AN EXAMINATION OF THE INTEGRATION OF GRAPHING CALCULATORS
IN FORMAL ASSESSMENTS THAT ACCOMPANY
HIGH SCHOOL MATHEMATICS TEXTBOOKS

by

Kimberly Joy Graham

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APPROVAL

of a dissertation submitted by

Kimberly Joy Graham

This dissertation has been read by each member of the dissertation committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Maurice J. Burke

Approved for the Department of Mathematical Sciences

Kenneth L. Bowers

Approved for the College of Graduate Studies

Bruce McLeod
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Kimberly Joy Graham
April 14, 2005
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ABSTRACT

To support teachers in their efforts to integrate graphing calculator technology in the assessment of student learning, mathematics educators need to know the extent and the quality of graphing calculator usage in assessment materials that accompany published mathematics textbooks. If improved student understanding through the use of graphing calculators is a goal of the curriculum and if the use of graphing calculators as recommended by the *Principles and Standards* (NCTM, 2000) is truly valued, but graphing calculators are not integrated into assessments, then this fact demonstrates a lack of alignment of the curriculum. The researcher analyzed and compared the extent and quality of graphing calculator use in formal assessments that accompany three third-year textbooks used in NSF-funded curricula and that accompany seven Algebra 2 textbooks used in non-NSF-funded curricula. Quantitative data were collected using a rubric constructed by the researcher. The rubric was constructed based on Senk, Beckmann, and Thompson’s (1997) coding scheme and the recommendations of the *Principles and Standards* (NCTM, 2000). In addition, the researcher examined the use of graphing calculator technology in the textbooks’ instructional materials that support the formal assessments. The study demonstrated that the issue of analyzing and comparing curricula on the extent and quality of graphing calculator use in formal assessments is very complex with many factors involved. Results of the study raised many questions, including “What is meant by a Standards-based use of graphing calculators?” The researcher found differences in the extent and quality of graphing calculator use between the ten curricula examined. Regarding the use of graphing calculators, the goals and assessments were found to be in general alignment for the ten curricula. The extent and quality of graphing calculator use was also generally aligned between the textbooks and their formal assessments, with some inconsistencies associated with the quality of use.
CHAPTER 1

PROBLEM STATEMENT AND SIGNIFICANCE OF STUDY

Introduction

Calculator use in mathematics classrooms has grown significantly in the past 15 years. The 1989 National Assessment of Educational Progress (NAEP) study revealed that approximately 18% of eleventh-grade students reported using a calculator almost daily for classwork. In the 2000 NAEP study, based on a sample of twelfth graders, 68% of the students reported using a calculator almost every day for classwork, demonstrating substantial increase from 1989 in classroom use of technology. As additional evidence of the widespread use of calculators, a total of 87% of twelfth grade students said they always or sometimes used a scientific, graphing, or symbol manipulator calculator for tests and quizzes (NAEP, 2000). Sixty-two percent of these students reported that the calculator they used was a graphing calculator (NAEP, 2000). In light of the prevalent usage of graphing calculators, the current study investigated the extent and quality of graphing calculator use in formal assessment materials that accompany published mathematics textbooks, using the recommendations of the National Council of Teachers of Mathematics’ (NCTM) Principles and Standards for School Mathematics (PSSM) (2000) as a framework.
Assessment and Graphing Calculators

Graphing calculators can facilitate a variety of assessment techniques (Adams, 1997) and enable alternate solution methods (Forster & Mueller, 2002; Harvey, 1992). However, research that has analyzed questions given on tests where calculators were allowed indicates an emphasis on the assessment of lower-order thinking skills. One study in particular, conducted by Senk, Beckmann, and Thompson (1997), used a coding scheme based on the Standards (1989) to examine test items, including the nature of calculator use in test items. In an investigation of teacher-constructed tests, Senk and her colleagues found that the vast majority of the test items were low level, and neutral or inactive with respect to the use of calculator technology.

Researchers have also examined published assessments in terms of national standards. Studies have shown that some widely used assessments in K-12 mathematics fail to reflect recommendations of national standards. In an examination of six standardized eighth grade mathematics tests, for instance, Romberg, Wilson, Khaketla, and Chavarria (1992) showed that test items did not well represent the NCTM’s content and process standards. Moreover, the researchers found that test items were predominantly procedural.

In 1990, the National Science Foundation (NSF) responded to a call for new curricular materials by funding curriculum development projects, including five projects at the secondary school level. Martin et al. (2001) evaluated five secondary mathematics textbook series funded by the NSF. Martin et al. found that each series well represented the expectations of the content and process standards of NCTM’s *PSSM* (2000). While several studies (Nicely, Jr., 1991; Taylor, 1991) have examined published assessments in
light of the *Curriculum and Evaluation Standards* (NCTM, 1989), few studies have examined the impact of the *PSSM* (NCTM, 2000) on published assessments. The lack of research on the influence of the *PSSM* (NCTM, 2000) is noteworthy because the *PSSM* (NCTM, 2000) represents an updated version of the 1989 *Standards* with respect to graphing calculator technology.

