The Pedagogy for Developing Statistical Literacy in Hong Kong Primary Education

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Abstract

Primary and secondary students in Hong Kong are generally taught superficial level of statistical literacy as doing statistical calculations and graphing, and the teaching does not aim at how to construct reasoned argument that is the core of statistical literacy skills. Perhaps, that is why most Hong Kong students can only manage calculation and graphing tasks. This imbalance is observed from the contents of local textbooks, examination papers as well as statistical projects of the students.

Much statistics education research has been conducted in Western culture and as such cannot be directly applied to Chinese learners in Hong Kong because human learning is under great influence of one's own culture. All in all, it has compelled the author to review various definitions of statistical literacy and conduct literature review on cultural and psychological backgrounds of Chinese learners so as to come up with an operational definition of statistical literacy as well as implications for classroom teaching in Hong Kong primary schools in order to improve pedagogy for developing statistical literacy in a wider context.

Keywords: Chinese learners, reasoning, statistical thinking, statistical communication

Introduction

Primary and secondary students in Hong Kong are generally taught superficial level of statistical literacy with an emphasis on statistical calculations and graphing without aiming at teaching how to construct reasoned argument that is the core of statistical literacy skills. This imbalance is observed from the contents of local textbooks, examination papers, and statistical projects of students. For example, Li and Shen (1992) pointed out that graphing flaws were associated with no conceptual understanding of statistics in entries to secondary student statistical project competitions in Hong Kong. A few years later, briefing seminars, mostly about how to obtain and use official statistics and how to do statistical graphing, were held for students and teachers every year well before the deadline of project submission. Subsequently, Li (2003) reported that the graphing flaws had been corrected and fancy statistical graphs and charts were produced by means of computer software but lines of statistical argument were not properly constructed or not well grounded. Yet, students' reasoning skills still have not much improvement after twenty years. There are two major reasons. First, statistical (data handling) topic is a fairly few strand to which less than 10% of curriculum hour is allocated in Hong Kong Primary Mathematics Curriculum. Many teachers, who completed their undergraduate and teacher education much earlier, are not statistically competent as statistical topics were not well taught in those days (Lajoie & Romberg, 1998; Spangler, 2014). Second, most teachers have strong deductive reasoning skills but not inductive reasoning skills which are essential for solving statistical problems. That is probably why in-service teacher training program, like Professional Development Program for In-service School Teachers on Learning and Teaching of Probability and Statistics, is offered by teacher colleges from time to time (Garfield & Everson, 2009; Richards et al., 2014). The program aims at underpinning teachers' statistical and probabilistic knowledge and skills.

Much statistics education research (e.g., Garfield, 2003; Schield, 2002, etc.) has been conducted in Western cultures. It cannot be directly applied to Chinese learners in Hong Kong because human learning is under great influence of one's own culture. All in all, it has compelled the author to address the question of how to teach Hong Kong primary students statistical literacy in a wider context. In the present paper, he reviews various definitions of statistical literacy and conduct literature review on cultural and psychological backgrounds of Chinese learners so as to come up with an operational definition of statistical literacy as well as implications for classroom teaching in Hong Kong primary schools.

Statistical Literacy

Irrespective of the wordings used in the definitions of statistical literacy given by Gal (2002, 2003), Garfield (1999), Mandinach and Gummer (2013), Phillips (2001), Schield (1999, 2001; 2014), and Watson (1996, 1997), they have one commonality as being able to read statistical information. Biggeri and Zuliani (1999) as well as Garfield (1999) pinpointed the needs for reading statistics used in the news, media, polls, etc.

Another commonality is about the ability to evaluate statistical information or results critically. Although Garfield (1999) and Watson (1996, 1997) did not mention this ability explicitly, they supplemented their definitions in various ways. Phillips (2001), Watson (1996), and Schield (2001) enlisted the ability to use statistical language; summarize data and construct statistical tables, charts, and graphs. In addition, Schield found that reading, comparing, and interpreting data presented in tables, and selecting proper statistical tools that form part of statistical literacy. Watson raised the need for processing data if they have been collected.

The term “statistical literacy” was elaborated more extensively by Schield. Schield’s (1998) preliminary definition of statistical literacy targeted a statistical tool, descriptive statistics, and three statistical methodologies: statistical inference, Bayesian statistics, and evidential statistics. Only descriptive statistics is within Mathematics syllabus in Hong Kong primary education but not the statistical methodologies, if they are to be seriously treated. Schield (2002) discussed chance-based literacy, fallacy-based literacy, and correlation-based literacy. Chance-based literacy which primarily focuses on a study of variation due to chance is equivalent to having an understanding of probabilistic or stochastic phenomena (Gal, 2002; Phillips, 2001; Schield, 2001). Among these three kinds of statistical literacy, primary students should be taught chance-based literacy which is useful for evaluating inductive arguments encountered in our daily lives or studying variation due to chance.

Statistical Literacy Hierarchy

A synthesis of the above definitions proposes that statistical literacy would operate efficiently or more systematically at three different levels: comprehension, planning and execution, and evaluation according to Pierce et al. (2014) (refer to Table 1).

