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Exploring Attitude toward Statistical Graphs among Singapore Secondary School Students

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Abstract: This study investigated attitude toward statistical graphs among a large sample of Singapore secondary school students (n = 907) in 2003. Attitude toward Statistical Graphs (ASG) was defined in terms of five aspects: enjoyment, confidence, usefulness, critical views and learning preferences. These students (13 to 15 years old) completed a Questionnaire of Attitude toward Statistical Graphs (QASG). In general, boys and girls held similar neutral to positive views about enjoyment, confidence, and usefulness of statistical graphs, were neutral about critical views aspect about statistical graphs, and preferred the traditional teaching approaches, namely teacher's clear explanation and practice. Grade level (S1 to S3) and stream (Special, Express, Normal Academic, and Normal Technical) had statistically significant but small interaction effects on the enjoyment, confidence, and usefulness aspects. Implications for teaching and future research are discussed.

Key words: Attitude; Statistical education; Singapore students; Secondary schools; Learning preferences

Introduction

With increasing attention given to the topic, *Statistics* or *Data Analysis*, in the school mathematics curriculum across the world, it is necessary to study what statistical knowledge and skills students are required to acquire and how they feel about learning statistics. Understanding and critical attitude toward statistics are two fundamental aspects worthy of study (Gal & Garfield, 1997). Although critical attitude is an important goal in learning statistics, only a few studies on students' attitude toward statistics have been conducted. This is pointed out by Gal, Ginsburg, and Schau (1997) in a review: "only a small number of studies (less than 50) and a few instruments (about 10) have been published on the nature and correlates of statistics attitude, and many of these studies are small scale or limited" (p. 47). Furthermore, most of these studies and instruments about attitude toward statistics are conducted among college students only. After an extensive search by the authors, no studies were found that investigated attitude toward statistics, including statistical graphs, which is the main focus of this paper, among school students. One plausible reason for this lack of research at the school level is that statistics has only recently been included in the school mathematics curriculum in many countries.

Within the statistics curriculum, statistical graphs constitute a large component, usually taught beginning at the primary level. This study sought to contribute to knowledge about attitude toward statistical graphs (ASG) among school students.

Definition of Attitude toward Statistical Graphs (ASG)

The study of attitude in educational research has a long history, but different definitions of *attitude* have been proposed by educators, leading to a lack of consensus about its meaning and interchangeability with similar words like *beliefs* and *perception* (Aiken, 1996; Leder, 1992; Leder & Forgasz, 2002; McLeod, 1992). This study followed the suggestion by Kulm (1980) and attempted to define ASG operationally in terms of salient attitude aspects (or dimensions) commonly discussed in the literature; see the following sections. This resulted in the following five aspects included in the Questionnaire of Attitude toward Statistical Graphs (QASG) for this study: *enjoyment*, *confidence*, *usefulness*, *critical views* and *learning preferences.* The following sections explain how these five aspects are derived from research and instruments about attitude toward statistics in general.

Instruments about Students' Attitude toward Statistics

According to Gal, Ginsburg and Schau (1997), there are four commonly used instruments about students' attitude toward statistics: Statistics Attitude Survey (SAS), Statistical Anxiety Rating Scale (STARS), Attitudes Toward Statistics (ATS), and Survey of Attitudes Toward Statistics (SATS).

The Statistics Attitude Survey (SAS) (Roberts & Bilderback, 1980) was designed for advanced undergraduate and graduate students. It contains 34 items on a 5-point Likert scale and covers personal competence in solving statistical problems, beliefs about statistics, and affective responses to statistics. This instrument has strong internal consistency, with reported Cronbach's alphas of 0.95, 0.93, and 0.94, depending on the samples used.

The Statistical Anxiety Rating Scale (STARS) was developed by Cruise and Wilkins (cited in Onwuegbuzie, 2000). It is designed to explore statistics anxiety. It is a 51-item, 5-point Likert-type instrument with six subscales: *worth of statistics* (similar to the value or usefulness of statistics), *interpretation anxiety* (experienced by someone who tries to interpret statistical information), *test and class anxiety* (associated with taking a statistics test or course), *computation self-concept* (related to actual mathematics computations), *fear of asking for help* (from other students or teachers), and *fear of statistics teachers*. Reliability of the subscales, as measured by Cronbach's alpha, ranged from 0.68 to 0.94 (median = 0.88).