Graphing calculators represent a continuing area of development and innovation in mathematics education. Numerous studies have described the impact of the instructional use of graphing calculators on student learning (Drijvers & Doorman, 1996; Ellington, 2003; Harskamp, Suhre, & Van Streun, 2000; Penglase & Arnold, 1996, Wilson & Krapfl, 1994). Ellington’s (2003) meta-analysis of graphing calculator research revealed that calculators are most effective in the improvement of students’ operational and problem-solving skills when used in both instruction and testing. Harskamp, Suhre, and Van Streun (2000), found the performance of weaker students significantly increased due to graphing calculator use. Kutzler (2000) draws an analogy between cars and graphing calculator technology. Just as cars facilitate traveling longer distances, graphing calculators enable the study of more complex, more realistic problems. Graphing calculators are particularly valuable for the study of families of functions (Manouchehri & Pagnucco, 2000), including quadratic functions (Barrett & Goebel, 1990; Kutzler, 2000; Simmt, 1997; Taylor & Miitag, 2001) and logarithmic and exponential functions (Forster, 1998; Kennedy, Vasquez, & Huber, 2003; Lindsay, 2000, Smith & Shotsberger, 1997); transformation of functions (Choi-Koh, 2003; Fernandez, 2001); and modeling with functions (Barrett & Goebel, 1990; Ferrucci & Carter, 2003; Kennedy, Vasquez, & Huber, 2003; Manouchehri & Pagnucco, 2000).
With the growing use of calculators in the mathematics classroom and the proven benefits of calculator use, assessment in the presence of graphing calculators has become an increasingly important issue. Kissane (2000) raised questions related to the issue of how graphing calculators are being used in assessment. One key question Kissane asked was, “How can examinations be designed to ensure that mathematical thinking is paramount, rather than calculator use?” (2000, p.12). In other words, test items that require or allow for the use of graphing calculators should also require students to think beyond pushing the calculator’s buttons. In their analysis of the impact of graphing calculators on assessment in calculus, Anderson, Bloom, Mueller, and Pedler (1999) identified important student skills underlying effective graphing calculator use. The skills included student interpretation of graphical results and translation between graphical, symbolic, and numerical representations. The authors concluded that the necessity of these skills “require[s] a change in the tasks set to assess student achievement” (Anderson et al., 1999, p.498). In classrooms that utilize graphing calculators, assessments should incorporate problems focusing on thoughtful use of graphing calculators.

The NCTM’s *PSSM* (2000) provides recommendations for mathematics educators in the areas of assessment and technology. Although the *Standards* (1989, 2000) do not give specific recommendations with regard to formal assessments in the presence of graphing calculator technology, the *PSSM* (2000) supplies a framework of expectations on the general use of graphing calculators in the mathematics classroom. The framework provides guiding principles that can be used to examine the use of graphing calculators in formal assessments.
The existence of standards, however, does not ensure that classroom teachers are familiar with the standards (Cohen & Hill, 2000; Burian-Fitzgerald, McGrath, & Plisko, 2003). According to the 1999 Third International Mathematics and Science Study (TIMSS) study, less than half (40.2%) of public school eighth graders were taught by teachers who were “very familiar” with the NCTM Standards (Burian-Fitzgerald, McGrath, & Plisko, 2003). In mathematics classes where technology is present, it is the teacher’s responsibility to implement appropriate and effective student assessments. Teacher assessment practices depend largely on beliefs, experience, and curricular materials (Cronin-Jones, 1991; Doerr & Zangor, 2000, Hawthorne, 1992; Remillard, 1999). Teachers who are less familiar with the Standards will rely even more heavily on beliefs, experience, and curricular materials.

Textbooks

Textbooks are very influential in teacher curricular decisions (Eisner, 1987; Harpster, 1999; TIMSS, 1996). In particular, researchers have reported that publishers’ assessment materials that accompany the textbook have a strong impact on high school teacher assessment practices in the classroom (Taylor, 1991; Cooney, 1992; Madaus, West, Harmon, Lomax, & Viator, 1992; Senk et al., 1997). Using a random sample of 138 high school algebra and geometry teachers in Ohio, Taylor found that approximately 65% of the teachers used publisher-provided testing materials as a source for problems to include on teacher-constructed tests. Studies by Cooney (1992) and Madaus, West, Harmon, Lomax, & Viator (1992) reported that secondary teachers regularly use both unmodified tests provided by their textbook’s publisher and teacher-made tests. Teacher-
made tests were usually “close adaptations of textbook tests” (Madaus et al., 1992, p.15).
The majority of the high school teachers in Senk et al.’s (1997) study used publisher-provided tests either as a source for teacher-constructed tests or as the actual test. Thus, teachers often rely on textbook-published assessments, or they select questions directly from these materials to construct their own assessments.

Statement of the Problem

To support teachers’ efforts to integrate graphing calculator technology in the assessment of student learning, mathematics educators need to know the extent and the quality of graphing calculator usage in assessment materials that accompany published mathematics textbooks. If improved student understanding through the use of graphing calculators is a goal of the curriculum and if the use of graphing calculators as recommended by the PSSM (2000) is truly valued, but graphing calculators are not integrated into assessments, then there is a lack of alignment of the curriculum.

Purpose of the Study

The purpose of this study was to investigate the extent and quality of graphing calculator use in assessment materials that accompany published mathematics textbooks. Specifically, the study compared published, formal assessment materials used in NSF-funded integrated curricula to published, formal assessment materials used in non-NSF-funded curricula in terms of graphing calculator use. The basis for comparison of the formal assessment materials was a rubric constructed by the researcher. The rubric was based on a coding scheme developed by Senk, Beckmann, and Thompson (1997) and a
framework derived from the recommendations related to assessment and technology contained in the *PSSM’s* (NCTM, 2000) assessment principle, technology principle, and process standards.

The researcher identified quadratic, exponential, and logarithmic functions as three topical areas particularly amenable to the integration of graphing calculators. The sample of formal assessments was chosen from third-year textbooks of the NSF-funded curricula and from algebra 2 textbooks of the non-NSF-funded curricula, since these textbooks cover the topics of quadratic, exponential, and logarithmic functions.

**Research Questions**

1. To what extent do formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula incorporate graphing calculator technology? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of extent of graphing calculator use?

2. What is the quality of graphing calculator use in formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula, as measured by a rubric based on Senk, Beckmann, and Thompson’s (1997) coding scheme and the recommendations of the *Principles and Standards* (NCTM, 2000)? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of quality of graphing calculator use?
3. How do the textbooks mentioned in questions 1 and 2 make use of graphing calculator technology in the instructional materials that support their formal assessments? How do the textbooks from the NSF-funded curricula compare to the textbooks from the non-NSF-funded curricula in terms of graphing calculator use in the instructional materials that support their formal assessments?

**Definition of Terms**

**Alignment:** “The degree to which expectations and assessments are in agreement and serve in conjunction with one another to guide the system toward students learning what they are expected to know and do” (Webb, 2002, p.1).

