Design and Study of the Instrument to Assess Students' Attitude toward Graphing Calculator

Nataliya Reznichenko

February 2007

Abstract

Assumptions: In mathematics learning, one of the considerations in the graphing calculator (GC) use is to understand students' attitude toward calculators.
Rationale: This presentation describes design of an assessment instrument of students' attitude toward graphing calculator.
Objectives: A pilot study that assessed the effectiveness of the developed instrument was conducted in the Developmental Mathematics classes at CCBC-Essex, MD.
Theoretical framework: As a powerful tool, GC are becoming common in mathematics classrooms at all levels (Dick, 1992). Ellington (2003) conducted a meta-analysis of findings from 54 research studies on calculator use in pre-college mathematics classes. She used additional category for analysis that was not included in previous studies. This category was students' attitude toward the use of calculators in mathematics.
Techniques: The instrument being developed is the Attitudes to Graphing Calculators (GC) in Mathematics Learning Questionnaire. The best instrument should provide both validity and reliability. In the pilot study that assesses the reliability of the developed instrument, the instrument was administered to a convenience group of 17 students-volunteers of the Developmental Mathematics classes at CCBC-Essex, MD.
Results: To calculate statistics for the collected data I've used the CORR procedure from the SAS package (Delwiche & Slaughter, 2004). Reliability indices for all of the measures were calculated using Cronbach's alpha internal consistency coefficient.
Conclusions: Based on the positive results of the pilot study, it can be concluded that developed instrument has good internal consistency reliability. Developed instrument can be used to examine the attitudes toward GC in mathematics learning.
Summary: In mathematics learning, one of the considerations in the graphing calculator (GC) use is to understand students' attitude toward calculators. This presentation describes design of an assessment instrument of students' attitude toward GC. A pilot study that assessed the effectiveness of the developed instrument was conducted in the Developmental Mathematics classes at CCBC-Essex, MD. Positive result is presented.

Justification of the Instrument

Today, electronic technology (ET) is widely used in the teaching and learning of mathematics. In the Principles and Standards for School Mathematics, the National Council of Teachers of Mathematics (NCTM, 2000) noted that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p. 24). A position statement of NCTM on the use of calculators strongly urged that calculator usage be promoted by school districts, teachers at every level, authors, and educators (NCTM, 1998). In view of NCTM’s position on ET use, educators and researchers need to answer the following questions: (1) How ET in mathematics teaching and learning is being used? (2) How the process of mathematics learning with ET occurs? (3) What effects it has on the learning outcomes? One of the considerations in the calculator use is to understand students’ attitude toward calculators. This paper describes design of an instrument to assess students’ attitude toward calculator use in mathematics learning. Also, it presents the results of a pilot study that assessed the effectiveness of the developed instrument.

The Role of Graphing Technology

One of the modern types of calculators is the graphing calculators (GC). Algebraic graphing tools transform data from either tabular or equation format into graphic representation. As a powerful tool, the GC is becoming common in mathematics classrooms at all levels (Dick, 1992).

The use of the GC was specifically supported by the NCTM in Curriculum and Evaluation Standards (NCTM, 1989). NCTM recommended that GC should be used to facilitate students’ understanding of functions by a multiple representation approach to functions. The multiple representation approach to functions can be reached by using tables, graphs, symbolic expressions, and real-world modeling that are featured in GC.

The literature suggests that GC improves problem solving skills (Dick, 1992). According to Dick, the following are some examples of how graphing technology assists with problem solving: (1) GC frees up time for instruction by reducing attention to algebraic manipulation; (2) GC supplies more tools for problem solving especially useful for students with weaker algebraic skill; (3) with GC, when students are free from numerical and algebraic computations, they perceive problem solving differently to concentrate on problem set up and on analyzing solutions. By carrying out complicated mathematical tasks, GC allows students to spend more time working with mathematical problems at a higher cognitive level. When used effectively, it becomes a tool to help students actively construct their own knowledge bases and skill sets. In the student-centered learning environment, GC encourages students to reflect on and involve not just their own ideas, but those of their peers as well (Dick, 1992).