The Attitudes Toward Statistics (ATS) scale (Wise, 1985) is a 5-point Likert-type instrument, consisting of two subscales, *field* and *course*. The 20-item *field* subscale deals with students' attitude toward the usefulness of statistics in general or in their field of study. The 9-item *course* subscale is concerned with students' attitude toward their statistics course. The Cronbach's alphas were 0.92 and 0.90 for the *field* and *course* subscales, respectively. Two-week test-retest reliabilities were 0.82 for *field* and 0.91 for *course*.

The Survey of Attitudes Toward Statistics (SATS) (Dauphinee, Schau, & Stevens, 1997) has 28 items dealing with four aspects: (a) *affect*: positive and negative feelings concerning statistics; (b) *cognitive competence*: attitude about intellectual knowledge and skills applied to statistics; (c) *value*: attitudes about the usefulness, relevance, and worth of statistics in personal and professional life; and (d) *difficulty*: attitudes about the difficulty of statistics as a subject. A 7-point Likert scale was used. Reported Cronbach's alphas ranged from 0.81 to 0.85 for *affect*, 0.77 to 0.83 for *cognitive competence*, 0.80 to 0.85 for *value*, and 0.64 to 0.77 for *difficulty*.

These instruments have moderate to high internal consistency and the items can be used as the basis to develop new instruments. In this study, the design of QASG involved three major modifications to address some limitations of the above instruments: (a) to develop items suitable for school students rather than undergraduate and graduate students (which all the above instruments are designed for), (b) to assess attitude toward a specific statistics topic (namely statistical graphs) rather than statistics in general, in line with long-standing recommendation to measure attitude toward specific aspects of mathematics rather than mathematics in general (Begle, 1979), and (c) to measure aspects of attitude not included in these instruments. In particular, focusing on a specific topic can provide findings that are easier to interpret compared to findings about attitude in general.

Each of the cited instruments covers several aspects indicating the multidimensional nature of attitude. Common aspects of attitude are found among the instruments. For example, SAS and SATS consider students' affective feelings toward statistics and personal competence in solving statistical problems. ATS and SATS deal with the usefulness of statistics in personal and professional life. The *enjoyment*, *confidence* and *usefulness* aspects of QASG were deduced from these instruments but focused on statistical graphs. They were consistent with the four aspects suggested by Gal and Ginsburg (1994) when one measures school students' attitude toward statistics: (a) interest or motivation for further learning, (b) self-concept or confidence regarding statistical skills, (c) willingness to think statistically in every situation, and (d) appreciation for the relevance of statistics in their personal and vocational life.

The *critical views* aspect, not included in the cited instruments above, was specially designed for this study to explore general views about statistical graphs held by students. For example, when provided with a statistical graph, a person may simply accept the data shown in the graph or may query the source of the data. It is important to foster a critical attitude toward statistics through learning statistics (Garfield, 1995). A critical attitude avoids the two extremes of naïve acceptance and cynical rejection of statistical results, epitomized by the oft-repeated saying, "There are three kinds of lies: lies, damned lies, and statistics" (see Best, 2001). Acquiring a critical attitude will help people to distinguish between good statistics and bad statistics and to make informed and wise decisions. This critical attitude can be developed through asking good questions to examine the effectiveness, implications, and alternative interpretations of the statistical information (Best, 2001; Gal, 2000; Healy, 1999). This approach applies to statistical graphs as well. Therefore, students should have in their mind a list of questions, like "What is the purpose of the graph?" or "Can the data shown in the given graph be displayed using another graphical representation?", when they read and interpret a statistical graph. These questions could monitor students' thinking of statistical graphs, and reflect how analytical and thoughtful they approach the graphs.

The fifth aspect of ASG is about *learning preferences*. As its name indicates, this aspect examines students' preferences to various teaching and learning activities about statistical graphs. Gal, Ginsburg and Schau (1997) stressed the need to study students' attitude to what should happen in a statistics classroom. This knowledge can provide useful information for school teachers who wish to take into consideration the needs and expectations of their students.

Research Questions

This study aimed to describe ASG among a sample of Singapore secondary school students. Although the findings are of particular interest to teachers and educators in Singapore, the nature of ASG unraveled in this study will contribute to a more comprehensive understanding about attitude toward and learning of statistical graphs among school students, a much neglected area of statistics education research. Three research questions were formulated.

