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Pre-service Teachers' Beliefs Regarding Inquiry Learning and the Use of Graphing Calculators

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Abstract: The purpose of this study was to examine the beliefs of preservice teachers at various stages in their undergraduate middle childhood mathematics education program regarding the learning and teaching of mathematics by inquiry and the use of graphing calculators as a facilitator of such learning. Data were collected from approximately 80% (*n* = 95) of the middle childhood mathematics education preservice teachers who were enrolled in a mathematics content or mathematics methods course during the spring of 2003 in a Midwestern university in the United States. Of this number, a stratified random sample of 65 preservice teachers (13 each in five subgroups) was selected to represent the number of combinations of mathematics content and mathematics methods courses in which a preservice teacher might be currently or previously enrolled as well as five different stages of cohort (i.e., groups of preservice teachers who take certain courses at the same time during their undergraduate study) scenarios.

Analysis of data from the two-part questionnaire yielded some interesting information about the beliefs and attitudes of the preservice teachers regarding inquiry learning, use of graphing calculators, and other related variables. For influence of number of inquiry mathematics courses, there were statistically significant differences for the beliefs about use of graphing calculators $F(4, 64) = 4.674, p < .01$. However, Tukey HSD results indicated that the significant differences are found between those preservice teachers who had two courses $(MD = -16.62, p = .003)$, or three courses $(MD = -14.62, p = .011)$, compared to those with six courses. There was also a statistically significant difference for influence of type of professor (methods or content) that the preservice teachers held most responsible for helping them both to know how to use the graphing calculators and how to use them in the classroom, $F(4, 64) = 13.864, p<.0001$. Tukey HSD results indicated that the significant differences held for six of the 10 possible comparisons: comparing those with two and five courses $(MD = -3.85, p = .005)$; and those with two courses and six courses $(MD = -7.00, p< .001)$.

Introduction

The National Council of Teachers of Mathematics confirmed its support for appropriate use of calculators in the mathematics classroom for students of Grades K-12 more than ten years ago (NCTM, 1989, pp. 19, 124) by stating that calculators should be "available to all students at all times" (p. 124). Although that statement does not speak specifically about graphing calculators, a later NCTM position (NCTM, 2000) might lead one to believe that this statement is also true of graphing calculators for upper grades (Grades 9-12) and perhaps certain grades during the middle childhood years. While many mathematics educators proposed that the appropriate use of calculators might enhance student learning and make mathematics more accessible to previously disenfranchise students, there was and still remains some opposition to these claims.

Perhaps much of the opposition shortly after the release of the 1989 Standards was due to a misunderstanding of the phrase "available … at all times" (NCTM, 1989, p. 124). Many opponents seemed to believe some of the myths of calculator usage and were concerned that students might *use* calculators all of the time, ignoring their own ability to solve these problems without technology (Pomerantz, 1997). Fear that students would become too reliant upon the technology and thus become mathematically disabled as well as disenfranchised in the learning process was among some of the concerns cited by 37% of the secondary teachers (n = 27) in a study reported by Simonsen and Dick (1997). However, these scenarios are not supported in the intent of the NCTM Standards. The goal for appropriate use of technology implies that students should become adept at determining when the use of technology will be most appropriate.

The appearance of a principle for technology in the *Principles and Standards of School Mathematics* (NCTM, 2000) affirms, "technology is essential in teaching and learning mathematics" (p. 11). Of the many published studies since the 1989 NCTM Standards that have investigated various variables related to the teaching and learning of mathematics with technology—particularly graphing calculators—the findings typically support appropriate calculator usage (Allison, 2000; Blume & Heckman, 1997; Brawner, 2001; Ellington, 2000; Graham & Thomas, 2000; Harskamp, Suhre, & Van Streun, 2000). Results of these and similar studies tend to be associated with better student achievement scores; decreased or no gender/ethnic differences in academic performance; better understanding of numbers, variables, functions, algebraic reasoning and problem solving; and improved student attitudes toward mathematics. Other studies also investigated links among graphing calculators and teacher and student attitudes (Chamblee, 1996; Merriweather & Tharp, 1999; Myers, 1999; Rosenberg, 1996); instructional methods used when teaching with graphing calculators (Smith, 1998); and frequency of computer usage (Nath, 1995).

Although the percentage of students who use calculator technology in the high schools tends to be as high as 80% (Texas Instruments, 2002), the usage during the middle school and elementary grades tends to be much lower (Dunham, 1999). Accepting the premise that calculator use holds great potential for all school children it seems strange that this potential has not been more fully realized after more than 10 years of increased availability of calculators. "Their role in mathematics instruction has not reached the level of NCTM's goals stated … [in the 1989 NCTM Standards]" (Dunham, 1999, p. 3-23). Perhaps the notion that "the effective use of technology in the mathematics classroom depends on the teacher" (NCTM, 2000, p. 25) leads to a vital source of this paradox. Teachers cite the need for continuous and effective professional development to help them feel comfortable with the use of graphing calculators in the class (Tharp, Fitzsimmons, & Ayers, 1997; Simonsen & Dick, 1997).

