Students' Attitudes and Reflections on the Effect of Graphing Technology in the Learning of Statistics

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Abstract: The problem of students' negative attitudes towards statistics seems perpetual to most statistics educators. Meanwhile, a new mathematical realism has emerged in the mathematics classroom enhanced with graphing technology. Many studies (Arcavi & Hadas, 2000; Selinger & Pratt. 1997; Shoaf-Grubbs, 1995) have indicated that graphics calculator (GC) can enhance students' mathematical thinking through symbolic, algebraic and graphic presentations. Burrill (1996) found that GC can empower students to solve statistical problems by actively engaging them in "doing" statistics with real data in real situations. A study was conducted on 76 diploma undergraduates taking the Introductory Statistics course. Quantitative analysis on students' attitudes towards statistics after the GC intervention shows that there is an improvement. In addition, qualitative analysis of the students' daily reflections in this study shows that the use of GC in the learning of statistics seems to provide positive impacts on students' enjoyment in statistics, their conceptual understanding and tool competency. Students claimed that they enjoyed statistics more with GC primarily because it removes the tedium of certain mathematical tasks such as performing complicated computation. Furthermore, they regarded highly the importance of GC technology in their future undertakings.

Introduction

Statistical literacy is vital to all aspects in the modern life that deal with data based information. Ben-Zvi (2000) construes that "statistical thinking offers simple but non intuitive mental tools for trimming the mass of information, ordering the disorder, separating sense from nonsense, and selecting the relevant few from the irrelevant many" (p.129). In fact, most of the decisions made in our lives that involved the use of data are statistically reported. Furthermore, inferential statistics is widely used in making political, social, economic, as well as scientific decisions. Under such circumstances, statistics education today is compelled to undergo some changes and reorganization. It follows that undergraduates in the higher institutions are given the liberty to pursue a first course in statistics regardless of their future profession. In addition, the use of new technological tools to support students' constructive learning through "doing" and "visualizing" statistics is strongly emphasized.

The recent notions of community and practice have gained recognition of becoming the basic units for analysis of classroom interaction. Ju and Kwon (2004) pointed out in this perspective that cultural and social processes are integral to mathematical activity. In this context, statistics class is a community practice whereby learners share their ways of doing statistics and create their own culture through daily practice of statistics. Recently, a more realistic approach to the teaching and learning of statistics has emerged with the use of graphics calculator (GC). Burrill (1996) claimed that GC could empower students to solve statistical problems by actively engaging them in "doing" statistics with real data in the real situations. Wilson and Krapfl (1994) suggest that there is a need to focus on the qualitative aspects of knowledge construction of students using GC. Farrell (1996) in her study about teachers' roles when using GC technology in a high school pre-calculus class discovered that one's attitude and belief about mathematics and mathematics education could have influenced his/her role in using GC. On the relationship between the learners and the tool, according to Hiebert et al. (1997) learners construct mathematical meaning with the tool in accordance to the way it is used. Doerr and Zangor (2000) explained further the norm for tool usage emerges as students and teacher interact with the tool and with each other. They envisaged that through these interactions both teacher and students construe the meaning of GC as a tool for mathematical learning within the classroom.

It is common among the undergraduates who enrolled in a statistics course to experience negative attitudes towards statistics. Schau, Dauphinee, and Del Vecchio (1992) found that students attributed their negative feelings in statistics to poor teaching besides poor mathematics self-concept and achievement. If GC has the potential to change the practice of teaching statistics by the teacher then how far can it change the practice of learning statistics among the students? How do students react to the inclusion of GC in their statistics class?

In order to extricate students' perceptions and opinions towards learning statistics with GC, a study was conducted. This study was designed to investigate into the impact of GC in general on the classroom practice among the students. In this paper, I report on the results of the study conducted in a Malaysian classroom that examined (1) the attitudes of students towards statistics and towards using GC to learn statistics, (2) the social interactions in the statistics class integrated with GC, (3) the students' beliefs and knowledge in using GC to learn statistics, and (4) how do students value the new GC technology in their learning of statistics.

Method and Data analysis

Respondents and Contexts

The respondents for this study consisted of 76 Second Year Diploma undergraduates who were taking the Introductory Statistics course. These respondents were non-mathematics majors but were required to pass the statistics paper in order to graduate. All of them had no experience in using GC.