**Assessment:** “The process of gathering evidence about a student’s knowledge of, ability to use, and disposition toward, mathematics and of making inferences from that evidence for a variety of purposes” (NCTM, 1995, p.3).

**Bloom/Cooney Rubric:** A modification by Harpster (1999) of Bloom’s and Cooney’s taxonomies used to classify questions from tests and quizzes in mathematics. The rubric consists of the following levels: Level 1 – Simple computation or recognition, Level 2 – Comprehension, Level 3 – Application, and Level 4 – Non-routine or open-ended problem.

**Graphing Calculator Active:** An item for which the use of a graphing calculator is necessary for all practical purposes to obtain a solution.

**Graphing Calculator Inactive:** An item for which the use of a graphing calculator is not possible for all practical purposes.
**Graphing Calculator Neutral:** An item for which it is possible to use a graphing calculator to obtain a significant part or all of the solution, but the item could be reasonably answered without a graphing calculator.

**Formal Assessment from Mathematics Textbook:** An assessment in which students work individually on paper-and-pencil tasks, with limited time to complete the tasks. Examples of formal assessments are tests and quizzes (NCTM, 2000).


**Higher-Order Thinking Skills:** Thinking skills that include transfer, analysis, synthesis, and evaluation.

**Lower-Order Thinking Skills:** Thinking skills that include recall and performing an algorithm.

**Standards-based:** Constructed with deliberate attention to addressing the *Principles and Standards for School Mathematics* (NCTM, 1989, 2000).

**Transitional-Order Thinking Skills:** These include skills from *Transfer*, Level 3 of the Harpster/Burke taxonomy.
Significance of the Study

What is assessed is a statement of what is important and valued (Chudowsky & Pellegrino, 2003; Stiggins, 1999; Wiggins & McTighe, 1998; Wilson, 1994), and so assessments should be designed around curricular goals (Wiggins & McTighe, 1998). Furthermore, “quality assessments arise from and accurately reflect clearly specified achievement expectations for students” (Stiggins, 1999, p.21). Students perceive that the material they are graded on is ultimately what is important to learn (Wilson, 1994). Thus, teacher assessment practices, including the selection of topics and tools to include in assessments, have an impact on what students value. Research has demonstrated the value of integrating graphing calculators into teaching and learning mathematics (Drijvers & Doorman, 1996; Ellington, 2003; Harskamp, Suhre, & Van Streun, 2000; Penglase & Arnold, 1996, Wilson & Krapfl, 1994). If we truly value the use of graphing calculators in the curriculum and want students to value their use, assessments should incorporate the use of graphing calculators. Waits and Demana state, “It is all right to give some tests without technology. It is not all right to give all tests without technology because doing so makes technology seem unimportant and an add-on to the curriculum” (2000, p.60).

If improved student understanding through the use of graphing calculators is a goal of the curriculum and if the use of graphing calculators as recommended by the PSSM (2000) is truly valued, but graphing calculators are not integrated into assessments, then this demonstrates a lack of alignment of the curriculum. Webb and Romberg write, “Alignment means that if certain materials or equipment are being used in instruction and
are part of the mathematics experiences of the learners, then these materials and equipment should be used in assessment” (1992, p.43). This study provides information for mathematics educators, including secondary mathematics teachers and writers of curriculum, on the assessment materials that accompany mathematics textbooks with regard to the use of graphing calculator technology. In particular, the information details the extent to which graphing calculators are integrated into formal assessments in a manner consistent with the recommendations of the PSSM (2000).
CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The review of literature is comprised of five parts. The first part focuses on curricular implementation of graphing calculator technology in relation to the recommendations of the NCTM *Principles and Standards for School Mathematics (PSSM)* (2000). The second part of the literature review provides background information on issues related to teaching and learning with graphing calculator technology. These issues include benefits and complications of graphing calculator use, teacher beliefs about instruction with graphing calculators, and appropriate classroom use. The third part, on assessment, includes an overview of assessment of student understanding and a discussion of important considerations for assessment in the presence of graphing calculator technology. The overview and discussion are followed by a look at studies that have examined the cognitive level of test items.

In order to gain insight into the study of assessments provided with published mathematics textbooks, the fourth part provides an in-depth examination of research studies that have evaluated various features of mathematics textbooks. Features of mathematics textbooks examined include the use of technology, the use of graphing calculator technology, assessment materials that accompany textbooks, and the influence of the Standards. The final part of the literature review examines methodologies of studies related to the current study, building the methodological framework of the current
study. The methodological framework is followed by a summary of the literature review and the theoretical framework of the study.

Curricular Implementation and Standards

When one examines the use of technology such as graphing calculators to teach mathematics, it is important to consider the prescribed or recommended curriculum on all levels – national, state, district, and school. On the national level, recommendations and goals related to the use of technology, and specifically graphing calculators, are woven throughout the *PSSM* (NCTM, 2000). The *PSSM* (NCTM, 2000), including the Assessment Principle and the Technology Principle, provide recommendations for mathematics educators in the areas of assessment and technology. The Assessment Principle suggests that not only should teachers employ formal assessments, such as tests and quizzes, they should also utilize alternative assessments. Alternative assessments include journals and constructed-response tasks to collect information about student learning through instruction. Further, assessment “should focus on students’ understanding as well as their procedural skills” (2000, p.23). The Technology Principle states, “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (2000, p.24). Furthermore, “technology must be embedded in the mathematics program rather than be treated as just another flashy add-on” (NCTM, 2000, p.373). If technology is embedded in the curriculum, then technology should also be embedded in assessment.