1. What are the levels of ASG among secondary school students, with respect to the five aspects: *enjoyment*, *confidence*, *usefulness*, *critical views*, and *learning preferences*?

2. What are the relationships among the five aspects of ASG? The findings will provide further evidence about the multidimensional nature of attitude.

3. How do students' ASG differ with grade level, stream (ability grouping), gender, and computer usage?

Relevant to the last question, findings about gender differences on attitude toward statistics among college students are not consistent (Roberts & Saxe, 1982; Waters, Martelli, Zakrajsek, & Popovich, 1989; Zeidner, 1991). On the other hand, students may have used computers to plot statistical graphs, but no studies have examined the relationship between computer usage and ASG. This research question is particularly relevant to the current trend, in particular in Singapore, to use Information and Communications Technology (ICT) in the teaching of statistics and mathematics.

Methodology

This study was a survey of a large cohort of Singapore secondary school students about their ASG using a specially designed questionnaire, QASG.

Subjects

The population of this study was Singapore secondary school students. Due to practical limitations, convenience sampling was used to select the schools for this study. A total of 21 schools were randomly selected from all the secondary schools in Singapore in 2003. These schools were approached via telephone, email or personal visit. Finally, five schools agreed to participate in the study. Singapore secondary school students are streamed into one of the four courses: Special (S), Express (E), Normal Academic (NA) and Normal Technical (NT), with S students the more capable and NT the least capable academically. One of the five schools included students in Special (S) stream only, while the other four schools had students in the Express (E), Normal Academic (NA) and Normal Technical (NT) streams. The five schools were located in different parts of Singapore: one in the North, two in the South, and two in the West zone.

The subjects of the study consisted of 907 students in 27 classes from Secondary 1 to Secondary 3 in these five schools. For the school which had S students only, the head of mathematics department was requested to select one class from each of Sec 1, Sec 2, and Sec 3. For the other four schools, the first author randomly selected two grades from Sec 1 to Sec 3 for each school. Then, the heads of mathematics department of the four schools were asked to select one E class, one NA class, and one NT class from each of the two specified grades. Table 1 shows the distribution of the sample by grade level, stream, and gender.

Table 1
Distribution of the Survey Sample by Grade Level, Stream, and Gender

	S		E		NA		NT		Total	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Sec 1	19	18	35	42	34	35	36	23	124	118
Sec 2	17	16	54	64	52	49	53	40	176	169
Sec 3	17	19	69	39	47	40	52	37	185	135
Total	53	53	158	145	133	124	141	100	485	422
	106 (11.7%)		303 (33.4%)		257 (28.3%)		241 (26.6%)		907 (100.0%)	
2003 statistics	18065 (8.8%)		104780 (50.7%)		55755 (27.0%)		27826 (13.5%)		206426 (100.0%)	

The percentages of boys and girls in the whole sample were 53.5% and 46.5% respectively. These values were close to those in the population in year 2003 (boys: 51.9%; girls: 48.1%) (Ministry of Education, 2004). The percentages of S and NA stream students were close to those in the population (see Table 1), but E stream students were under-represented and NT stream students were over-represented in the sample. Nevertheless, the relatively large sample size and its compositions give some confidence that the findings are descriptive of the attitude among Singapore secondary students.

In Singapore, statistical graphs are taught at different levels: picture graphs at Primary 1 and 2; bar graphs at Primary 3; line graphs at Primary 4; pie charts at Primary 6; histograms at Secondary 1; dot diagrams and stem-and-leaf diagrams at Secondary 2. Hence, the secondary school students in this sample would have sufficient learning experiences with statistical graphs to form certain attitude toward these graphs to give credible responses to the questionnaire items.

Questionnaire of Attitude toward Statistical Graphs (QASG)

QASG is made up of 49 items divided into three parts: A, B, and C. The 5-point Likert scale is used. Some of the items were modified from the instruments cited above.

Part A has five sections measuring students' *enjoyment* and *confidence* when they are asked to (1) read information from a graph, (2) give opinions about an issue based on the data shown in a graph, (3) judge whether or not a graph is correctly constructed, (4) construct a graph by hand, and (5) construct a graph by computer. Each of the sections (1) to (5) has five items, with two about *enjoyment* and three about *confidence.* Ten of these 25 items are negatively worded to discourage response set. One sample item is shown below (SD = Strongly Disagree; D = Disagree; U = Uncertain; A = Agree; SA = Strongly Agree):

	1. When I am asked to read information from a statistical graph,	SD	D	U	A	SA
a	I find it difficult to read information from most types of statistical graphs.	1	2	3	4	5
b	I do not enjoy doing it.	1	2	3	4	5
c	I am confident in reading information from most types of statistical graphs.	1	2	3	4	5
d	I am interested in doing it.	1	2	3	4	5
e	I am good at reading information from most types of statistical graphs.	1	2	3	4	5

The five items in section (5), shown below, are optional. They are answered by those who have experiences of using computer to draw statistical graphs.

