Are Mathematics Students' Learning Styles Related to Their Preferred Method of Learning How to Use Advanced Calculators?

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Abstract

One of the learning styles models used for investigating students' preferences is based on the Visual, Aural, Read-Write or Kinesthetic (VARK) modalities for receiving information. This paper presents the research findings of a survey study on Singaporean and Australian students, contrasting students' VARK preferences with their instructional learning preferences when using graphing calculators and calculators with computer algebra systems (advanced calculators). Students filled in an adapted 7-item instrument about their VARK preferences, and were also asked to indicate their most preferred instructional method of learning how to use the calculators to solve mathematics problems. It was found that students generally preferred visual and kinesthetic instructional methods when learning how to use calculators, regardless of their VARK preferences. Results also show that there were regional differences in students' VARK preferences. Overall, the results suggest that students adapt their learning preferences to different contexts, and that advanced calculators lend themselves to visual and kinesthetic modalities of learning.

1. Introduction

Using technology for mathematics learning and problem solving has become part and parcel of the essential mathematical skillset. Mathematical literacy in the 21st century includes the use of mathematical tools such as graphics calculators (GCs) and calculators with computer algebra systems (CAS) [9]. The use of advanced calculators such as GCs and CAS calculators is integrated into the mathematics curricula of various regions around the world. In certain regions like Singapore and Victoria, Australia, advanced calculators are used in the senior secondary mathematics examinations (see [9]). Thus the effective use of advanced calculators by students affects their senior secondary mathematics achievement and gate-keeps their entrance to the university and tertiary education.

Prior reviews of studies and meta-analyses on the impact of calculators [1] have established that the use of advanced calculators can have a positive effect on students' mathematics achievement and attitudes towards mathematics. However, there were also cautions about underutilization and the over-use of the calculators [1]. Familiarity with the tool is important to harness its potential for learning mathematics. Learning how to use a new technology while simultaneously making use of the technology to learn mathematics concepts can pose a challenge for some students, since using new technology imposes additional cognitive demands on students [1]. Researchers have been investigating factors affecting students' learning of technologies and learning styles is one such factor [16].

The study of learning styles has been one that is both complex and perplexing, embroiled with controversy and unresolved issues (see [4] and [11]). The field gained momentum since the end of the 1970s, and educators and researchers continue to investigate learning styles as "a way to address individual differences in learning" ([4], p. 445). In the 1980s and 1990s, there was a bloom of theories and instruments developed to investigate people's learning styles. Due to the myriad of different definitions, theoretical models and instruments in the field, it has been likened to a jungle [4]. There were attempts to consolidate the field in the 2000s and 2010s and issues and critiques were raised (see [4], [2], and [11]). These included the lack of evident-based studies on the effectiveness of using learning styles models to improve student outcomes [11], the commercialization of instruments, manuals and various packages by some leading figures in the field [2], and the ease and convenience of online inventories prompting possible "mindless and atheoretical empiricism" ([2], p. 62) by university researchers. Despite critiques, learning styles continue to be used in various disciplines in higher education [16], and particularly in field of educational technology such as online learning [3].

Of interest to this study is the learning style model that is related to the different modalities in which individuals prefer to perceive and process information. Advanced calculators offer the features of multiple representations – numerical, graphical, and algebraic. Besides investigating the roles that multiple representations play in students learning, researchers have also investigated other modes of representation such as verbal and kinesthetic [5]. There is a body of research into students' preferences for mathematical representations. However, little is known about students' modality preferences when learning how to use the calculators, a context which might play an important part in their representational preferences when using the calculators to solve problems. In the learning styles literature, preferences for perceptual and sensory modalities such as visual, aural, read/write, and kinesthetic modalities [6] seem to have some parallel features relating to how students learn to use the GC and CAS calculators: visual – graphs on the calculator screen and screenshots; aural – teacher instruction and peer discussions; read-write – text, symbols and written instructions; and kinesthetic – solving contextual problems, actual pressing of the calculator buttons and working with the calculator. The VARK framework – Visual, Aural, Read/Write, and Kinesthetic – of modal preferences that individuals have in receiving and transmitting information (see Table 1) is used in this study [6]. Flemings' [6] emphasis is on the "pragmatic part, of the complex set of attributes that make up a learning style" (p. 46), since "students and teachers can do something about learning when they know their modality preference" (p. 46).