Table 1. A statistical literacy hierarchy

Level	Description
1. Comprehension	• To study the context, content, measurement, and measurement units of data • To read the implicit meaning of summary statistics • To find data relationships • Etc.
2. Planning and Execution	• To organize raw data • To select secondary data relevant to the scope of research study when necessary • To reorganize secondary data for amalgamation • To choose and utilize proper statistical tools • To describe data using numerical measures, such as mean, median, mode, range, variance, standard deviation, and so on • To construct statistical graphs, charts, and tables • Etc.
• Evaluation	• To justify the reliability and validity of statistical results • To evaluate the context, the power and the limitations of statistical claims • To reason arguments on the basis of statistical evidence • Etc.

The hierarchy of statistical literacy arranged into these three levels is useful for educating students in different academic levels. The general public may just need to read statistical information, for example, weather forecasts, demographic trends, statistics about public opinion polls and so forth. Arousing the general public's awareness of the use of reasoning about daily issues is thus absolutely essential for developing their statistical literacy. In contrast, planning and execution tasks require reading beyond the data, a skill required of statistical practitioners. Thus, there is not a single definition for the term "statistical literacy" since the variety of knowledge required ranges from simple to complex and is hierarchical in nature.

Implications for Classroom Teaching

Misconceptions about the arithmetic mean and statistical graphing are common learning problems in Hong Kong primary education arising from only focusing on a mathematical operation without a full grasp of statistical literacy skills. To help students cope with concepts of arithmetic mean and statistical graphing, education requires quality teaching that helps students develop thinking, reasoning, and communication skills within the context of statistics. Unfortunately, the teaching pedagogy in Hong Kong generally aims at transmitting knowledge and preparing students for public examinations by rote learning, while these examinations assess low-level cognitive tasks (Biggs, 1996). It is assumed that rote learning and memorization are equivalent in Western context but Hong Kong students, in fact, develop understanding prior to adopting memorization as a learning strategy to attempt examination questions (Marton et al., 1996). This is an appeal to us not to apply education research conducted in Western cultures to Chinese students because human learning is under great influence of one's own culture. It is thus worth noting how cultural and psychological factors that can reshape approaches to statistics learning.

In general, many Hong Kong teachers exercise their authority in classrooms where the students listen but do not question or activate higher order thinking to justify what have just been told before accepting the knowledge transmitted. This pedagogy practice is under deep influence of Chinese culture with an emphasis on obedience, hierarchy of respect, patience, collaboration, and proper behaviour, following the realm of Confucianism developed by the Chinese philosopher, Confucius (Murphy, 1987). The students want instructions about what to do rather than thinking how to do. As such, they cannot manage open-ended statistical problems.

Chinese students see learning as a goal to achieve for fulfilling parents' and social expectations. They perceive achievement as being not personal but for their group or family so they would co-operate rather than compete. But, this is different from achievement in Western culture that is regarded as individual accomplishment (Salili, 1996). It would be better to foster social interaction between teacher and student as well as student and student so as to engage students with high cognitive process. Students review and reinterpret the inputs gained from these interactions to create their own beliefs, ideas, and experiences as in collaborative learning (Biggs, 1996). However, one may query whether collaborative learning can promote learning among Chinese students. In Tang's (1996) study, Hong Kong students were benefited from collaborative learning in the way analyzing and comparing perspectives, challenging peers' standpoints, sharing and exchanging views, supplementing ideas, and stimulating deep thinking. Using this ground, learning can be organized to foster collaborative learning in Hong Kong primary classrooms. For example, a teacher can pose two questions in a problem, "What affect human pulse rates?" by inviting a class of students to respond collaboratively. One question may be "Is there any difference in pulse rate between male and female students?" and another one may be "Is there any difference in pulse rate among levels of physical exercise?"

Knowledge of data is essential for progressing statistical works because data have intrinsic meaning (Wegman, 2000) that forms part of an investigative process. The use of official statistical data can be a part of statistics education because these data have quality and may serve as common grounds in many research studies. Teachers should teach how to justify the limitations and scope of data. Apart from using the data, data which can be collected by students, especially the context of the data closely related to the students give inclination to task engagement and accomplishment (Goos et al., 2013). This induces teachers to consider how data should be collected by their students in terms of its scope and quantity with the reach of their students. For example, a class of the Primary 6 students should be asked to collect data collaboratively – pulse rates of their classmates before and after running for 30 metres in a school playground. In the data collection process, students are assigned different tasks, some take resting pulse rates, some take pulse rates after running, some record the pulse data, some monitor data collection and recording, and some offer assistance or co-ordination. The students should have fun in collecting the data and derive understandings and interpretations of the tasks in hand through their active involvement. The teacher can liaise with their PE teacher because the data collection would be better conducted in PE lessons as to allow the students to do warm-up exercises before running. Both teachers can work to shoulder in looking after student safety and discipline beyond monitoring the flow of data collection. Students are then divided into small groups to do calculations, statistical graphing, and collaborative report writing.