5. Have you used a computer to construct a statistical graph? ☐ **Yes** ☐ **No**
If you tick Yes, please respond to the statements below.
If you tick No, you can skip the statements below and go on to Part B.

	When I am asked to construct a statistical graph using computer,	SD	D	U	A	SA
a	I find that constructing a statistical graph by computer is very easy.	1	2	3	4	5
b	I can do it very well.	1	2	3	4	5
c	I enjoy using computer to draw statistical graphs.	1	2	3	4	5
d	I have difficulty in using computer to draw statistical graphs.	1	2	3	4	5
e	I feel that it is boring to use computer to construct statistical graphs.	1	2	3	4	5

Part B has 12 items shown below: five about *usefulness* (see Table 4) and seven about *learning preferences* (see Table 6). These seven learning preferences items cover both traditional and innovative activities, the latter to reflect trends in the Singapore context (Ministry of Education, 2002).

The 12 items in Part C are about *critical views* toward statistical graphs; see Table 5 below. Since there was no existing instrument on this aspect, the items were created by the first author based on the ideas in Healy (1999), Gal (2000), and Best (2001). The students are to tick how often they think of the twelve questions when they come across a statistical graph in textbooks, newspapers, magazines, or other media using the 5-point scale: Never, Rarely, Sometimes, Often, Most of the time.

A pilot test of the instrument was conducted in October and November 2002. A total of 188 students from the four streams of two secondary schools (not in the main study) took the earlier version of QASG during school hours. Four mathematics teachers from the two schools administered the survey. They were requested to record the time students took to complete QASG and any questions students asked during the administration. According to the results of the pilot study, minor changes, like wording of the items, were made to QASG.

Data Collection

For three of the five schools, the first author and two colleagues administered QASG during after-school hours. A letter providing instructions for administering QASG was sent to the two colleagues one day before the survey. For the other two schools, the school teachers administered QASG during remedial lessons. The instruction letter was sent to these two teachers through their heads of mathematics department. The administration of QASG in the five schools was completed in the April 2003. Students generally took about 15 minutes to complete QASG.

Results and Discussion

The mean score of a student's responses to the items under each of the four aspects, *enjoyment*, *confidence*, *usefulness*, and *critical views*, was taken as a measure of his or her attitude toward that aspect. Cronbach's alphas were calculated after the negatively worded items were reverse scored. The Cronbach's alphas for *enjoyment* and *confidence*, excluding the optional items about computer use, were 0.84 and 0.79 respectively. The Cronbach's alphas for *usefulness* and *critical views* were 0.54 and 0.82 respectively. These alpha values were adequate for this study to indicate moderate level of internal consistency (Nunnally, 1967, p. 226), though the alpha for *usefulness* is a bit low. The items in the *learning preferences* aspect do not form a uni-dimensional construct. Hence, the Cronbach's alpha was not calculated for these items, and no summative score for learning preferences was used for subsequent analysis.

Research question 1: Students' Attitude toward Statistical Graphs

Enjoyment. The mean *enjoyment* scores for each of the four aspects of statistical graphs (graph reading, graph interpretation, graph evaluation (correctness), and graph construction by hand) are given in Table 2 for the whole sample, the Non-computer group (NCG), and the computer group (CG). In general, the students did not have strong like or dislike toward working with statistical graphs. They seemed to enjoy graph reading most and graph interpretation least, probably because graph interpretation is not a common activity in statistics lessons and it is more challenging than just reading values from the graphs. The CG students had slightly higher means than the NCG students. The CG students reported enjoying using computer to construct statistical graphs (mean = 3.56). This suggests that experiences of constructing graphs by computer might raise the enjoyment level. With respect to the Singapore context of providing "activities for pupils to use IT tools to access and import data, and to explore and display these data" (Ministry of Education, 2000, p. 37), the result shows that more effort is required to achieve this objective.