Table 1

VARK Framework (adapted from Fleming [6], pp. 1-2)

Preference	Description
Visual (V)	Includes the depiction of information in charts, graphs, flow charts, and all the symbolic arrows, circles, hierarchies and other devices that teachers use to represent what might have been presented in words. It does not include pictures, movies, videos and animated websites (simulation) that belong with Kinesthetic below.
Aural (A)	A preference for information that is spoken or heard, such as discussion, oral feedback, email, mobile phone chat, discussion boards, oral presentations, classes, tutorials, and talking with other students and teachers.
Read/Write (R)	A preference for information displayed as words either read or written, such as quotes, lists, texts,

Preference	Description
	books and manuals.
Kinesthetic (K)	A preference related to the use of simulated or real experience and practice. Although such an experience may invoke other modalities, the key is that the student is connected to reality through experiences, examples, practice or simulation. This mode is where students use many senses (sight, touch, taste and smell) to take in their environment to experience and learn new things.

Although Fleming's model is not specific to mathematics (it does not have numeric or symbolic modes which might be subsumed under Read/Write preferences), it appears to be a useful model that covers aspects of students' representational preferences that would be relevant to mathematics learning with technology use. Fleming's [6] model also takes into account multimodal preferences, of which there are two types: an individual can select different modes according to the learning situation, or might assimilate the same input via different modes in order to learn. This is consistent with the literature on mathematics education where students can have multiple approaches or preferences. In contrast to other VAK (Visual/Aural/Kinesthetic) learning style models which are popular in schools, but noted for their lack of research scholarship [11], the VARK learning styles inventory has been found to have some validity [10], and has been used in research studies [16].

To investigate the potential use of students' learning styles as a factor influencing their use of technology, this study examines students' instructional preferences when learning to use advanced calculators and compare them with their VARK learning styles.

2. Methods

This study, part of a larger study, was conducted using the online survey platform SurveyMonkey [13]. Students from Singapore were invited to participate through schools, and Victoria students were invited through schools and recruited using a Facebook advertisement [15]. It should be noted in Singapore GCs are required in all the senior secondary mathematics written examinations, whereas in Victoria, Australia the more advanced CAS calculators were allowed to be used in intermediate and advanced level mathematics in a school-based examination and one of the two written examinations at grade 12 [9].

Students' VARK learning styles were measured using an adapted version of the VARK instrument for high school students [6]. The instrument comprised with 13 items. Each item provides a situation and students select out of a list of four options (corresponding to visual, aural, read-write and kinesthetic preferences) those that they think most describe them. Students could choose more than one option. The items had been modified to suit the learning context, such as one where an English project was changed to Mathematics project:

I need to do a mathematics project about a story of a famous mathematician. I would prefer to:

- design or draw a diagram depicting the story.
- read out a version of the story to the class.
- read some articles related to the story and then write my own article about the story.
- act out a scene from the story.

Not all items are mathematics based, such as the following item:

I like websites that have:

- interesting design and visual effects.
- interesting written information and articles.
- audio channels for music, chat, and discussion.
- things I can click on and do.

The full 13-item instrument was tested in a trial of 41 Singaporean students. The 13 items of Fleming's instrument have been modified and from analyses of the items, seven items were selected based on reliability (i.e., students' preferences for these items were the most consistent with their final VARK preferences). The scoring method was simplified from the original complex scoring system that is a step function of students' individual VARK scores, to using the preference mode(s) with the highest score as their VARK modality preference.