The *Curriculum and Evaluation Standards* (NCTM, 1989) recommend an increase in the use of graphing calculators in assessment. The more recently released
PSSM (NCTM, 2000) calls for the appropriate use of technology such as graphing calculators in teaching and learning mathematics, and provides some specific recommendations for how to integrate graphing calculators into teaching. For example, the Algebra Standard for grades 9-12 advises that instructional programs should enable students to “recognize how the values of parameters shape the graphs of functions in a class” (NCTM, 2000, p.299). A graphing calculator allows students to “easily explore the effects of changes in parameter as a means of better understanding classes of functions” (NCTM, 2000, p.299). Although the Standards (1989, 2000) do not provide specific recommendations with regard to formal assessments in the presence of graphing calculator technology, the PSSM (2000) provides expectations on the general use of graphing calculators in the mathematics classroom. The researcher summarized the expectations into a framework of six guiding principles. The six guiding principles based upon the PSSM (2000) are as follows:

1. Electronic technologies (such as graphing calculators) are essential tools for teaching, learning, and doing mathematics (p.24). Thus, graphing calculators should be incorporated into teaching, learning, and doing mathematics.

2. Assessment “should focus on students’ conceptual understanding [higher-order thinking skills] as well as their procedural skills [lower-order thinking skills]” (p.23). Given this, the graphing calculator should be used to facilitate the connection between conceptual understanding and procedural skills.

3. Graphing calculators should be used for mathematical modeling (p. 26, p. 297), studying changes in parameter and classes of functions (p.26, p.299), formulating and exploring conjectures (p.25), and representing and studying
the behavior of polynomial, exponential, rational, and periodic functions (p.297).

4. More general support for the use of technology includes that it enables the study of many cases (p.25), of more complex problems (problems that require higher-order thinking skills) (p.26), and of real-world problems (p.297). Therefore, graphing calculators should also be used for the study of many cases, of more complex problems, and of real-world problems.

5. Students should be expected to justify and explain their solutions to problems (p.342). Given this, students should be able to justify and explain their solutions to problems that are solved using a graphing calculator.

6. Students should be able to connect mathematical ideas (p.354) and translate among mathematical representations (p.360, p.363). Thus, the graphing calculator should be used to facilitate translating and making connections between multiple representations (algebraic, numeric, and graphic).

The framework can be employed to examine formal assessments on the use of graphing calculators and is the basis for the rubric developed for this study.

On the local level, state standards differ in the specificity of their recommendations for the use of technology. Mathematics standards were examined for the states of South Carolina, Texas, and Florida, as these states were considered in the selection of the textbook sample for the current study. California was initially one of the states considered, but was ruled out because textbook adoptions in California are determined by each district. South Carolina’s state standards document for
Grades 9-12: Algebra says:

Hand-held graphing calculators are required as part of instruction and assessment. Students should use a variety of representations (concrete, numerical, algorithmic, graphical), tools (matrices, data), and technology to model mathematical situations in solving meaningful problems. Technology includes, but is not limited to, powerful and accessible hand-held calculators as well as computers with graphing capabilities (SCDE, 2004).

Under South Carolina’s Standard II, students are expected to “Translate among and use algebraic, tabular, graphical, or verbal descriptions of quadratic, rational, exponential and other functions using computer algebra systems, spreadsheets, and graphing calculators” (SCDE, 2004). The standards for Texas are called the Texas Essential Knowledge and Skills (TEKS) for Mathematics. Under “Basic understandings,” TEKS says:

(5) Tools for algebraic thinking. Techniques for working with functions and equations are essential in understanding underlying relationships. Students use a variety of representations (concrete, numerical, algorithmic, graphical), tools, and technology, including, but not limited to, powerful and accessible hand-held calculators and computers with graphing capabilities and model mathematical situations to solve meaningful problems (TEA, 2004).

After this initial statement, graphing calculators are not specifically referred to again in the TEKS. Unlike South Carolina and Texas, the Florida standards do not contain a general statement about technology. Florida’s “Sunshine State Standards” are vague and never specifically mention graphing calculator technology. For example, Standard 1 under Algebraic Thinking requires that students determine “the impact when changing parameters of given functions” (FLDE, 2004), but says nothing about technology.

Overall, state standards are still quite general in their recommendations regarding the use of graphing calculators. District and school curricula also vary, but typically lack specific recommendations. Consequently, the teacher is left to make many decisions about how students should be assessed in the presence of technology.
Graphing Calculator Technology

Graphing Calculator Benefits

Numerous studies have shown the potential of graphing calculators to improve student understanding of various algebraic concepts (Drijvers & Doorman, 1996; Ellington, 2003; Harskamp, Suhre, & Van Streun, 2000; Penglase & Arnold, 1996, Wilson & Krapfl, 1994). Wilson and Krapfl (1994) write, “Among the reported benefits is improved ability to conceptually connect alternative representations of functional ideas” (p.256). In their observation of students during experimental lessons, Drijvers and Doorman (1996) discovered that graphics calculators enabled students to engage in enlightening investigative activities and to become more flexible problem solvers.

Meta-analyses on graphing calculator research have been conducted by Hembree and Dessart (1986), Penglase and Arnold (1996), and more recently by Ellington (2003). With the exception of fourth grade students, Hembree and Dessart (1986) found the use of calculators in combination with traditional instructional methods improved average students’ basic paper-and-pencil skills in exercises and problem solving. A significant result from Ellington’s (2003) review was that calculators are most effective in helping to improve students’ problem solving skills and understanding of mathematical concepts when used in both instruction and testing.

One of the more notable studies, conducted by Harskamp, Suhre, and Van Streun (2000), showed that weaker students exhibited the most dramatic benefits of graphing calculators. The researchers investigated the impact of graphing calculators on student problem-solving performance and solution strategies in a one-year, grade 10 functions
and calculus course in the Netherlands. The sample of students was broken into two experimental groups and one control group. One experimental group consisted of three sections of the course that used graphing calculators throughout the entire year, and the second experimental group was composed of five sections that used graphing calculators for two months. The control group, four sections of classes, did not use graphing calculators at all. In a pre-test/post-test experimental design, the researchers found that the most significant increases in student performance were for weaker students in the experimental groups. Furthermore, students’ use of graphical strategies increased with the availability of a graphing calculator. It should be noted that the degree of benefit derived from the graphing calculator could also vary depending on a teacher’s specific strategies of integration.