Procedure

The teaching of Introductory Statistics course was conducted using TI-83 Plus. Each student was given a GC during the lesson. The course contents include the one and two variables descriptive statistics, some principles of data collection methods and sampling techniques. The topics chosen were Measures of Central Tendency, and Correlation & Simple Linear Regression. The whole discourse consisted of twelve lessons. One lesson was two hours long and there were two lessons in one week. The whole intervention course was conducted in six weeks.

Data Collection

This study employed three different methods in collecting data: (i) survey questionnaires, (ii) classroom observation, and (iii) students' written reflections.

Instrument

Respondents were given a similar set of questionnaire (39 items) measuring their attitudes towards statistics and their confidence in using GC to learn statistics at the beginning and at the end of the intervention period. All items are 5-point Likert scale ranging from 1 (strongly disagree) through 3 (neutral) to 5 (strongly agree).

There are 28 items measuring attitudes toward statistics taken from the Survey of Attitudes towards Statistics (SATS) Pre and Post Version developed by Gal, Ginsburg and Schau (1997). The SATS questionnaire measures the four aspects of students' attitudes towards statistics: *cognitive competence*, *affect, value* and *difficulty*. Another 11 items that follow measure students' attitudes towards using GC to learn statistics (STech) were adapted from an instrument called the Attitudes to Technology in Mathematics Learning Questionnaire (MTech) which was developed and validated by Fogarty et al. (2001). Appendix A lists all the items in detail.

Data analysis

The survey questionnaire was analyzed using SPSS version 11.5. The total scores obtained were used to give a general description of the respondents' attitudes in statistics and their confidence in using GC to learn statistics. Qualitative content analysis was used to elicit meaning from the written text and to summarize the message content. Themes and patterns were categorized according to the characteristics of the phenomena being studied. The outcomes were contextualized and analyzed using the Non-numerical Data Indexing Searching and Theorizing Q.S.R. Nud*ist (Richards, 2000), a computer software for qualitative data analysis.

Results and Discussions

(i) *Survey questionnaires*

Initial test on the item reliability of the instrument shows the reliability coefficients for all the scales and subscales as follows:

Table 1. The summary of reliability measures – Scale (ALPHA)

	Cognitive	*Affect*	*Value*	*Difficulty*	SATS	STech
N of Cases	76	76	76	76	76	76
N of Items	6	6	9	7	28	11
Alpha	.8480	.7938	.7488	.7249	.7505	.7950

Comparing scores for attitudes towards statistics and towards using GC in learning statistics

The total scores for SATS and its components and also STech were obtained and compared before and after the GC intervention. Table 2 below displays the total sum of scores for the six aspects before and after GC intervention. Wilcoxon Signed Ranks test was conducted to test for the significance of the results before and after GC intervention.

Comparison between the groups in Table 3 shows that the total sums of scores for all the six aspects with the exception of *difficulty* were higher after the GC intervention than before the intervention. Hence the result infers that respondents' were more optimistic towards GC after they were exposed to its' usage. Results displayed in Table 3 shows that the different in scores observed before and after the GC intervention for all aspects were indeed statistically significant at 95% confidence level for the study sample.

Table 2. Total sum of scores for SATS, its four components and STech

Variables	No. of items	N	Sum of score		Difference in sum of scores
			Before	After	
SATS	28	76	5601	5929	328
Cognitive	6	76	1202	1406	204
Affect	6	76	1172	1348	176
Value	9	76	1602	2045	443
Difficulty	7	76	1625	1130	-495
STech	11	76	2408	2800	392

Table 3.Wilcoxon Signed Ranks Test for attitude scores before and after the GC intervention

Aspects	Mean rank	Z	Asymp.Sig. (2-tailed)
SATS after-SATS before	38.06 37.97	-2.099	.036*
STech after-STech before	28.67 41.00	-4.234	.000***
Cognitive after-Cognitive before	32.33 39.83	-3.474	.001**
Affect after-Affect before	31.61 37.40	-3.021	.003*
Value after-Value before	22.66 41.03	-5.435	.000**
Difficulty after-Difficulty before	42.37 15.64	-6.689	.000***

*Significant at $p < .05$ level, **Significant at $p < .01$ level, ***Significant at $p < .0005$ level

Based on the total sum of scores, it was found that after the GC intervention students in the study sample were generally more positive towards statistics (SATS). They appreciate more about the knowledge and skills they learn in statistics (*cognitive competence*), feel better about statistics (*affect*) and also regard highly the importance of statistics to their future (*value*). Their attitudes towards using GC to learn statistics (STech) had improved as well indicating that they favour the use of the tool in learning statistics. For the aspect of *difficulty*, the higher the total score indicates statistics is perceived easier as a subject. In the study sample, the total score for *difficulty* was lower after the GC intervention indicating that students in the study sample found that statistics taught with GC is more difficult than before.