This researcher desired to look more closely at the role, experiences, and related contexts of the preservice teacher (and of the inservice teacher as the longitudinal study follows into the entry years). Responding to calls for future research as identified in two Texas Instruments research documents, this paper addresses the following questions regarding preservice teacher beliefs and experiences related to the use of graphing calculators and learning mathematics by inquiry:

1. How do preservice teachers' beliefs about inquiry learning and use of graphing calculators relate to their frequency of use of graphing calculators in their mathematics learning (and eventually their teaching)?

   Specifically: How is the number of inquiry-based or "inquiry-rich" college mathematics content, mathematics education, and mathematics methods classes taken during the preservice years related to

   a. The frequency of graphing calculator use during the preservice years
   b. Beliefs about learning mathematics by inquiry
   c. Beliefs about use of graphing calculators to support learning of mathematics?
2. What other variables related to middle school mathematics preservice teachers beliefs and attitudes about inquiry learning and use of graphing calculators may be associated with frequency of graphing calculator usage and positive beliefs about learning mathematics by inquiry?

Highlights of Procedure

Survey items were taken from salient points made in the literature as well as survey questions of previous studies (Simonsen & Dick, 1997; Heflich, Dixon, & Davis, 2001; Tharp, Fitzsimmons, & Ayers, 1997; Forster & Taylor, 2000; Fey & Sinith, 1999; Nicol, 1999; Damnjanovic, 1999). A reliability coefficient was calculated for this composite survey. Survey questions were grouped together to form composite variables to identify beliefs that may be closely associated with characteristics of inquiry learning (inquiry), traditional learning/teaching (non-inquiry), use of graphing calculators (pro- or con-graphing calculators), graphing calculator procedures, teacher efficacy, and the roles of college content professors and mathematics methods professors regarding support for use of graphing calculators. In the future (for longitudinal analysis), the researcher will analyze changes in beliefs, and a randomly chosen subset of this group will be selected for personal interviews to follow-up on written survey responses.

Highlights of Results

With regards to frequency of graphing calculator usage, the strongest relationship (between inquiry oriented respondents and pro-graphing calculator respondents) only accounted for approximately 14% of the variance among the variables. In other cases, frequency of graphing calculator usage basically had a small negative effect (accounting for at most 4.4% of the values) on inquiry orientation or positive usage of the graphing calculator. The results seem to provide a mixed view on preferences for inquiry learning or the more traditional teaching/learning experience. Responses also show a strong tendency for a preference for one-on-one interaction with the teacher, either listening to the teacher explain or having the teacher personally explain the answer to a question (Part I, survey items 7 and 11). Results also indicated a stronger preference for exploring a concept after the teacher has given a formal introduction ($\bar{x}$ = 3.062) rather than exploring before ($\bar{x}$ = 2.077). These results seem consistent with the overall mean results of 2.864 *(SD = 0.369)* for a preference for inquiry classes compared to a mean result of 2.649 *(SD = 0.463)* for a non-inquiry class preference.

An analysis of these results by groups (based upon the number of mathematics courses taken or currently enrolled in at the time of the survey) as shown in Table 1 indicate there were statistically significant differences with regards to inquiry (both as a preference for learning and as related to experiences in the classroom with and without a graphing calculator) between the responses of students who have taken two or three mathematics courses and those who have taken six math courses, and between those who have taken two courses and those who have taken four courses. Figure 1 shows the comparisons for which statistically significant differences were obtained.

Table 1

Comparison of Mean Values By Groups (Number of Mathematics Classes Taken)

Source	*SS*	*df*	*MS*	*F*
Inquiry:				
Between Groups	2283.631	4	570.980	4.674**
Within Groups	7329.385	60	122.156	
Total	9613.015	64		
Methods or Content Professors:				
Between Groups	402.985	4	100.746	13.864*
Within Groups	436.000	60	7.267	

Total	838.985	64

**p < .0001, **p < .01*

For influence of number of inquiry mathematics courses, there were statistically significant differences for the beliefs about use of graphing calculators $F(4, 64) = 4.674, p < .01$. Tukey HSD results indicated that the significant differences were between those preservice teachers who had two courses *(MD = -16.62, p < .01)* or three courses *(MD = -14.62, p< .05)*, compared to those with six courses. There were also statistically significant differences for influence of type of professor (methods or content) that the preservice teachers held most responsible for helping them both to know how to use the graphing calculators and how to use them in the classroom, $F(4, 64) = 13.864, p <.0001$. Tukey HSD results indicated that the significant differences held for six of the 10 possible comparisons: comparing those with two (Math2) and five (Math5) courses *(MD = -3.85, p < .01)*; and those with two (Math2) and six (Math6) courses *(MD = -7.00, p < .001)*.