Students were also asked to indicate, from a list of ten instructional methods of learning how to use the advanced calculators to solve mathematics problems, their most preferred method. The ten methods were derived based on the researcher's own teaching experience in Singapore, as well as readings of learning styles and modality preferences. A discussion of the gender differences in Singaporean students' responses to this item and other related items in the questionnaire of the full study has been presented elsewhere [12]. The list is as follows, with an additional 'others' option for students to indicate if they have other most preferred methods:

a. See my teacher's demonstration in class
b. See the steps my friends show me on their calculators*.
c. Look at the calculator screen captures in notes, textbooks or manual
d. Discuss answers with my friends
e. Listen to a teacher who explains the steps and concepts clearly and thoroughly
f. Listen to a teacher who reads out the steps given in notes, textbooks or manual
g. Copy down the steps my teacher writes on the board
h. Make my own notes
i. Try out the steps on the calculator at the same time I see a demonstration or hear an explanation or read the instructions
j. Try the buttons out and play around with the calculator
k. Other methods: please explain.

* the term "calculator" was specified as GC or CAS calculators according to the region.

It is acknowledged that there might be ambiguities, for example kinesthetic methods may also engage multiple modalities (see Table 1). It was assumed by the researcher that methods (a), (b), and (c) roughly correspond to a visual modality, methods (d), (e), and (f) correspond to an aural modality, methods (g) and (h) correspond to a read/write modality, and methods (i) and (j) correspond to a kinesthetic modality.

3. Results and Discussions

There were a total of 964 responses received from Singaporean (37.1% males, 62.9% females) and 176 from Victorian students (31.3% males, 68.8% females). Data were collected and Chi-square tests were conducted using IBM SPSS Statistics 22 software [8]. The distributions of Singaporean and Victorian students' VARK modality preferences are shown in Table 2.

Table 2

Percentages of Students' Most Preferred VARK Modality Preferences by Region

	Mode	Singapore (N = 964)	Victoria (N = 143)
Single	V	25.2%*	7.7%
	A	25.2%*	17.5%
	R	16.4%	42.7%
	K	5.4%	0.7%
Multi-modal		27.8%	31.5%

* This is not an error. Both groups happened to have the same percentage (N=243 for both), even though they are mutually exclusive.

It can be seen that Singaporean and Victorian students had different distribution patterns for their VARK modality preferences, particularly for the single modes. Both these patterns are also markedly different from the data collected over September to December 2015 on the *VARK* website by Fleming [7], which had 63.8% multi-modal, and 36.2% single preferences (V = 3.9%, A = 8.6%, R = 9.3%, and K = 14.4%). This may be due to the changes to the original instrument and the scoring system used in the present study. To further investigate regional differences, the individual modes (V, A, R, and K) were analyzed in relation to students' highest scoring modality. That is, students with multi-modal preferences such as VA were considered twice, under the individual modalities V and A. The results are shown in Figure 1. There were significant differences in the distributions of VARK modalities between Singaporean and Victorian students for Visual, Read/Write and Kinesthetic styles ($\chi^2_{\text{Visual}}(1, 1106) = 17.3$, $p < .001$; $\chi^2_{\text{Read/Write}}(1,1106) = 70.8$, $p < .001$; $\chi^2_{\text{Kinesthetic}}(1,1106) = 4.29$, $p < .05$) but not for Aural ($\chi^2_{\text{Aural}}(1, 1106) = 1.62$, $p = 0.204$). The percentages of most preferred VARK mode within each region are shown in Figure 1. The percentages add up to more than 100% due to the presence of multi-modal preferences. It can be seen that a significantly higher percentage of Singaporean students had Visual as their most preferred VARK mode (S'pore = 43.8%, Vic = 25.4%), whereas a much higher percentage of Victorian students had Read/Write (Vic = 69.0%, S'pore = 32.5%) as their most preferred VARK mode. There was also a significantly higher percentage of Singaporean than Victorian students with Kinesthetic as their most preferred VARK style (S'pore = 13.2%, Vic = 7.0%, $p < .05$).

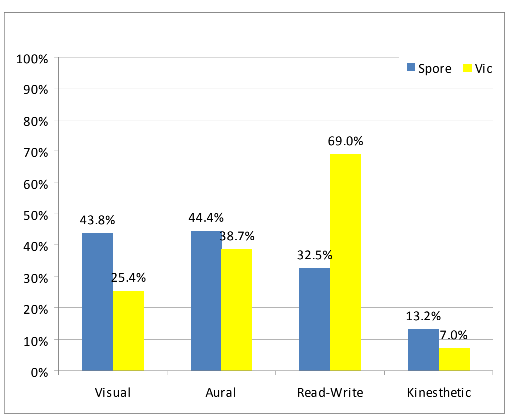

Figure 1 Percentages of students by region with most preferred VARK styles

These findings suggest that there are regional differences in VARK preferences. Singaporean students have a stronger preference for Visual modes of input, and Victorian students have a stronger preference for Read/Write modes. This may be due to differences in the senior secondary classroom structure (lecture-tutorial system in Singapore versus classroom teaching in Victoria), or in socio-cultural contexts. The explanations for this difference are worthy of further investigation.