The strength of relationship between SATS and STech

Based on Cohen's (1988) suggested guidelines for determining the strength of the relationship (r), Table 4 shows that attitudes towards statistics (SATS) was moderately and positively correlated to attitudes towards using GC to learn statistics (STech) before the GC intervention ($r_{\text{before}} = .391$, p <

.001) and after the GC intervention ($r_{after} = .463$, $p < .001$). This means that students' attitudes towards statistics have some influences on their attitudes towards using GC in learning statistics and vice versa.

(ii) *Classroom observation*

Four facilitators throughout the whole discourse reported the classroom atmosphere and classroom behaviour of the students besides the observation done by the researcher. In general, what was noticeable was that in a GC-enhanced classroom, active and interactive learning preceded the traditional chalk and talk method. One facilitator noted: "*The class was noisy but it is a good sign of learning because they were busy asking questions. Discussions were seen among the students and between students and lecturer*." Another noticed the students were actively involved in the process of learning with GC when she commented: "*During the process of using GC, as usual there were group discussions among the students. They were asking each other how to use GC. Some of them were helping the weaker ones*."

The introduction of GC seemed to make the classroom atmosphere livelier, as most of the students participated actively in the classroom activity and much more collaborative learning activity was observed as well. It was a pleasant surprise to notice a great difference in students' classroom behaviours during the normal class lessons compared with lessons with GC. Students sat in groups or paired up doing statistics without being instructed to do so by the lecturer. Evidence was obtained from a written report: "*Most of the students communicated with each other. They participated in a group discussion to get the final answer. Most of them worked in pairs.*" In addition, peer teaching, working collaboratively and cooperatively among students were common scenes in the classroom when one reported: "*When they were confused in receiving instruction from the lecturer, they overcome this by encouraging and helping each other*."

The information gathered from the classroom observation provides evidence that the classroom climate was different from the conventional classroom settings. Students were reported to experience more freedom to talk with one another and involved in a group discussion. The relationship between lecturer and students has also changed from authoritarian to a friendlier manner. However, did the students find this kind of teaching and learning with GC technology enticing? There were positive reports stating that students showed interest in learning how to use GC, for example: "*Everyone in the class showed interest in learning how GC functions*." Moreover, the classroom atmosphere was noted to be generally cheerful as illustrated by the remark: "*While using GC the students were cheerful and were moving about freely to find out the correct answer*."

Nevertheless, the negative side of the GC intervention was recorded in the facilitators' notes. It was observed that most of the classroom teaching with GC was interactive in nature. The lecturer was seen busily showing the students how to use the GC correctly. Often class attention was focused on what was displayed on the GC screen. There was lesser eye contact between the lecturer and the whole class. What went unnoticed was a few students in the class who were passive were neglected. One facilitator duly reported: "*There was this boy who sat in the class for only ten minutes and left unnoticed*." The consequence of inattention of this manner has caused some students to act indifference in their learning as reported by another facilitator: "*Some were not paying attention. They don't ask questions even though they don't know how to solve the problem.*" It follows that such an occurrence if left unchecked may further lead to frustrations and dissatisfaction among the passive students.

(iii) *Respondents' written reflections*

When the respondents were asked to reflect on their experience in the GC-enhanced statistics lessons, almost all pointed out that using GC helped to promote better understanding of statistical concepts. They were noticed using GC in a more meaningful way such as checking their answers worked out by hand, comparing and discussing their answers with friends, plotting graphs with GRAPH button and using the dynamic features for instance the TRACE and ZOOM buttons to explore the graphs generated. Respondent wrote that: "*By looking at the graph I can get the answer accurately by using TRACE. I can also get the numeric answer correctly*." Respondents were reported to benefit from the dynamic feature in GC when one remarked: "*When we need a more accurate answer we just use the ZOOM key repeatedly until we get it*."