Table 2
Summary Description of Responses to Enjoyment

Aspect	Whole sample		NCG		CG	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Graph reading	896	3.28 (0.99)	573	3.23 (0.99)	313	3.38 (0.99)
Graph evaluation (correctness)	899	3.16 (1.02)	575	3.12 (0.99)	314	3.23 (1.06)
Graph construction by hand	901	3.11 (0.99)	577	3.07 (0.97)	314	3.21 (1.02)
Graph interpretation	900	3.02 (1.06)	576	2.97 (1.05)	314	3.14 (1.09)
Graph construction by computer					310	3.56 (0.96)

Note: (1) Ten students did not specify whether or not they had experience of constructing graphs by computer. Thus, N for the whole sample was ten less than the total of N for NCT and CG. (2) The above note applies to all subsequent tables which involve the comparison between NCG and CG.

Confidence. Table 3 gives the results about this confidence aspect. A similar pattern is obtained as for *enjoyment:* the students were most confident in graph reading and least confident in graph interpretation, and the CG students were more confident than the NCG group in all four types of statistical graph work. The *confidence* levels were generally higher than those of *enjoyment*. The CG students expressed some confidence in using computer to construct statistical graphs.

Table 3
Summary Description of Responses to Confidence

Aspect	Whole sample		NCG		CG	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Graph reading	903	3.45 (0.79)	577	3.41 (0.80)	316	3.55 (0.78)
Graph evaluation (correctness)	902	3.24 (0.80)	577	3.20 (0.78)	315	3.33 (0.84)
Graph construction by hand	901	3.13 (0.75)	575	3.03 (0.74)	316	3.34 (0.71)
Graph interpretation	903	2.99 (0.74)	578	2.92 (0.71)	315	3.12 (0.78)
Graph construction by computer					311	3.46 (0.89)

Usefulness. In general, the students expressed neutral to positive views about the usefulness of statistical graphs, as shown in Table 4. This result is similar to the neutral view about the relevance of mathematics expressed by Secondary 3 Singapore students as reported by Ghamaruddin (2000). The students in the present study claimed that statistical graphs were most useful in showing numerical information but these graphs in newspapers did not quite help them to better understand the accompanying article. As in the case for *enjoyment* and *confidence*, the CG group scored higher about the usefulness of statistical graphs than the NCG group.

Table 4
Summary Description of Responses to Usefulness

Items	Whole sample		NCG		CG	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
b6: Statistical graphs are useful in showing numerical information.	856	3.69 (0.99)	566	3.62 (0.98)	280	3.86 (0.99)
b1: Statistical graphs are useful in real life situation.	870	3.65 (1.05)	575	3.65 (1.02)	285	3.69 (1.10)
b8: Statistical graphs make it easier for me to make sense of the data.	864	3.56 (0.99)	570	3.52 (0.98)	284	3.68 (0.99)
b4*: Knowledge of statistical graphs is not necessary when studying other subjects.	860	3.27 (1.11)	569	3.24 (1.08)	281	3.35 (1.15)
b11*: A statistical graph shown in newspaper does not help me better understand its accompanying article or report.	867	3.09 (1.09)	572	3.06 (1.07)	285	3.12 (1.12)

Note: * These items are negatively worded. The reversed means are reported in the table.

Critical views. The results are reported in Table 5. In general, the students claimed to ask these questions rarely or some of the times only (mean scores from 2.86 to 3.37). The CG group had higher mean scores on all the items compared to the NCG group, but for both groups, the rankings of the questions are virtually the same.

The two questions they were likely to ask are whether the graph is easy to understand and whether the data are clearly shown in the graphs. These two questions are related to practice exercises in statistical graphs commonly given to students. On the other hand, they were unlikely to question the source of the data, alternative representations, purpose of the graph (quite unexpected), and any misleading features in the graph. This cluster of questions pertains to higher order critical analysis of statistical graphs, and these students may not have sufficient practice in this type of analysis in their statistics lessons. This leads us to the next section about the learning activities preferred by these students.