Responses for students' most preferred method of learning how to use the calculators were then analyzed. Not all students answered the question (S'pore=946, Vic=138). There were similarities and differences by region in students' most preferred method of learning how to use the calculator, shown in Table 3. It can be seen in Table 3 that the top three most preferred methods of learning how to use the calculators were the same:

- (i) trying out the calculator steps at the same time they see/listen/read the instructions (Kinesthetic; Vic = 37.0%, S'pore = 42.3%);
- (a) watching the teacher's demonstration (Visual: Vic = 22.5%, S'pore = 19.8%); and
- (j) trying the buttons out and playing around with the calculator (Kinestheic; Vic = 17.5%, S'pore = 13.1%).

Table 3

Frequencies and Percentages of Singaporean and Victorian Students Who Selected (a) – (j) as Their Most Preferred Method of Learning How to Use the Calculator.

	Region				Diff in % within region (S % - V %)
	Singapore		Victoria		
	Count	% within Region	Count	% within Region	
a) see my teacher's demonstration in class.	187	19.8%*	31	22.5%	-2.7%
b) see the steps my friends show me on their calculator.	35	3.7%	6	4.3%	-0.6%
c) look at the calculator screen captures in notes, textbooks or manual.	55	5.8%	4	2.9%	2.9%
d) discuss answers with my friends.	11	1.2%	3	2.2%	-1.0%
e) listen to a teacher who explains the steps and concepts clearly and thoroughly.	93	9.8%	10	7.2%	2.6%
f) listen to a teacher who reads out the steps given in notes, textbooks or manual.	2	0.2%	1	0.7%	-0.5%
g) copy down the steps my teacher writes on the board.	18	1.9%	14	10.1%	**-8.2%****
h) make my own notes.	21	2.2%	0	.0%	2.2%
i) try out the steps on the calculator at the same time I see a demonstration or hear an explanation or read the instructions.	400	42.3%	51	37.0%	**5.3%****
j) try the buttons out and play around with the calculator.	124	13.1%	18	17.5%	-4.4%
Total	946	100.0%	138	100.0%	

* Shaded cells represent the top three methods with the highest percentages within each region.
** Bolded percentages indicate where the percentage difference between regions is more than 5%.

Table 3 shows that for most methods the percentages are similar for both regions, except for methods (g) and (i) where there were differences greater than 5%. A higher percentage of Victorian than Singaporean students most preferred to (g) copy down the steps their teachers wrote on the board (Vic = 10.1%, S'pore = 1.9%), whereas a higher percentage of Singaporean than Victorian students most preferred to (i) try out the calculator steps at the same time they see a demonstration or listen to an explanation or read the instructions (S'pore = 42.3%, Vic = 37.0%). This seems consistent with students' VARK preferences since method (g) can be classified as using a Read/Write style preferred by more Victorian students, and method (i) as using a Kinesthetic style while engaging multiple modes preferred by more Singaporean students.

There were four Singaporean and two Victorian students who had not selected a method from the list and provided answers to their most preferred methods. It was not possible to categorize these responses according to *VARK* modalities because there were ambiguities as to which modes were engaged. For example, a student said "all (the methods) are equally effective for me to use the GC".

For the final analysis, students in each region were grouped by their VARK preferences and their calculator learning preferences were plotted (see Figures 2 and 3). The patterns of distribution of calculator preferences between each VARK group were examined to see if there are any relationships between VARK preferences and calculator preferences.