There was evidence of increased interest in learning statistics and increased personal confidence about statistics. Students felt engaged with the statistics lessons presented with GC technology and believed that they have learned the lessons in a much better and more advanced way. One student remarked: "*I have learnt a lot from using GC to plot histogram and changing its class width. It is a good idea to learn with this new tool because I see and know about the changes (on screen) when I change the values of the class width*." In addition, they were noticed to engage in intelligent partnership with GC. For example one wrote: "*I can learn step by step with GC. It helps to improve my understanding of correlation and regression and also the relationship involved better*." Yet another revealed that: "*I can understand the calculation with the use of GC.... I use GC to guide me and teach me*." Furthermore, they have learned to present the statistical data numerically, symbolically and graphically. One respondent reported: "*It is very interesting to explore with GC. You can easily call out diagram, information or graph*." Yet another informative finding indicates that even though the students found GC difficult to handle at times, they were excited about its use in the statistics lessons. One respondent expressed: "*I can understand sometimes but there are other times I cannot understand how to use GC. Anyway I am happy to learn statistics with GC*."

In the event of using GC to learn statistics, the students felt that the new knowledge gained and their ability to operate GC make them better off than their peers who learn statistics the traditional way. They expressed that they were proud to be chosen to use GC or to gain the new knowledge as one remarked: "*I feel proud to use GC because I am one of the DBS students who was chosen to use this tool.*" Moreover, they considered themselves better and more learned than those without the GC knowledge. These respondents perceived knowing how to use GC would enhance their social status when one wrote: "*Using GC makes it easier for me to calculate and plot graph. I feel great to have this knowledge when I compare myself to those who do not have knowledge about GC*." As it were, these remarks suggest that students looked upon themselves as technologically able and valued themselves as more capable in statistics than their peers who are unacquainted with GC.

Despite of all these, the state-of-art technology was anticipated to bring in some difficulties to the statistics classroom as well. The word "difficulty" was repeated in a number of remarks made by the respondents. For example it was noted in one of the writings: "*I find it is very difficult to use GC because I don't know which button to press as it has so many function buttons*." And another: "*The instructions are too complicated. There are too many steps to follow…when we are asked to generate regression equation into y =, we can't do it straight away. It is difficult to remember these steps.*" Further analysis shows that most of the difficulties faced by the respondents were in fact technically based. Thus it appears that we are introducing a new type of problem, the "technical complexity", to the novice students while using GC as a tool for expediency in statistics.

Another issue raised is "How successful is GC being integrated into the social processes desired by the students in their statistics classroom?" A comprehensive review of a number of research studies by Schofield (1995) concludes that many teachers who attempt to use computer technology in instruction have difficulty in adjusting to what may appear to be noisy and disorderly classroom. Although most of the respondents responded favourably towards GC, there was a handful who were unenthusiastic towards new changes. It seems that this group of students could be facing the same problem of adjusting to the new learning environment with GC. In fact they were noted to use GC solely to do calculation and to plot graph only. Further, they found themselves virtually unable to attain a deeper learning by solving the statistical problem on the GC screen or to make up any meaning from the "electronic" graph generated by GC. One respondent responded with remorse: "*It is very difficult to remember the functions in GC…I cannot see anything (meaningful on the screen) as compare to learning with manual method. Sometimes I feel it is too fast for me to catch up when using GC…I will prefer not to use GC if I could*." Under such circumstances, it is very likely that these students will opt for the traditional method in which they can get the teacher to delineate all the steps clearly on the board and to act as an expert to check their confusion.

To date, report on students describing the traditional method of solving problem with the scientific calculator (SC), the "SC method", is unheard of. However, students in the study sample were most often found to describe the method of solving problem with GC the "GC method". As GC is not allowed in the examination, one respondent was found to remark: "*Without GC I don't know how to apply the GC method in my final then. I am not confident of plotting graph with paper and pencil method in my test.*" Obviously students in the study sample still perceived using GC as another additional method to do statistics. Respondent expressed that: "Using *GC to do calculation is perfect because it is built for calculation. For the learning of concepts the old method is still preferable. GC is just another additional method that helps us to learn statistics*."