Table 5
Summary Description of Responses to Critical Views

Questions	Whole sample		NCG		CG	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
c5: Is the graph easy to understand?	892	3.37 (1.20)	572	3.29 (1.22)	310	3.51 (1.15)
c3: Is the data clearly shown in the graph?	885	3.25 (1.17)	569	3.20 (1.16)	306	3.35 (1.17)
c12: What conclusions can I draw from the graph?	900	3.17 (1.32)	576	3.09 (1.34)	315	3.34 (1.29)
c6: Is the graph suitable for the type of data shown?	888	3.10 (1.18)	567	3.06 (1.19)	312	3.17 (1.15)
c9: Can I trust the data shown in the graph?	888	3.04 (1.24)	571	3.04 (1.24)	308	3.07 (1.22)
c11: Does the graph support the claims made in the accompanying article or report?	898	3.01 (1.17)	574	2.96 (1.67)	315	3.10 (1.18)
c4: Is the graph attractive?	887	2.99 (1.23)	569	2.89 (1.24)	308	3.20 (1.17)
c2: What do the labels of its axes mean?	896	2.92 (1.19)	573	2.84 (1.19)	313	3.09 (1.17)
c8: Where does the data shown in the graph come from?	890	2.89 (1.23)	567	2.86 (1.22)	314	2.96 (1.23)
c7: Can the data shown in the graph be displayed using another type of statistical graphs?	887	2.88 (1.16)	566	2.82 (1.13)	312	3.01 (1.21)
c1: What is the purpose of the graph?	898	2.87 (1.22)	573	2.81 (1.19)	316	2.98 (1.25)
c10: Is there anything misleading in the graph?	878	2.86 (1.20)	564	2.78 (1.17)	305	3.04 (1.23)

Learning preferences. Table 6 shows the results for the seven items about learning preferences. The students strongly preferred the two traditional approaches: teacher's clear explanation and a lot of practice. Group work seemed to be preferred more by the NCG than the CG group; indeed, group work is rather rare in Singapore secondary classes, with only 15% of the 8238 secondary school students in the

TIMSS 1994 study reported engaging in this activity (Kaur & Pereira-Mendoza, 2002). On the other hand, the CG group had stronger preference for the use of computer in lessons than the NCG group. This is not surprising as the CG students might have some positive previous experiences with this activity. Although the students may have a mild preference for collecting data, they definitely disliked writing reports about statistical graphs. Report writing, an important form of mathematics communication encouraged by the Ministry of Education of Singapore (2000), has only recently been included as an alternative assessment technique in local schools, and this sample of students may not be familiar with this activity.

Table 6
Summary Description of Responses to Learning Preferences

Questions	Whole sample		NCG		CG	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
b3: I like my teacher to explain clearly when we learn statistical graphs.	862	3.88 (0.98)	568	3.90 (0.94)	284	3.86 (1.02)
b10: I will be able to understand statistical graphs better if I do a lot of practices.	861	3.72 (1.06)	567	3.70 (1.04)	284	3.76 (1.10)
b5: I like to work in groups when we study statistical graphs.	867	3.60 (1.12)	575	3.64 (1.09)	282	3.54 (1.16)
b2: I will learn better if the teacher uses computer to teach statistical graphs.	863	3.37 (1.05)	567	3.31 (1.04)	286	3.49 (1.06)
b9: I like my teacher to use everyday examples to explain statistical graphs.	862	3.29 (1.08)	567	3.20 (1.07)	285	3.47 (1.10)
b7*: It is a waste of time to collect data ourselves when we are learning statistical graphs.	864	3.23 (1.09)	569	3.24 (1.04)	285	3.23 (1.17)
b12: The teacher should ask us to write a short report about the given statistical graph.	825	2.42 (1.19)	555	2.46 (1.19)	270	2.35 (1.19)

Note: * This item is negatively worded and its reversed mean score is reported in the table.

Research question 2: Relationships among aspects of ASG

Likert-type scale as used in this study and other studies on attitude provides ordinal data. However, parametric tests are commonly applied to the data derived from Likert-scale in practice (Dooley, 1990; Yu, 2002). This approach is adopted here.

The relationships among the four aspects of ASG, namely *enjoyment*, *confidence*, *usefulness*, and *critical views* were investigated using Pearson product-moment correlation coefficients. The results are given in Table 7. The correlations ranged from 0.23 to 0.45 and were positive and statistically significant at the 0.001 level.