In terms of teaching specific topics, graphing calculators have been found to be particularly valuable for investigating families of functions (Manouchehri & Pagnucco, 2000), including quadratic functions (Barrett & Goebel, 1990; Kutzler, 2000; Simmt, 1997; Taylor & Miitag, 2001), logarithmic and exponential functions (Forster, 1998; Kennedy, Vasquez, & Huber, 2003; Lindsay, 2000), the transformation of functions (Choi-Koh, 2003; Fernandez, 2001), and modeling with functions (Barrett & Goebel, 1990; Ferrucci & Carter, 2003; Kennedy, Vasquez, & Huber, 2003; Manouchehri & Pagnucco, 2000).

**Topics Most Amenable to Graphing Calculator Use**

The studies of quadratic, logarithmic, and exponential functions are among the topics that are most amenable for utilizing a graphing calculator in ways that enhance
student learning. Several examples from the literature illustrate potential uses of graphing calculators to study these topics. With regard to quadratic functions, for example, Taylor and Miitag (2001) discuss seven methods for solving a quadratic equation, three traditional methods and four methods that use a graphing calculator. The traditional methods are factoring, completing the square, and using the quadratic formula. Four methods that use a graphing calculator are: “graphing with the CALC feature,” “quadratic-formula program,” “TABLE,” and “Solver” (Taylor & Miitag, 2001, pp.349-350). With the CALC feature, students can approximate and visualize the roots or zeros of a quadratic function. The quadratic-formula program is useful for more complex solutions and should be used when the answer is more important that the solution method. The TABLE feature enables students to explore the behavior of the quadratic function around the zeros. With the Solver function, students can verify the location of zeros. This example illustrates how the study of quadratic functions becomes more dynamic in the presence of graphing calculator technology.

In a paper by Kennedy, Vasquez, and Huber (2003), the authors provide examples of activities that utilize graphing calculator technology to help students develop an understanding of exponential modeling in real-world situations (p.358). In one activity, for example, students are given real-world data on Florida manatees in three categories: year, number of deaths by watercraft, and number of registered watercraft. Students are asked to use a graphing calculator to graph three different relationships using the data and to choose a model to represent each of the three relationships.

Lindsay (2000) gives an example of a “technology-rich” assessment task on exponential functions. The problem requires students to plot the graphs of \( y = e^x, y = 2e^x, \)
y = 4e^x, and y = -e^x on the same screen, using a specified viewing rectangle. Students are asked to explain why the four graphs are different, and to sketch and explain the graph of y = ce^x, where c is a positive real number (Lindsay, 2000, p.12). This example demonstrates how a graphing calculator can be used to assess students’ conceptual understanding of parameter changes and the family of “base e” exponential functions.

Graphing Calculator Complications

There are also potential problems associated with student misconceptions about scaling features of the calculator and inaccurate representations of graphs (Demana & Waits, 1990; Mitchelmore & Cavanaugh, 2000; Wilson & Krapfl, 1994). One example of an inaccurate graph representation, provided by Wilson and Krapfl (1994), is that calculator graphs typically do not show asymptotes as students are shown in textbook graphs. Other categories of errors associated with graphing calculators relate to students’ incomplete understanding of function domain, end behavior of functions, and solutions of inequalities, as well as students’ belief that all numbers are rational (Penglase & Arnold, 1996).

However, graphing calculator complications, if handled properly by the teacher, can be turned into learning situations. Teachers can make students aware that they should carefully and critically analyze calculator results, and steer students towards exercising “a more flexible solution procedure” (Drijvers & Doorman, 1996, p.430). Complications associated with graphing calculators should also be considered in the construction of assessment items. This raises the question of whether mathematics
textbooks overtly address the possible complications associated with the use of graphing calculators.

**Curriculum Issues Related to Graphing Calculators**

In considering the influence of technology on the mathematics curriculum, Kissane (2000) identified several issues that should be addressed. One issue is the use of graphing calculators. Are they used for demonstration purposes or are they used for problem solving and exploration activities? Should exam questions change to accommodate graphing calculators? How can exams be designed to ensure mathematical thinking in the presence of calculators? Rather than tacking the use of graphing calculators onto the curriculum as an appendage, Kissane concluded that graphing calculators should be integrated within the curriculum.

Even if graphing calculators are integrated within the curriculum, the nature of actual implementations and assessments will vary depending on the teacher. Ball and Cohen (1996) point out that curricular material should be “created with closer attention to processes of curriculum enactment” because “the enacted curriculum is actually jointly constructed by teachers, students, and materials in particular contexts” (p.7). What is prescribed in terms of graphing calculator use will have varying enactments. Teachers make the ultimate decisions about formal assessment, such as whether to use teacher-made tests or published tests. It is unknown to what extent textbooks advise or educate teachers on the construction of their own tests and on when to allow students to use graphing calculators on tests.
Teacher Beliefs

Not only will assessment decisions made in the classroom differ between teachers, but factors such as teacher knowledge and beliefs also have an impact on curricular decisions and the implemented curriculum (Cronin-Jones, 1991; Doerr & Zangor, 2000; Hawthorne, 1992; Remillard, 1999). Cronin-Jones (1991) investigated the influence of teacher beliefs on the implementation of a science curriculum package on wildlife species. The study had two purposes: one was to identify major categories of teacher beliefs that influence implementation of the curriculum, and the second was to decipher how exactly these beliefs influence the implementation process. Case studies were conducted with two middle school teachers and each of their classes of students. The study identified four major categories of beliefs as having a strong influence in the teachers’ implementation of the curriculum. These included beliefs about how students learn, a teacher’s role in the classroom, student ability levels, and importance of content topics. A significant finding of the study was that “teachers significantly alter intended curricula to make them more congruent with their own teaching contexts and belief systems” (Cronin-Jones, 1991, p.248).