Ellington (2003) conducted a meta-analysis of findings from 54 research studies on calculator use in precollege mathematics classes. In this meta-analysis, Ellington presented the following conclusion on the calculator use in instruction and assessment: operational, computational, conceptual, and problem-solving skills were improved. According to Ellington, general problem-solving skills include two aspects: (1) the number of problems attempted as the result of having access to a calculator during instruction; (2) the ability to select the appropriate problem-solving strategy.

GC allow student learning to occur at a higher cognitive level and serves to facilitate inquiries, explorations, and problem-solving activities. GC can be use in the different ways: (1) as a tool for the symbolic manipulation or graphical display of mathematical functions and equations; (2) as a facility for the collection, examination and analysis of data; (3) as a tool to foster collaborative learning and teach students to work as a team; (4) as a tool to aid in solving realistic problems that enables the student to concentrate on problem aspects and interpretation rather than computational aspects; (5) as a tool to discover, visualize, or investigate mathematical theories.

Construct Identification

Ellington (2003) analyzes student attitudes toward mathematics. Ellington identifies student attitude toward mathematics and student achievement as the two constructs that were involved in the calculator-based studies over the last 30 years the most. These two constructs were also featured in the first meta-analysis on the calculators and writing by Hembree and Dessart (1986). Six categories of attitude, developed through the Minnesota Research and Evaluation Project included in the Mathematics Attitude Inventory (Sandman, 1980), were outlined by Ellington (2003) as the following: (1) attitude toward mathematics; (2) anxiety toward mathematics; (3) self-concept in mathematics; (4) motivation to increase mathematical knowledge; (5) perception of mathematics teachers; (6) value of mathematics in society. According to Ellington, most studies involved only the first category—attitude toward mathematics.

Ellington (2003) also points at the use of other attitude measures like the scales developed by Aiken (1974) and Fennema and Sherman (1976). These instruments provided results related to the other five categories. The additional category that was not included before but was used by Ellington is the category of students’ attitude toward the use of calculators in mathematics.

Concept and Definition of Attitude

Attitude is an important concept in social sciences that helps us to understand people's reaction to an object or change in their behavior (Allport, 1966). This reaction can be positive or negative. Attitude is also a factor in predicting human behavior that predicts how behavior can be influenced (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980).

A definition of attitude given by Gall, Borg, and Gall (2003) is "an individual's viewpoint or disposition toward a particular 'object' (a person, a thing, an idea, etc.)" (p. 273). Gall et al. state three components of attitudes as the following: (1) affective—includes the feelings about the attitude object; (2) cognitive— includes the beliefs or knowledge about the attitude object; and (3) behavioral— includes the predisposition to act toward the attitude object in a particular way.

Description of the Instrument

I have designed the instrument to assess students' attitudes toward the use of GC in mathematics learning. It was developed to assess students' attitudes to the capabilities of GC to enhance understanding and learning of mathematical concepts and theories. Particular attention was given to explorations and scientific visualizations to ensure that GC plays a pivotal role in reaching the learning outcomes.

According to Gall et al. (2003), the following scales can be used for measurement of attitudes: (1) Thurstone—expresses the agreement or disagreement with a series of statements about the attitude object; (2) Likert—checks the level of agreement (e. g., strongly agree, agree, neutral, disagree, or strongly disagree) with various statements; (3)

semantic differential—presents a series of bipolar adjectives (e.g., fair-unfair, valuable-worthless, good-bad, and so on).

Survey studies in the form of questionnaires have the power to obtain information from large samples. They also permit the measurement of educational variables as well as the relationship among them (Gall et al., 2003). Researchers extensively use questionnaires to identify and characterize attitudes toward technology (Kay, 1989, 1990; Forgaty, Cretchley, Harman, Ellerton, & Konki, 2001). Unlike existing scales that contain separate measures of attitudes toward mathematics and technology (e.g. computers), the developed instrument assesses students' attitude when they are using a graphing calculator (GC) to learn mathematics.