Table 7
Correlations among Enjoyment, Confidence, Usefulness, and Critical Views

	Enjoyment	Confidence	Usefulness
Confidence	.44*		
Usefulness	.34*	.45*	
Critical Views	.36*	.24*	.23*

* p<0.001 (2-tailed)

According to Cohen (1988), the size of a correlation is an indicator of the *practical* significance of a relationship, with correlations of about 0.3 (irrespective of sign) taken to indicate moderate practical effect. Of the six correlations, four had both statistical and practical significance. Feelings of *enjoyment* were positively associated with all the other three aspects, in particular with *confidence*, a finding also reported about mathematics learning in general (e.g., Kloosterman & Cougan, 1994). On the other hand, weaker relationships were found between *critical views* and *confidence* and *usefulness.* A possible explanation is that the students were not familiar with most of the ideas under *critical views*.

The relationships between *learning preferences* and the other four aspects of ASG are given in Table 8. Preferences for both the traditional approaches (teacher's clear explanation and practice) were positively associated with *enjoyment* and *usefulness.*

Table 8
Correlations between Learning Preferences and Enjoyment, Confidence, Usefulness, and Critical Views

Learning Preferences	Enjoyment	Confidence	Usefulness	Critical Views
b2: use computer	.24*	.07	.15*	.15*
b3: teacher's explanation	.22*	.12*	.33*	.16*
b5: group work	.05	-.04	.09*	.09
b7 (reversed): collect data	.24*	.17*	.28*	.08
b9: use every day example	.21*	.14*	.20*	.17*
b10: practices	.35*	.17*	.33*	.17*
b12: write a report	.16*	-.07	-.04	.12*

* p<0.01 (2-tailed)

Enjoyment was also related to preferences for computers, collection of data, and everyday examples, but not so for group work. Indeed, preference for group work did not correlate significantly with all the four aspects of ASG.

Research question 3: Relationships between student characteristics and their ASG

As reported above, the CG group had more positive attitude than the NCG group on most aspects of ASG. A detailed analysis of the composition of the two groups reveals that the NCG group had the similar distribution as the whole sample in terms of gender, grade level and stream, while the CG group had relatively more Sec 2 and fewer Sec 1 students compared to the whole sample. This indicates that in general the CG and the NCG groups did not have other distinguishing characteristics from each other. Therefore, it is reasonable to conduct independent sample t-tests to further investigate the differences between these two groups statistically. The results are given in Table 9. All the differences were statistically significant at the 5% level. In particular, students who had used computer to construct statistical graphs were more confident and asked more critical questions about these graphs than those who had not used computers.

Table 9
Independent-samples t-tests of aspects of ASG between NCG and CG groups

Aspects of ASG	NCG	CG	Mean diff.	*t*-value	*p*-value	Effect size
	Mean (SD)	Mean (SD)				
Enjoyment	3.10 (0.79)	3.24 (0.82)	0.14	2.54	.011	0.18
Confidence	3.14 (0.57)	3.33 (0.55)	0.19	5.01	<.001	0.35
Usefulness	3.41 (0.62)	3.53 (0.62)	0.12	2.66	.008	0.19
Critical views	2.97 (0.69)	3.15 (0.67)	0.18	3.78	<.001	0.26

Differences due to student characteristics of grade level, stream, and gender were investigated using three-way ANOVA tests for each of the four aspects, *enjoyment*, *confidence*, *usefulness*, and *critical views*. The significance level of each ANOVA test was set to be 0.0125 (= 0.05/4) in accordance to the Bonferroni technique (Huck, 2000). A summary of the findings are given in Table 10, with details given in Wu (2005).

There were no gender differences among Singapore secondary school students in all the four aspects of ASG. This adds to the inconclusive findings about gender differences in attitude toward statistics, albeit among university students.

Grade level and stream had statistically significant but small interaction effects on *enjoyment*, *confidence*, and *usefulness*. The follow-up tests of simple main effects produce complicated results. There were statistically significant stream differences in *confidence* and *usefulness* within each grade level, with decreasing mean scores in the order of S, E, NA, and NT streams in general. This finding is not unexpected because of the nature of these students by stream.

Table 10
Summary of the Four ANOVAs on Relationships between Student Characteristics and ASG

Source	Enjoyment	Confidence	Usefulness	Critical views
Grade level	×	√	×	×
Stream	×	√	√	×
Gender	×	×	×	×
Grade level × Stream	√	√	√	×
Grade level × Gender	×	×	×	×
Stream × Gender	×	×	×	×
Grade level × Stream × Gender	×	×	×	×

Note: √statistically significant at the 0.0125 level; × not statistically significant at the 0.0125 level

There were statistically significant grade level differences in *confidence* within S, E, and NA students, with students at higher grade expressing higher level of confidence, as expected. However, there was no change in confidence among NT students at different grade levels. Indeed, what was surprising was that older NT students tended to have lower enjoyment level and to hold less positive view about the usefulness of statistical graphs.

