓	✓	✓	×	✓	✓	✓
	Decision-making involves engagement with a familiar real problem	×	✓	✓	×	×	×	×	×	×	×	×	×
	Decision-making requires inter-personal processes such as discussion, communication, argumentation, negotiation, and collaboration	✓	×	✓	×	✓	×	×	×	×	×	×	×

Table 4. Competence aspects associated with decision-making, according to the information provided by the Thai participants on the questionnaire

		TEACHER											
		T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
ASPECTS	Decision-making involves opportunity to build students' own decision criteria	×	×	×	×	×	×	×	×	✓	✓	✓	✓
	Decision-making involves personal or societal values	×	×	×	×	×	×	×	×	×	×	✓	×
	Decision-making demands from students to make use of their own mathematical and statistical literacy skills	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
	Decision-making involves engagement with different steps of the open-ended approach	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓
	Decision-making involves engagement with a familiar real problem	×	×	✓	×	×	×	×	×	✓	×	×	×
	Decision-making requires inter-personal processes such as discussion, communication, argumentation, negotiation, and collaboration	✓	×	×	✓	✓	×	×	×	×	×	×	×

Three Japanese and four Thai respondents highlighted that decision-making involves an opportunity for students to build their own criteria or rules for decision, which is emphasized in the literature as one of the main characteristics of the decision-making process—cf. Brown, 2005; Edelson et al., 2006; Garfield & Ben-Zvi, 2008, p. 277.

The fact that decision-making involves engagement with a familiar real problem was pointed out by only two Japanese and two Thai teachers. This could be a reason for having ten participants selecting tasks posing object-related questions to students.

Nine Japanese and ten Thai participants indicated that decision-making involves engagement with different steps of the open-ended approach (Becker & Shimada, 1997, p.1). These teachers mentioned aspects such as "coming up with a diversity of ways of thinking", "generating alternative designs", "dealing with problems related to uncertain events", "opportunity to decide about parameters and methodologies", and so on.

Finally, only three Japanese and three Thai respondents explicitly related the decision-making process to social and inter-personal processes such as discussion, communication, argumentation, listening to other, expose ideas, common understanding, and persuasion and negotiation to build consensus. This result was quite unexpected in the case of Japan, since a typical Japanese mathematics lesson has the "neriage" phase, in which students discuss the validity and pertinence of their proposed ideas.

Conclusions

This study found how the surveyed Japanese and Thai mathematics teachers conceptualize decision-making and the tasks intended to promote it at secondary school level. A majority of the respondents from both countries selected tasks with features such as embedment in a real-life context, having multiple ways of solving, need of connecting different statistical ideas, and engagement with statistical investigations. All these features are, indeed, characteristics of tasks able to promote decision-making skills indicated in the specialized literature. However, it seems that surveyed Japanese teachers are more inclined than Thai ones to present students with pre-manufactured data representations—9 Japanese teachers against 5 Thai—, which may indicate a more deterministic approach in teaching statistical contents in the case of Japan.

Regarding the different cognitive aspects identified in teachers' explanations of why they chose their tasks, the majority of participants from both countries explicitly related to decision-making aspects such as engagement with steps of the open-ended approach, and practical use of mathematical and statistical literacy skills. However, other main features of decision-making—e.g., formulation of personal decision criteria, engagement with particular social processes, and values—were not noted by the large majority of surveyed Japanese and Thai teachers. These aspects can be interpreted as a lack of depth in their KCT, and hence in their PCK.

It is also worthy to highlight that 8 Japanese and 5 Thai participants selected tasks in which alternatives were not provided. Then, implicitly, these teachers are fostering decision-making skills through the use of value-focused thinking, because students will need to explicitly articulate their values in the form of alternatives, which results in increased achievement of the decision-maker's values (Keeney, 1988, pp. 465-467).

Due to the fact that realization of the potential of any task to promote decision-making heavily depends on teachers' statistical knowledge for teaching (González, 2014), it seems that secondary school mathematics teachers from both countries need to improve their professional knowledge about what decision-making is and how to promote it.

Finally, some possible future research questions that arise from this research include the following: How do teachers implement the chosen tasks? What values do students show during the lesson implementation?

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