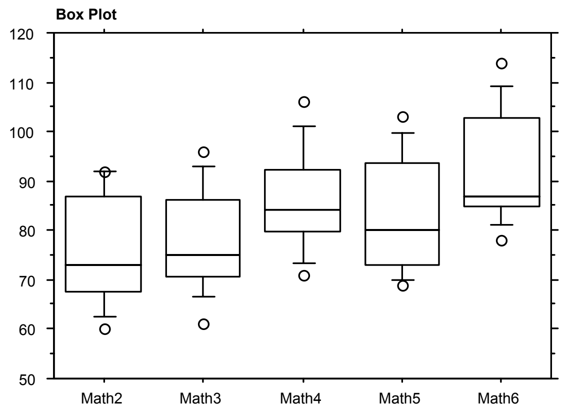

Figure 1. Group Survey Ratings with Regards to Mathematical Inquiry
(Note: Math*N* represent *N* (Numbers) of Math Courses Taken)

There were no statistically significant differences among the groups with regard to preferences for non-inquiry mathematics teaching and learning. Survey results regarding beliefs about graphing calculators and the role of graphing calculators for preference in learning mathematics indicated that the middle childhood majors did not have a particularly positive view of use of graphing calculators. More students indicated they did not prefer to learn a concept that is taught first using a graphing calculator, or taught while using a graphing calculator.

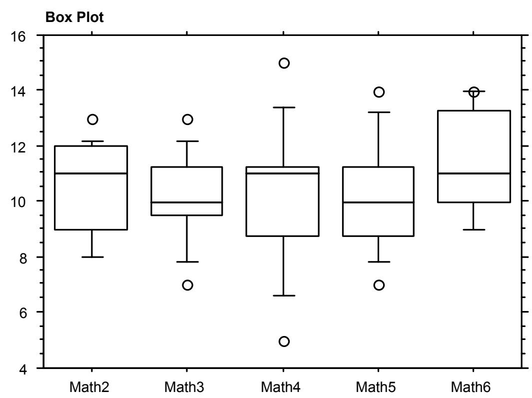

Figure 2. Beliefs Regarding Proper Graphing Calculator Procedures

Regarding beliefs about proper graphing calculator procedures, there were statistically significant differences between the groups of preservice teachers who had taken three math courses (Math3) and those who had taken six math courses (Math6) ($t = -2.497$, $p < .05$l, $\bar{x}_{\text{Math3}} = 10.231$, $SD_{\text{Math3}}=1.739$; $\bar{x}_{\text{Math6}}=11.538$, $SD_{\text{Math6}}=1.808$).

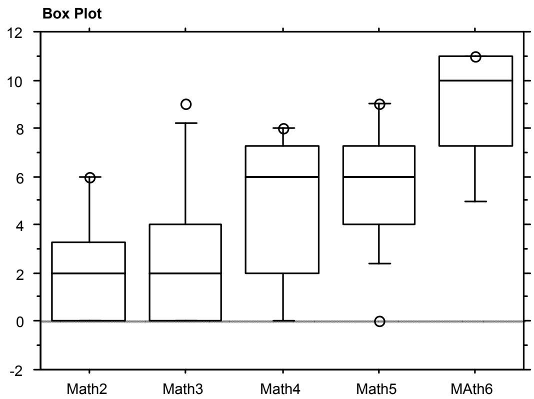

Figure 3. Beliefs Regarding the Roles of Methods Professors

With slightly less than half of the participants using their graphing calculators very often, the program should consider that there are missed opportunities for preservice teachers to build a better understanding of mathematics, to recognize that use of graphing calculators supports inquiry-based learning, and to "build confidence in their abilities to use and teach with graphing calculators" (Tharp, Fitzsimmons, Ayers, 2000, p. 555). Survey items in Part II showed that although almost 97% of the preservice teachers own their own graphing calculator, however, only 66% of them used their graphing calculators during their calculus class (perhaps building on high school skills during the freshmen year). The percentage was reduced to approximately 50% for most other content courses, and almost 25% in the mathematics methods class.