No group differences with respect to grade level and stream were found for the *critical views* aspect. A possible explanation was that these students from different streams and at different grade levels did not have sufficient experience asking these critical questions about statistical graphs. If students develop their attitude toward statistics based on their learning experiences in schools (Gal, Ginsburg, & Schau, 1997), then more attention should be directed to enriching these experiences in statistics lessons.

Conclusions and Implications

The above sections have discussed some interesting findings about attitude toward statistical graphs (ASG) among a large sample of Singapore secondary school students from four different streams and three grade levels. These students, irrespective of gender, did not particularly enjoy working with statistical graphs, were only moderately confident about their ability in statistical graphs, had positive view about the useful of these graphs, but seldom asked critical questions when they dealt with these graphs. These neutral to moderately positive attitude levels were consistent with Kulm's (1980) observation that most mathematics attitude scores reflect neural rather than negative attitudes. Students who had worked with computers (CG group) had more positive attitude than those who reported no experience with computers (NCG group). Students who were more able and at higher grade level tended to have more positive attitude, though exceptions were found with respect to the Normal Technical students. In general, these students much preferred traditional teaching approaches (teacher's clear explanation and practice) to the less familiar (and probably more active and more involved) learning activities, such as writing reports. These findings give rise to several implications discussed below.

The role of attitude toward statistical graphs should not be underestimated in the teaching of these graphs. Theories and research in mathematics education generally support a positive but small relationship between attitude and achievement (Gal & Ginsburg, 1994; Gal, Ginsburg, & Schau, 1997; Wise, 1985). Research to study this attitude–achievement relationship should look into specific classroom situations (Kulm, 1980), and designing attitude questionnaires like QASG to measure specific aspects of attitude and toward specific topics is a move in the right direction (Begle, 1979).

The *critical views* aspect of ASG was created by the first author using ideas culled from various sources. This has theoretical implications. It adds a new dimension to current conceptualization of attitude. Similar critical items can be constructed to cover attitude toward other topics in statistics and mathematics and be included into instruments used to measure such attitude. The 12 critical questions measuring this aspect for ASG were found to have acceptable internal consistency, and an exploratory factor analysis had identified three factors, which were called *presentation, meaning*, and *values* (see Wu, 2005 for details). Further research is needed to validate this *critical views* aspect by applying confirmatory factor analysis to data collected from larger and more heterogeneous samples in different countries. In addition to self-administered questionnaire, this aspect should be studied using qualitative techniques. A fruitful approach is to conduct task-based interviews probing students' choice of critical questions and their reasoning when they are given examples of statistical graphs taken from mass media. This technique can be used to assess not only the understanding of concepts and skills embedded in the graphs but also the critical attitude toward these graphs.

The *critical views* questions constitute the meta-knowledge which helps a person to become more aware of and hence to monitor his or her thinking of statistical graphs. On the practical front, teachers should model in their lessons how to ask these questions and ways to find answers appropriate to the students' level of understanding. This provides the necessary scaffolding and practice for students to develop a critical mindset and competence to deal with statistical graphs. This will serve the students well in their future career and daily life when they have to make decisions based on statistical graphs commonly found in the media. Further research will help to isolate factors that can promote the inculcation of this critical attitude.

The teaching of statistical graphs should take into consideration students' needs, preferences, and expectations, though this implication should be applied only with careful deliberation of alternatives. This study found that many students preferred clear explanation and practice; this preference for traditional methods is consistent with findings from other studies about how mathematics is to be learned and what constitute the desirable qualities of effective teachers from the perspectives of the students from different countries (e.g., Lim & Wong, 1989; Wong & Veloo, 1997). These two traditional methods provide the foundational learning experiences for many school students, and on this foundation the teachers can judiciously embed the more "progressive" techniques like group work, computer use, and report writing into their lessons. The teachers need training to learn about these techniques and critical reflection, including experimentation and action research, to discover what works for them. Students need to become more familiar with these learning experiences before they change their preferences. Bringing about these instructional changes is a life-long journey for both the teachers and students. Longitudinal research will increase our knowledge about the development of new attitude and changes to previously held attitude through different learning activities.

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