Statistical Literacy: Comprehension

The data collected by students are not just numbers; if requires students to study the contexts and contents of the data. Comprehension thus plays a vital role in choosing suitable data based on the context for addressing a statistical problem. Comprehension also requires reasoning about the pulse data that takes precedence over any statistical methods by looking beyond numerical representation and judging whether or not the measurement and measurement units of data cover a reasonable and meaningful range by comparing with the pulse rates available on various health websites, for example, http://www.hk-doctor.com/tool/html/Pulse_E.htm. The students may gain some insight into where the pulse data come from through deriving personal meaning.

Statistical Literacy: Planning and Execution

Planning and execution of statistical tasks requires the exercise of thinking, reasoning, statistical graphing and statistical communication. In planning, students must select appropriate tools among sum, arithmetic mean, pictogram, block chart, bar chart, and line chart because each tool serves a specific purpose and task. Apparently, the first two tools can provide summative measures, whereas the last four tools display the patterns in data graphically.

To execute the tasks, students use the sum to find out the total number of male and female students in their class. They can also draw a pictogram, block chart or a bar chart to contrast the difference between the number of male and female students. Basically, these graphing tools can serve for the contrasting purposes; a pictogram provides more visually appealing graphical elements to portray the difference. Beyond graph construction, students should be able to read within data, read between data, and read beyond data (Curcio, 1987). All of these help students internalize the concept of statistical data and gain understanding of and insights into the data. But, if students' difficulties lie in these areas of reading, instruction should aim at helping students develop perceptual processes to extract quantitative information from graphs; study data relationships and to make comparisons between different pieces of data; and synthesize statistical ideas from graphical information.

To respond to the first question posed by the teacher, students may want to compare male and female pulse rates by using summative measure. They would appreciate the tool, arithmetic mean rather than another tool, the sum. They do not merely perform mathematical operations but justify the usages of these two tools, and check the meaning of arithmetic mean in connection with the context of data comparison. They should also be aware of how the mean value of pulse rate is sensitive to the varying number of students or in either student gender. In addition, they can show how male and female pulse rates differ more vividly by examining and displaying patterns in the pulse data from the bar chart they construct in which y represents the frequency (the number of students) and x represents the pulse rate. They must decide how to organize the data bars in the bar chart by putting all male pulse rates on one side and all female ones on the other side but not to group male and female pulse rates side by side because these are not paired data, thus no comparison can be made in this way.

To attempt the teacher's second question, students may use the tool, sum to compare the pulse rates between "before running 30 metres" and "after running 30 metres" as long as there is no change in the number of students. They should switch to calculate the mean pulse rates for making the comparison. Of course, the meanings of these two tools are quite different. The former shows cumulative total of pulse rates, thus probably exaggerates the difference in pulse rates under two conditions. To facilitate the comparison, a grouped or side-by-side bar chart should be constructed by putting the bars representing the magnitude of pulse rates of "before running" and "after running" of each individual student side by side with a clear indication of the two conditions using a legend.

Statistical Literacy: Evaluation

A statistical process is far from complete until all the statistical findings are documented. Unfortunately, students did statistical reports poorly as displaying poor or no reasoned arguments and improper interpretation of statistical terms (Li, 2003; Li & Shen, 1992). Thus, it is of great importance to help students learn how to construct reasoned arguments on the basis of evaluation. Evaluation here refers to justifying whether or not the arithmetic means and statistical graphs make sense or deals with how well the statistical results can be turned into evidence in connection with the context of pulse data and problem setting. Prior to evaluation, students must find some reference materials about human pulse rates as ground. They may find pulse rates are influenced by age, gender, the level of physical activity (i.e., resting versus after physical exercise in the present problem), emotional states, physical conditions, and so forth. Males generally have lower pulse rates than females do. Students should evaluate whether the statistical results they obtain match or mismatch the ground in general. If it is a mismatch, they should evaluate the limitations and scope of data of the pulse data they have collected. They can easily identify how the data displaying in statistical graphs that they have constructed mismatch the ground. The graphs are very useful particularly in this investigative process.

Last but not least, most students cannot use statistical language properly (Dunn et al., 2016; Li & Shen, 1992). Teachers should be attentive to the use of a common language in expressing a statistical phenomenon, explaining whether and why a particular statistical method is valid or relevant in a specific problem context, and clarifying what can and what cannot reasonably be concluded from the data (Garfield, 1993).

Discussion

One would argue, albeit that everyone should be statistically literate, the level of statistical literacy for an individual depends on his/her personal and professional circumstances. Broadly, a person should demonstrate common sense in the process of enquiry, while reasoning critically about using statistics as evidence.

The goal of teaching data handling strand (statistical topics) is concerned with developing students' statistical literacy so that statistics learning should not be treated as merely performing mathematical operations and adopting mathematical rules strictly. It is in fact more closely associated with thinking and reasoning. Thinking and reasoning skills are valuable to the student's overall intellectual development. It is thus necessary to ground thinking and reasoning in the exercise of statistical literacy.

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