In a compelling book that described four case studies of junior high school English teachers, Hawthorne (1992) revealed that despite the prescribed or intended curriculum structured at the district level, little attention is paid by the district to actual practice and curricular decision-making at the classroom level. Hawthorne (1992) writes, “Curricular procedures and outcomes vary despite organizational attempts at prescriptors” (p.121). The curricular choices of the teachers in the case studies were framed by their professional expertise and personal experience.
Hawthorne (1992) identified three major areas of factors that influenced curricular choices along five dimensions. The three major areas of factors influencing teacher choices were: professional factors, client (student) factors, and personal factors. Professional factors included professional knowledge (subject-matter and pedagogical knowledge), professional expertise, and personal experience. Client factors were items such as student feedback and knowledge of students specific to the context. Personal factors included teacher abilities and values. Hawthorne pointed out that the secondary school reform movement (which began in the 1980’s) has focused on educational organization and general academic requirements, but not on “strategies to improve actual teaching and learning at the classroom level” (1992, p.128). In light of Hawthorne’s ideas, it should be noted that the integration of graphing calculator technology into teaching and learning mathematics can be prescribed at all levels, but teachers’ actual classroom practice, including assessment with graphing calculators, will vary.

Appropriate Classroom Use

Mathematics educator Goldenberg (2000) points out “there is no single, universally accepted view of the best use of calculators and computers in classrooms” (p.1), but he presents six principles to help decide what good use of technology is in the classroom. The six principles are: The Genre Principle, The Purpose Principle, The Answer vs. Analysis Principle, The Who Does the Thinking Principle, The Change Content Carefully Principle, and The Fluent Tool Use Principle. Although the principles are geared towards lesson design, they can also be taken into consideration in the design of assessment items. In accordance with Wiggins and McTighe’s (1998) design for a
“backward curriculum,” Goldenberg’s Genre Principle recommends that technologies should be selected specifically to further classroom goals. In other words, graphing calculators should be incorporated into a lesson if classroom goals include a focus on student understanding of a concept (where the graphing calculator can assist), without students being bogged down by procedural computations.

Other principles relevant to the current study are The Purpose Principle and The Who Does the Thinking Principle. The Purpose Principle says that unless learning how to perform a computation is the purpose of the lesson, calculators should be allowed when computational labor can detract from the lesson. Thus, it is appropriate to use graphing calculators for performing computations on assessment items if these computations get in the way of the main objective(s). The Who Does the Thinking Principle says that technology should be used to develop students’ capacity to think, and not replace student thinking. Thus, assessment items that incorporate the use of graphing calculators should require higher-order thinking skills and should not unintentionally simplify the main objective(s) of the item. Goldenberg’s Principles were taken into account in the development of the researcher’s rubric.

Assessment

In order to provide criteria for judging the quality of mathematics assessments, NCTM’s 1995 Assessment Standards prescribes asking the questions: What mathematics is reflected in the assessment? How does the assessment engage students in realistic and worthwhile mathematical activities? (NCTM, 1995). Teacher assessment practices should shift away from assessing only students’ knowledge of specific facts and isolated skills to
assessing students’ full mathematical power by going well beyond facts and skills (NCTM, 1995). These recommended shifts do not imply a discontinuity in the assessment of facts and skills. Both student mastery of knowledge and skills and mastery of reasoning are important (Stiggins, 1995). Overall, assessments should be designed to supply teachers with useful and consistent information about their students’ mathematical understanding (Romagnano, 2001). In Wiggins and McTighe’s (1998) book that promotes a “backward design” of the curriculum, the authors describe three stages in the backward design process. The first stage is to identify goals for student learning. The second stage is to determine acceptable evidence of the goals, and the third stage is to plan instruction accordingly. In relation to student learning, the authors describe six facets of understanding. Three of the facets most applicable to the current study are explanation, interpretation, and application. To provide teachers with evidence of student understanding, students need to explain, interpret and apply what they learn (Wiggins & McTighe, 1998, p.100).

Graphing Calculator Technology and Assessment

Researchers have examined how graphing calculators influence teacher assessment practices (Adams, 1997; Anderson et al., 1999; Forster & Mueller, 2002). In a study conducted by Adams (1997), three areas of informal assessment were considered in a teacher’s assessment of students in the presence of graphing calculators. The areas were oral discourse, classroom observations, and problem-solving investigations. Participants in the study were a community college instructor and her students in a college algebra course. The study found that graphing calculators improved the quality
of discourse in the classroom and enabled the teacher to assess student understanding more effectively through increased interaction with individual students. Furthermore, student-to-student discourse increased as a result of working with graphing calculators. The presence of graphing calculators facilitated teacher observations of the students and allowed students to solve problems more actively with the option of alternative solution methods.

In formal assessment tasks that could be either employed or constructed by teachers, Anderson, Bloom, Mueller, and Pedler (1999) identified changes that graphing calculators induce on the assessment of calculus and mathematical modeling at the undergraduate level. Anderson et al. said assessment tasks should:

1. state explicitly whether an exact answer is required or to what precision approximate answers need to be given.
2. test how well students can interpret graphical information.
3. test translation skills in moving from one representation to another (numerical, graphical, symbolic)
4. place greater emphasis on requiring students to interpret information or provide evidence of reasoning used to arrive at answer. (1999, p.498)

The suggestions were taken into account in the construction of the instrument utilized in the current study.

Forster and Mueller (2002) investigated how students used a graphing calculator to answer questions on a calculus examination. Seven examination questions that were either graphing calculator active or neutral were selected for the inquiry. The researchers interviewed ten students to determine specifically how they had used their graphing
calculator on the exam questions. Results varied for each of the questions in terms of whether a traditional approach or graphing calculator approach was used. For example, the majority of students used a graphing calculator for graphing a rational function, but used traditional methods for evaluating a limit. The study showed that despite the presence of graphing calculators, student solution methods vary in terms of the extent to which the graphing calculator is utilized to solve a problem.

In a paper that analyzed research on the use of calculators in testing, Harvey (1992) described three types of tests related to the use of calculators: *calculator-passive tests*, *calculator-neutral tests*, and *calculator-based tests*. Calculator-passive tests permit students to use calculators, but are constructed without taking into account or planning for calculator use. Calculator-neutral tests also permit students to use calculators, but are developed intentionally so that none of the test items require calculator use. Calculator-based tests are developed so that a calculator is required on some of the items. Harvey (1992) defined an item *calculator-acceptable* as follows:

An item is *acceptable* if (a) the objective(s) tested by it are the same whether or not a calculator is used and (b) the difficulty [level of the item] seems to be approximately the same when a calculator is used (as compared to when a calculator is not used) (p.144).