The instrument being developed is the Attitudes to Graphing Calculators (GC) in Mathematics Learning Questionnaire. It is a survey questionnaire made up of 23 items (Appendix A). The proposed instrument measures attitude from the subscales of cognitive and affective components. Cognitive attitude refers to beliefs or knowledge about GC and its capabilities. Affective attitude refers to feelings about GC. A Likert scale questionnaire is used to measure students' cognitive and affective attitudes when using GC in mathematics learning. All items use a 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree).

Cognitive component includes the students' tool competency and the value or usefulness the students attribute to the GC. The affective component addresses enjoyment using a GC or anxiety in using a GC. The tool competency refers to the required skills in using GC. Value or usefulness refers to whether the students viewed GC as a helpful tool in learning mathematics, in their daily activities, and for their careers. Enjoyment refers to whether students liked using GC during mathematics activities or not. Anxiety refers to whether students worried when using GC in mathematics activities.

The first eleven items of the instrument were adapted from the “Maths-Tech” (mathematics/technology) scale of the Attitudes to Technology in Mathematics Learning Questionnaire (shortened to MTech), an instrument developed and validated by Fogarty et al. (2001). Fogarty et al. (2001) reported internal consistency reliability with Cronbach’s coefficient alpha value of 0.90 for this scale, which is higher than the benchmark value of 0.70 (Nunnally & Bernstein, 1994).

The items in the instrument are divided into four groups. The first two groups measure cognitive attitudes including GC competency (items 1 to 11) and usefulness of GC (items 12 to 15). The second two groups measure the affective attitudes including enjoyment of using GC (items 16 to 19) and anxiety in using GC (items 20 to 23). Items 1, 7, 8, 9, 11, 16, 17, 18, 19 explore students’ positive attitudes. Items 2, 3, 4, 5, 6, 10, 12, 13, 14, 15, 20, 21, 22, 23) explore students’ negative attitudes.

Validity and Reliability of the Instrument

Determining Validity of the Instrument

In the statistical sense, validity and reliability are criteria for assessing the quality of the data collected. An instrument may produce valid data that is not necessarily reliable and vice versa. The best instrument should provide both validity and reliability.

The reference work on validity and reliability are the Standards for Educational and Psychological Testing. They are written by members of American Educational Research Association, American Psychological Association, and National Council on Measurement in Education and referred to as the Standards (APA/AERA/NCME, 1999).

Validity is defined in the Standards as “the degree to which evidence and theory support the interpretation of test scores entailed by proposed uses of tests” (p. 9). *Validity* means the instrument accurately measures what it supposes to measure. There is a need to discuss construct validity, i.e. to what extent does the instrument actually measure the construct that it is intended to measure.

The discussion of the instrument validity is based on validation of the attitude scales assessed by Fogarty et al. (2001). According to Fogarty et al., to determine the factorial validity of the scales, researchers have used data screening, principal axis factoring with oblique (oblimin) rotation with a three-factor solution requested. It can be concluded from their report that, as a part of their instrument, the “Maths-Tech” scale (i.e. the scale of general confidence in using technology to learn mathematics) is the construct that is valid with good internal consistency reliability. Based on the validation of this scale, the researcher concluded the validity of the presented instrument.

Determining Reliability of the Instrument

Reliability is defined in the Standards (APA/AERA/NCME) as “...the consistency of…measurement when the testing procedure is repeated on a population of individuals or groups” (p.25). *Reliability* means that the instrument generates consistent results over time.

In statistical interpretation, reliability is the extent to which measurement error is present in the results of the instrument (Oppenheim, 1992). Some of the error in measurement can be systematic. There might be problems if participants selecting socially acceptable responses on self-report measures such as attitude scales.

Respondents may be giving socially acceptable answers to the questions rather than revealing their own attitude.

The reliability of a questionnaire is the ability to give the same results when filled out by like-minded people in similar circumstances. Internal consistency gives the reliability of a measure on its own. It means how well items of the instrument relate to the rest of the items of the instrument. It is usually expressed as a correlation coefficient, for instance, Cronbach's alpha.