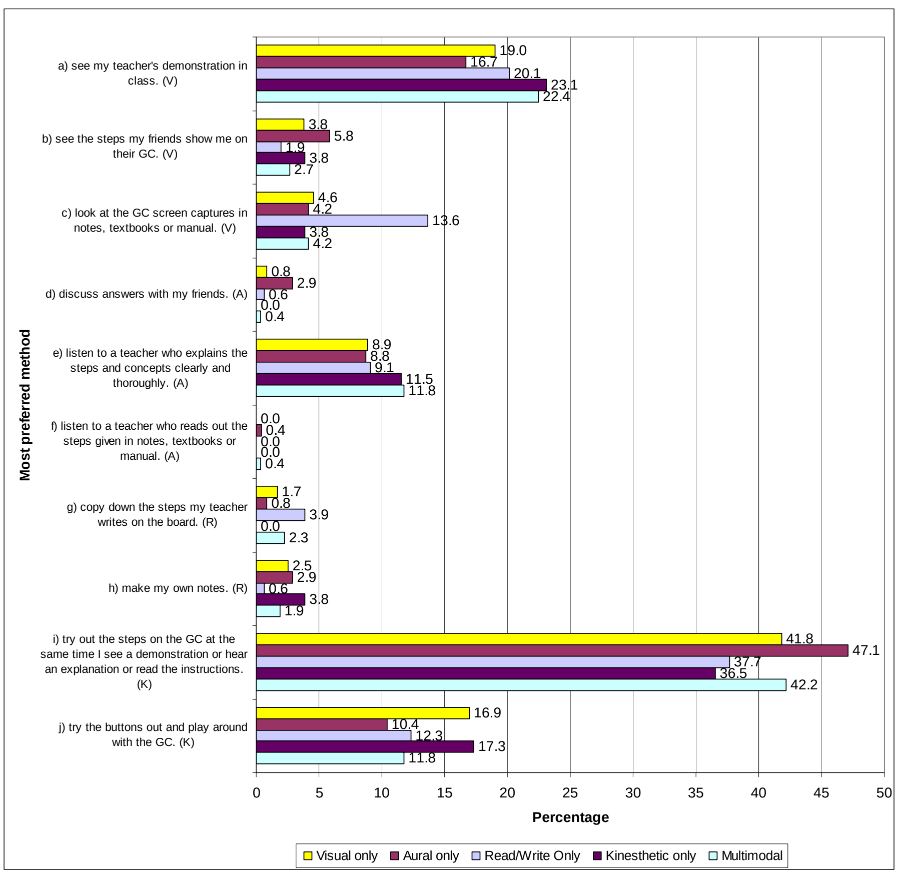

Figure 2 Comparisons of most preferred methods between Singaporean students who were Visual, Aural, Read/Write, Kinesthetic and Multimodal (valid *N*=946)