With the inclusion of GC in the statistics class, it does not mean that the whole process of teaching and learning is technologically operated. Teachers still play an important role in mediating the interaction between the tool and the classroom culture. Personal guidance and attention given by the teacher is still very much sought after by the student. One remark noted that: "*I can understand how to use GC with the lecturer's guidance but it is hard for me to do it alone.*"

In summary, the findings above impart some enriching information about the GC intervention. There were the quantitative data which reported that students found statistics more difficult as a subject after the GC intervention. They found that learning statistics with the conventional method is easier than with GC. This finding is supported by the qualitative data which revealed that students encountered yet another problem while learning statistics with GC. This problem is associated with the difficulties resulting from the "technical complexity" of GC. However, this type of difficulty is only temporary and can be overcome by giving more time for practice. Also, it was learnt that *affect* and *cognitive competency* do not comply with each other. Students who are highly motivated to use GC do not necessarily have high competency in using GC to engage in meaningful learning and vice versa. Nevertheless, students' attitudes towards statistics and their attitudes towards using GC to learn statistics have some influence on each other.

Conclusion and Recommendation

In general, students' reflections show that the use of GC in statistics has positive impact on their enjoyment of statistics, their conceptual understanding and statistical skills, as well as their social status among peers. They were able to experience the direct manipulation of the statistical data and explore their relationship with GC. Balacheff and Kaput (1996) characterize such phenomenon as "a new experiential mathematical realism".

Based on the enlightening observance of the "GC method" and "SC method", it is anticipated that the process of enculturation of "GC technology" in statistics will never materialize until the "GC method" begins to merge into students' inherent knowledge and not taken literally as another additional method to learn statistics. By then, students will be seen reaching spontaneously to do statistics electronically and visualize graphs scientifically with GC without hesitation.

Lastly, it is recommended that further research should include interviews with the students in order to explored further insights that are linked to the culture of statistics learning in a GC enhanced classroom. Lin (2001) pointed out that understanding how individual teacher handles new technologies is important because teachers are the mediator between the artefact and the classroom culture. Hence, it would be an added value to look into the strengths and weaknesses on the teacher's beliefs and ability in using GC to teach the topics.

Acknowledgements The author wishes to thank Statworks (M) Sdn. Bhd. for rendering its support and assistance to materialize the objectives of this study with the loan of TI-83 Plus during the whole discourse.

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Appendix A

List of the items in the four components of SATS

Components	Aspects	Items
Cognitive competence	Attitudes about intellectual knowledge and skills when applied to statistics	▪ I have trouble understanding statistics because of how I think* ▪ I have no idea of what's going on in statistics* ▪ I made a lot of math errors in statistics* ▪ I can learn statistics ▪ I understand statistics equations ▪ I find it difficult to understand statistics concepts*
Affect	Positive and negative feelings concerning statistics	▪ I like statistics ▪ I feel insecure when I have to do statistics problems* ▪ I get frustrated going over statistics tests in class* ▪ I am under stress during statistics classes* ▪ I enjoy taking statistics classes ▪ I am scared by statistics*
Value	Attitudes about the usefulness, relevance, and worth of statistics in personal and professional life	▪ Statistics is worthless* ▪ Statistics should be a required part of my professional training ▪ Statistics skills make me more employable ▪ Statistics is not useful to the typical professional* ▪ Statistical thinking is not applicable in my life outside my job* ▪ I use statistics in my everyday life ▪ Statistics conclusions are rarely presented in everyday life* ▪ I have no application for statistics in my profession* ▪ Statistics is irrelevant in my life*
Difficulty	Attitudes about the difficulty of statistics as a subject	▪ Statistics formulas are easy to understand ▪ Statistics is a complicated subject* ▪ Statistics is a subject quickly learn by most people ▪ Learning statistics requires a great deal of discipline* ▪ Statistics involves massive computations* ▪ Statistics is highly technical* ▪ Most people have to learn a new way of thinking to do statistics*

List of the items in STech

- GC makes it easier to explore statistical ideas
- I know GCs are important but I don't feel I need to use them to learn statistics*
- GCs are good tools for calculation, but not for my learning of statistics*
- I think using GC is too new and strange to make it worthwhile for learning statistics*
- I think using GC waste too much time in the learning of statistics*
- I prefer to do all the calculations and graphing myself, without using a GC*
- Using GC for calculations makes it easier for me to do more realistic applications
- I like the idea of exploring statistical methods and ideas using GC
- I want to get better at using GC to help me in statistics
- The symbols and language of statistics are bad enough already without the addition of GC technology*
- Having GC to do routine work makes me more likely to try different methods and approaches.

Items with an * are reversed in the scoring (1 becomes 5, 2 becomes 4, etc.). The scores are summed with higher scores correspond to more positive attitudes.