Cronbach's alpha is the most common measure of reliability. It is estimated from the consistency (i.e. how consistent responses are) of all items in the scale. It can vary between 0 and 1; the closer to 1 it is, the more reliable is the scale. Although there is no set rule, an alpha of .7 or above can be said to indicate acceptable reliability (Nunnally & Bernstein, 1994).

For the "Maths-Tech" scale that is used in the instrument, Fogarty et al. (2001) reported internal consistency reliability with Cronbach's coefficient alpha value of 0.90, which is higher than the benchmark value of 0.7. Based on this number, the researcher expected also good reliability for the presented instrument.

Pilot Study to Check Reliability of the Instrument

The aim of this part is describe a pilot study that assesses the effectiveness of the developed instrument. In the pilot study, the developed instrument was administered to a convenience group of former high-school graduates who was familiar with working with GC in the high-school mathematics classes. The participants were 17 students at the Community College Baltimore County (CCBC) Essex enrolled in the two morning classes in the course Intermediate Algebra in the Spring semester of 2005. Demographic data were not collected because of the time limit. Participation in survey was voluntarily.

Reverse coding was used for any positively worded items. For positively worded items, the scoring is the following: 1=5, 2=4, 3=3, 4=2, 5=1. For negatively worded items, the scoring is 1=1, 2=2, 3=3, 4=4, 5=5.

To calculate statistics for the collected data I've used the CORR procedure from the SAS package (Delwiche & Slaughter, 2004). Reliability indices for all of the measures were calculated using Cronbach's alpha internal consistency coefficient. The responses to the instrument allow considering the effectiveness of each item and selecting most effective items for inclusion in the scale. At the first step of the analysis of the responses, there is a need to identify items with which most respondents agree or disagree. These items don't help to differentiate respondents' results. Criterion for identification of these items would be their means and standard deviations. Items with extreme means and very low variances will be eliminated (Oppenheim, 1992).

Conducting the first step of the analysis of the data, I've observed that the means of the items have ranged from 2.64706 for the item 12 to 4.00000 for the items 21 and 23. The lowest standard deviation 0.85749 was observed for the item 2. Since there were no extreme value of means and very low standard deviations, I decided not eliminate the items based on this criterion.

At the second step of the analysis, internally consistent items were analyzed. The items in the scale are required to measure the attitude of the interest with as little error as possible. Therefore, the items which do not seem to relate to the total score for the questionnaire should be discarded. Criteria for this are the following statistics: 'item-total correlations' and 'alpha if item deleted' (Oppenheim, 1992).

> 'Item-total correlations' express how closely each item is related to all of the other items put together. A low correlation indicates weak relationship. Therefore, the item with low correlation is not measuring the same thing as the rest of the scale, and should be discarded. 'Alpha if item deleted' relates to Cronbach's alpha. The closer Cronbach's alpha is to 1, the better the reliability of the scale. If alpha would increase if a particular item was deleted, the item is considered to be removed from the scale (Oppenheim, 1992).

The data were analyzed for the correlations to identify the items with low or negative correlations. The items with negative correlations were not identified. The item 2 has the lowest correlation 0.272924. Since Cronbach's alpha for the instrument was indicated at the high value 0.93, I've decided not delete item 2.

To check internal consistency of the items within the cognitive attitude group--scale A and the affective attitude group--scale B, I've run the CORR procedure for these two groups separately. The result of Cronbach's alpha was indicated high for the both scales—0.91 and 0.87 for A and B correspondingly.

Based on the presented results of the pilot study, it can be concluded that developed instrument has good internal consistency reliability. It can be used to examine the attitudes toward GC in mathematics learning.

References

Aiken, L. (1974). Two scales of attitude toward mathematics. *Journal of Research in Mathematics Education, 5,* 67-71.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. London: Prentice-Hall.

Allport, G. W. (1966). Attitudes in the history of social psychology. In Jahoda, M. and Warren, N. (Eds). *Attitudes: Selected readings.* England: Penguin Books Limited.

American Educational Research Association, American Psychological Association, and National Council on Measurement in Education. (1999). Standards for educational and psychological testing. Washington, DC. Author.