If only (a) or (b) holds, the item was defined as *marginally acceptable* and if neither (a) nor (b) holds, an item was labeled *unacceptable*. It should be noted that Harvey’s definition of calculator-acceptable was based on an analysis of test items in terms of the use of a scientific calculator as opposed to the use of a graphing calculator. Tests that are calculator-passive and calculator-neutral have the possibility of containing items that are
unacceptable. Harvey provided the following as an example of an unacceptable problem from a calculator-passive test:

For which values of $x$ is $\tan x$ not defined?
(a) $-\pi$  (b) $-\pi/2$  (c) 0  (d) $\pi/4$  (e) $\pi/3$.

Asking students to compute the value of $(1/2)^{-3}$ is another example of an unacceptable item that could appear on a calculator-neutral test.

Harvey (1992) reviewed a study of calculator-neutral testing by Leitzel and Waits (1989) in which the investigators examined tests and test outcomes from the Ohio Early Mathematics Placement Testing Program for High School Juniors (EMPT). As part of the study, Leitzel and Waits investigated the difficulty and calculator sensitivity of test items on select EMPT tests. The measure for test item difficulty was undisclosed. A calculator sensitivity (CS) index was calculated for each test item as follows:

$$CS = \frac{\% \text{ correct by calculator using group}}{\% \text{ correct by non-calculator-using group}}.$$  

One of the three items with the lowest CS index required students to simplify the sum of two rational functions. Harvey judged this item as calculator-acceptable. One of the items with the highest CS index was to simplify $\sqrt{32} - \sqrt{2}$. Harvey classified this problem as unacceptable (1992).

Tests have to account for the fact that the presence of calculators enables changes in the solutions to mathematics problems (Harvey, 1992). For example, solving a system of equations could be done using a traditional method such as substitution or elimination. In the presence of a graphing calculator, one could graph the two equations as functions and find the point of intersection (if any) of the two functions. The researcher took
Harvey’s definitions and ideas on test development into consideration in the construction of the rubric utilized in the current study.

Test Item Assessment

Research studies have shown that teachers tend to rely on short-answer tests for assessment (Cooney, 1992; Garet & Mills, 1995; Senk et al., 1997; Taylor, 1991) and that there is a lack of assessment of higher-order thinking skills and conceptual understanding in test questions (Harpster, 1999; Madeus et al., 1992; Romberg et al., 1992; Taylor, 1991). An example of teacher reliance on short-answer tests is provided by Senk et al. (1997). The study investigated the assessment and grading practices of teachers from 19 mathematics classes in five high schools from three different states, and part of the study included an examination of teacher-constructed test items. The researchers found that 68% of the test items were low level, requiring only one or two steps to solve. An example of the lack of assessment of higher-order thinking skills and conceptual understanding in test questions is given by Madaus et al. (1992). The researchers examined mathematics textbook final test items and found that most of the items were at a low conceptual knowledge level (97%), at a low procedural knowledge level (92%), and required lower level thinking skills (95%).

Harpster’s (1999) dissertation provides further evidence of teacher’s lack of assessment of higher-order thinking skills as well as some explanation for high school teachers’ assessment practices. Harpster investigated whether Montana public high school teachers were influenced by profession-related factors in the cognitive levels of questions they would use to assess higher-order thinking skills. Factors of the teachers
that Harpster investigated included: amount of professional development, college coursework in assessment or evaluation, and highest academic degree earned.

Data were collected for the study through questionnaires and interviews. Questionnaires were sent to 220 teachers in seven different categories of schools. Schools were categorized based on size and Native American population. The questionnaires asked teachers to construct a problem that would test students’ higher level thinking skills and a problem that would test students’ lower level thinking skills. Harpster constructed a rubric based on Bloom’s Taxonomy and Cooney’s Taxonomy, called the Bloom/Cooney Rubric, to categorize the questions submitted by the teachers. Questions submitted by the teachers were coded based on four different cognitive levels using the Bloom/Cooney Rubric.

Harpster (1999) found that when asked to write a question that assessed higher-order thinking skills, most of the teachers wrote a question that assessed lower-order thinking skills. Furthermore, teachers’ construction of questions that assess higher-order thinking skills was not influenced by professional development or assessment-related coursework. The interviews revealed that most of the teachers had been assessed by their high school and college teachers in traditional ways. The teachers in the study weighed tests heavily in assessment, but also identified several obstacles in the assessment of higher-order thinking skills.
Mathematics Textbook Evaluation

Researchers have analyzed published mathematics textbooks’ context (Rivers, 1990) and content (Chandler & Brosnan, 1994; Irvin, 1993; Martin et al., 2001; Rock, 1992), including problems and tasks in published mathematics textbooks (Gomez, 1993; Nicely, Jr., 1985, 1991). In addition, studies have examined the use of technology in mathematics textbooks (Martin et al., 2001; May, 1994; Rivers, 1990; Rock, 1992) and assessment materials that accompany published mathematics textbooks (Taylor, 1991).

The Use of Technology in Mathematics Textbooks

Studies have described, in general terms, what technology is used for in mathematics textbooks (Martin et al., 2001; Rivers, 1990; Rock, 1992). For example, a study conducted by Rivers (1990) considered the influence of the *Curriculum and Evaluation Standards* (NCTM, 1989) on the context of algebra textbooks. Regarding the use of technology in the textbooks, the study’s findings were limited to the simple fact that all five textbooks included calculator exercises. Martin et al. (2001) evaluated five secondary mathematics curricula, funded by National Science Foundation (NSF) and designed to align with the *Standards* (NCTM, 1989). The researchers found that technology was frequently used in the NSF-funded textbooks as a problem-solving tool.