Conclusions, Limitations, and Implications

There are indications that frequency of graphing calculator use (including the number of years of experience using the graphing calculator) is related to teachers' attitudes regarding calculator use (Chamblee, 1996). However, a frequent misconception is that students can figure out which keys to press without direct instruction or that direct instruction should indicate the key presses, while ignoring the reasoning that supports those presses (Giamati, 1990). Perhaps frequency of use will improve when students are led to use the features of the graphing calculator through inquiry methods that are supported by reasoning about the key presses as well as the results obtained.

One may posit that much of the professional development for inservice teachers today regarding the use of graphing calculators is needed because they were not able to get the necessary support during their undergraduate programs. In particular, they did not get the support necessary to implement efficient graphing calculator use in the classroom. Attitudes about graphing calculators can lead to increased use of them in the classroom and, eventually, to gains in student achievement.

This study will continue to investigate beliefs of new students entering the program, and changes in beliefs over time as they progress toward their first two years of teaching. The numbers of participants in the subgroups will be increased to support more robust statistical analysis. However, it seems clear that some additional specific instruction and specific plans are needed to incorporate the efficient use of graphing calculators (and other technology) in the college mathematics classrooms taken by our middle childhood education majors. Classes taught by inquiry might also spend some reflection time debriefing the inquiry experience compared to a non-inquiry approach and discussing the benefits of using the graphing calculator to support that learning. The questions on this survey could be revised to obtain more information about the specific types of graphing calculator use are being suggested. Using the graphing calculator merely as a scientific calculator—though commendable—will not give the preservice teachers the experience they need in developing and analyzing graphs and data on the graphing calculator.

Selected References

Blume, G. W., & Heckman, D. S. (1997). Chapter 9: "What do students know about algebra and functions?" In Kenney, P. A., & silver, E. A. Eds. Results from the Sixth Mathematics Assessment of the National Assessment of Educational Progress. *ERIC Educational Document, ED* 409 172

Damnjanovic, A. (1999). Attitudes toward inquiry-based teaching: Differences between preservice and in-service teachers. *School Science and Mathematics, 99*(2), 71-76.

Dunham, P. H. (1999). Hand-held calculators in mathematics education: A research perspective.

Ellington, A. J. (2000). Effects of hand-held calculators on pre-college students in math classes: a meta-analysis. *Dissertation Abstracts International, DAI*, AAT 9996347.

Fey, M. H., & Smith, C. F. (1999). Opening spaces for collaboration and inquiry in teaching education classrooms: The place of resistance. *Action in Teacher Education, 21*(3), 102-110.

Forster, P. A., & Taylor, P. C. (2000). A multiple-perspective analysis of learning in the presence of technology. *Educational Studies in Mathematics, 42*, 35-59.

Graham, A. T., & Thomas, M. O. (2000). Building a versatile understanding of algebraic variables with a graphic calculator. *Educational Studies in Mathematics, 41*(3), 265-82.

Harskamp, E.G., Suhre, C. J. M., & Van Streun, A. (2000). The graphics calculator and students' solution strategies. *Mathematics Education Research Journal, 12*(1), 37-52.

Heflich, D.A., Dixon, J. K., & Davis, K. S. (2001). Taking it to the field: The authentic integration of mathematics and technology in inquiry-based science instruction. *The Journal of Computers in Mathematics and Science Teaching, 20*(1), 99-112.

Merriweather, M., & Tharp, M. L. (1999). The effect of instruction with graphing calculators on how general mathematics students naturalistically solve algebraic problems. *Journal of Computers in Mathematics and Science Teaching, 18*(1), 7-22.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

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

Nicol, C. (1999). Learning to teach mathematics: Questioning, listening, and responding. *Educational Studies in Mathematics, 37*, 45-66.

Pomerantz, H. (1997). *The role of calculators in math education*. Research compiled under the direction of Bert Waits, Professor Emeritus, Department of Mathematics, Ohio State University, for the Urban Systemic Initiative/Comprehensive Partnership for Mathematics and Science Achievement (USI/CPMSA). Superintendents Forum, Dallas, Texas.

Simonsen, L. M., & Dick, T. P. (1997). Teachers' perceptions of the impact of graphing calculators in the mathematics classroom. *The Journal of Computers in Mathematics and Science, 16*(2-3), 239-68.

Tharp, M. L., Fitzsimmons, J. A., Ayers, R. L. B. (1997). Negotiating a technological shift: Teacher perception of the implementation of graphing calculators. *The Journal of Computers in Mathematics and Science, 16*(4), 551-75.

The McKenzie Group. (2002). *Handheld technology and student achievement: A collection of publications.* An Independent Study Conducted for Texas Instruments Incorporated, Austin, TX: Author.

Texas Instruments. (2002). *Handheld graphing technology in secondary mathematics: Research findings and implications for classroom practice.* Burrill, G., Director. Prepared through a grant to Michigan State University. Austin, TX: Author.