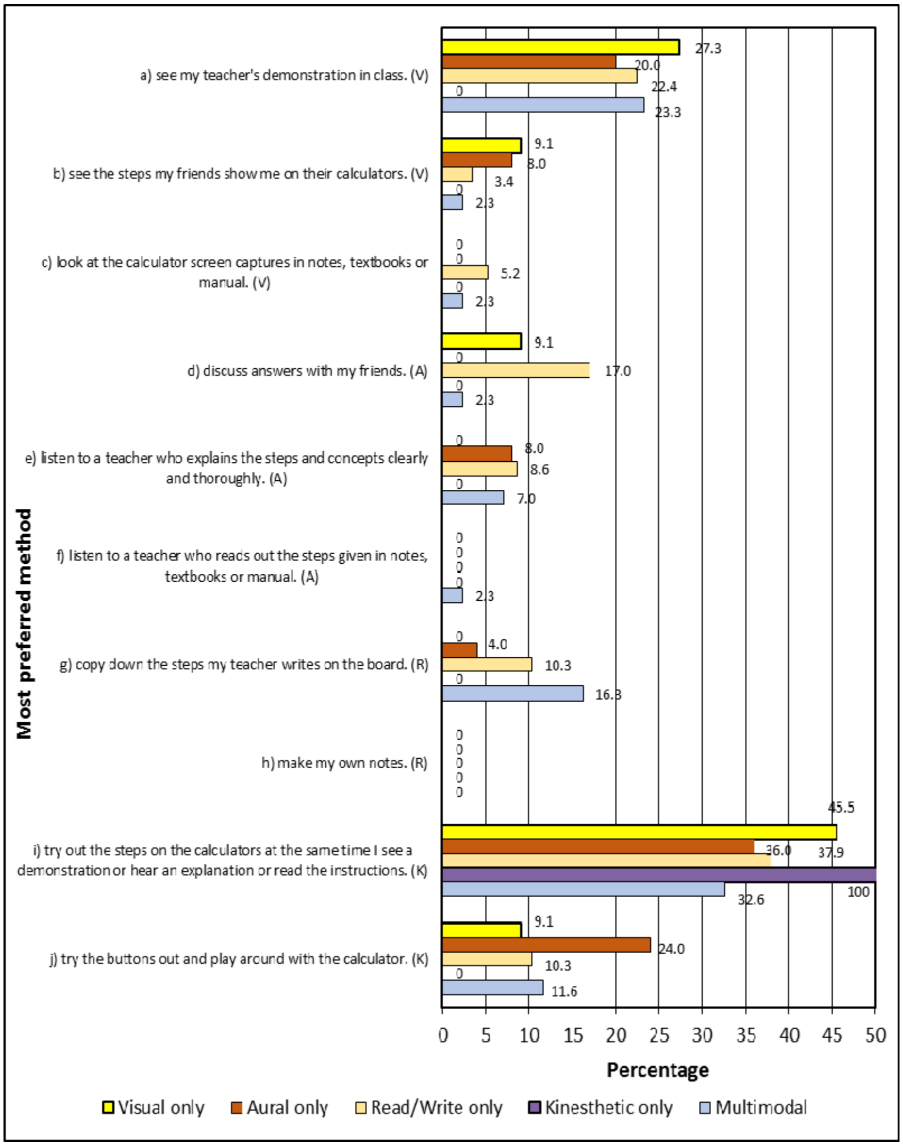

Figure 3 Comparisons of most preferred methods between Victorian students who were Visual, Aural, Read/Write, Kinesthetic and Multimodal (valid N=138)

It can be seen that there are similar patterns of distribution in the calculator preferences amongst students with various VARK preferences, in Singapore and Victoria. Methods (i) and (a), classified as kinesthetic and visual, had the highest percentages of students regardless of VARK preferences. There were more variability in the distribution of the Victorian students, because the number of responses was much smaller compared to Singaporean students ($N_{\text{Spore}} = 946$, $N_{\text{Vic}} = 138$); and there was only one Victorian student with kinesthetic only preference. Some indications of the alignment of VARK preferences and students' calculator preferences were seen, for example a much higher percentage of Singaporean students with Read/Write preference most preferred method (c) "look at calculator screen captures in notes, textbook and manual", compared to students with other VARK preferences. Overall this suggest that there was some association between students' VARK preferences and their calculator preferences, however the overwhelming responses demonstrated that students in both regions most preferred the kinesthetic method of trying out calculator steps at the same time as they see, listen or read the information on how to use the calculators.

4. Final Remarks

There were a few insights revealed by the results. One was that students' general VARK preferences might vary between cultures and regions. This is consistent with the characterization of information processing learning style models as being more malleable than stable [2]. Secondly, technology such as advanced calculators (GC and CAS calculators) might lend themselves more to visual and kinesthetic approaches of teaching and learning. Students in the study seemed to have adapted their modality preferences to the learning situation with technology, preferring to watch a teacher demonstration and to try out the steps on the calculator as they received information about its use, regardless of their general VARK preferences. This was seen in both regions, and especially significant considering the large dataset of 964 Singaporean students. The implication for researchers and educators intending to use learning style models in their course design is that they need to consider the influence of the learning environment and instructional context on students' style preferences. Designing instruction to match students' particular learning styles might not be a fruitful endeavor since students adapt to the new context. Their most preferred learning styles in the new context might not be consistent with their 'original' learning styles, as seen in this study. This could be a reason why matching experiments might not be successful [11]. Future directions for research could be on how students' learning styles change over time and context, on how teachers' instructional preferences might affect students' own learning preferences, and on investigating the effects of applying learning styles in educational contexts to improve learning.

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