Delwiche, L. D., & Slaughter, S. J. (2004). *The little SAS book: A primer (3rd ed.).* Cary, NC: SAS Institute Inc.

Dick, T. (1992). Symbolic-graphical calculators: Teaching tools for mathematics. *School Science and Mathematics, 92*, 1-5.

Ellington, A. J. (2003). A meta-analysis of the effects of calculators on students' achievement and attitude levels in pre-college mathematics classes. *Journal of Research in Mathematics Education, 34(5),* 433-463.

Fennema, E. & Sherman, J. (1976). Mathematics attitude scales: Instruments designed to measure attitudes towardthe learning of mathematics by males and females. *Journal of Research in Mathematics Education, 7,* 324-326.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* London: Addison-Wesley Publishing Company.

Forgaty, G., Cretchley, P., Harman, C., Ellerton, N., & Konki, N. (2001). Validation of a questionnaire to measure mathematics confidence, computer confidence, and attitudes towards the use of technology for learning mathematics. *Mathematics Education Research Journal, 13(2),* 154-160.

Gall. M. D, Borg, W. R. & Gall, J. P. (2003). *Educational research: An introduction (7th ed.).* White Plains, NY: Longman Publisher.

Hembree, R. & Dessart, D. J. (1986). Effects of hand-hald calculators in precollege mathematics education: A meta-analysis. *Journal for Research in Mathematics Education, 17(2),* 83-99.

Hembree, R. & Dessart, D. J. (1992). Research on calculators in mathematics education. In J. T. Fey (Ed.), *Calculators in mathematics education* (pp. 23-32). Reston, Virginia: NCTM.

Kay, R. H. (1989). A practical and theoretical approach to assessing computer attitudes: The computer attitude measure (CAM). *Journal of Research on Computing in Education, summer,* 456-463.

Kay, R. H. (1990). Predicting student teacher commitment to use of computers. *Journal of Educational Computing Research, 6(3),* 299-309.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards.* Reston, VA: NCTM.

National Council of Teachers of Mathematics (1998, reformatted 2002). Position statement: Calculators and the education of youth. Retrieved August 31, 2004 from URL

http://www.nctm.org/about/position_statements/position_statement_01.htm

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Nunnally, J. C., & Bernstein, J. H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.

Oppenheim, A. N. (1992). *Questionnaire Design, Interviewing and Attitude Measurement*. London: Pinter Publishers.

Sandman, R. S. (1980). The mathematics attitude inventory: Instrument and user's manual. *Journal of Research in Mathematics Education*, *11*, 148-149.

Appendix A

Attitudes to graphing calculators (GC) in mathematics learning questionnaire

The following statements refer to the way you feel about GC in learning of mathematics. Choose one from the following five-point scale:

1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree.

#	Question	1	2	3	4	5
1	Computing power makes it easier to explore mathematical ideas					
2	I know GC is important but I don’t feel I need to use it to learn mathematics					
3	GC is good tools for calculation, but not for my learning of mathematics					
4	I think using GC is too new and strange to make it worthwhile for learning mathematics					
5	I think using GC wastes too much time in the learning of mathematics					
6	I prefer to do all the calculations and graphing myself, without using GC					
7	Using GC for the calculations makes it easier for me to do more realistic applications					
8	I like the idea of exploring mathematical methods and ideas using GC					
9	I want to get better at using GC to help me with mathematics					
10	The symbols and language of mathematics are bad enough already without the addition of GC					
11	Having GC to do routine work makes me more likely to try different methods and approaches					
12	I don’t have any use for GC on a day to day basis					
13	I don’t think GC will be useful to me in my future job					
14	Anything that GC can be used for, I can do just as well some other way					
15	I don’t see how GC can help me to learn some new skills					
16	I enjoy using GC in mathematics activities					
17	GC is interesting, fascinating and easy to use					
18	I enjoy investigating mathematics problems using GC					
19	GC is very interesting and challenging to use					
20	I don’t feel comfortable when I learn mathematics using GC					
21	The thought of using GC in mathematics activities frightens me					
22	I am worried about using GC because I do not know what to do if something goes wrong					
23	The use of GC confuses me					