In her dissertation study, Rock (1992) examined and reviewed the quality of six mathematics textbooks at the seventh-grade level based on selected key features of their mathematics content. Evaluation of the use of technological tools in the textbooks was limited to technology use being “implied from the types of exercises coded and from authors’ comments” (Rock, 1992, p.94). When Rock reported the results of the study,
she said “none of the books presented their material such that the necessity to use technological tools was imminent” (1992, p.208). However, this statement seems to contradict Rock’s previous finding that the textbook *Real Math* encouraged students to use calculators for investigations, problem solving, and checking solutions. Some exercises of *Real Math* even required the use of a calculator. In the textbook entitled *Macmillan Mathematics*, one assignment of each chapter was devoted to technology. Discrepancies in Rock’s findings on calculator use point to a need for additional investigation into the use of calculators in textbooks. None of the studies by Rivers, Martin et al., or Rock took into consideration the quality or quantity of technology use. Furthermore, none of the studies considered the use of technology in ancillary assessment materials.

**The Use of Graphing Calculator Technology**

Studies have specifically investigated the use of graphing calculator technology in mathematics textbooks (May, 1994) and in teacher-constructed test items (Senk et al., 1997). In a dissertation study, May (1994) investigated how attitudes, teacher training, and curriculum issues impact secondary precalculus teachers’ integration of graphing calculators in light of the *Standards* (NCTM, 1989). A noteworthy component of May’s (1994) dissertation was to answer the research question, “How well do the new Texas precalculus textbooks align with the revised essential elements and do they differ in their use of graphing calculator technology?” (p.39). May compared four precalculus textbooks with a list of 35 essential elements in precalculus that require the use of technology. The list of precalculus essential elements was produced by the Texas Education Agency. An
example of one of the 35 essential elements is, “The student shall be provided opportunities to define and explore the characteristics of exponential functions (including base $e$), including the use of computer/calculator graphics technology” (May, 1994, p. 92). The researcher constructed and employed an instrument called the Textbook Content Analysis Form to evaluate four precalculus textbooks on each textbook’s utilization of graphing calculator technology with respect to the 35 essential elements. May investigated four uses of a graphing calculator: concept development, non-routine problem solving, computation/verification, and programming.

All four textbooks were found to be generally aligned with the essential elements for precalculus. However, four chi-square analyses, one for each of the four graphing calculator uses (concept development, non-routine problem solving, computation/verification, and programming), found significant differences (p<.01) between the four textbooks. Results showed three of the textbooks were similar to each other in their uses of graphing calculators, with one textbook an outlier. Data were tabulated using the instrument, giving each textbook a score out of 35 for each of the four graphing calculator uses. The three textbooks that were similar in their uses scored highly (at least 32 out of 35) for each of the uses of concept development, nonroutine problems, and computation/verification. Programming was the least common use for graphing calculators amongst all four textbooks. The textbook with the highest rating had a variety of real world applications and enabled “rich and diverse mathematical experiences” (May, 1994, p.56). Furthermore, it was found that the textbook’s use of calculators was generic (so that it would not become antiquated over time) and that teachers did not need extensive training in order to use the textbook. Limitations of
May’s study include that it did not consider the quality of graphing calculator use in the
textbooks and it did not look at ancillary assessment materials.

Regarding teacher-constructed test items, Senk et al. (1997) examined the
assessment and grading practices of teachers from 19 mathematics classes in five high
schools from three different states. One of the goals of the study was to document high
school mathematics teachers’ assessment practices and to comprehend teachers’
perspectives as they assess their students’ learning. Among the research questions of the
study was the question, “To what extent are teachers’ assessment and grading practices
consistent with the recommendations about assessment in the Curriculum and Evaluation
Standards (NCTM, 1989)? In particular, to what extent have teachers implemented
recommendations regarding the use of multiple assessment techniques, the use of
calculators and computers in assessment, and the assessment of communication and
reasoning?” (Senk et al., 1997, p.189).

The five schools in the study were selected to represent “a variety of
socioeconomic and educational opportunities” (Senk et al., 1997, p.190). Thus, schools
that utilized alternative forms of assessment were included as were some that used
calculators and computers in the classroom. In order to focus on topics specified in the
Standards (NCTM, 1989), teachers of courses called algebra, geometry, advanced
algebra, trigonometry, functions, and precalculus were chosen for the study. The sample
consisted of 8 men and 11 women. Twelve of the 19 classes in the study used textbooks
developed by the University of Chicago School Mathematics Project (UCSMP). The
UCSMP textbooks used assumed scientific calculators were available to students at all
times.
Senk et al. collected three sources of data based on one marking period: teacher questionnaires, assessment instruments used in each teacher’s target course, and an interview with each teacher. The questionnaires sought to obtain information on each teacher’s background and experience, target course, and assessment goals. Written tests were the primary assessment tool for each class, and tests and quizzes were similar in content and format. Therefore, tests were the only assessment instrument collected and analyzed. The researchers did not specifically state whether the written tests were published tests or teacher-made tests. However, the written tests were referred to as “teacher’s tests,” suggesting the tests were constructed by the teachers.

Data were analyzed by calculating the percentage of items assigned each code for each test given by the teachers throughout the semester. Subsequently, using all the tests administered by a teacher in the semester, mean percentages were calculated for items receiving each code. The researchers found that 68% of the test items were low level, meaning that they required only one or two steps to solve. With respect to the demand of scientific calculator or graphing calculator technology, the vast majority of the items were categorized as either neutral or inactive. The mean percentage of active items with respect to the features of a graphing calculator was 8%. Although most teachers perceived their assessment practices had been influenced by students’ access to technology, there was an “apparent lack of impact of technology on the types of test items teachers use” (Senk et al., 1997, p.210). Senk et al. broke test items down into two levels, “low” and “other.” “Low” items require one or two steps to solve and “other” items require three or more steps to solve. The researchers did not take into consideration whether or not items were calculator acceptable or the fact that use of a calculator can
influence cognitive level. Furthermore, the researchers did not analyze the mathematical content of test items. More refined and detailed classification of test items with regard to the use of graphing calculators would strengthen and further explicate the findings of the study.

Textbook Assessment Materials

The researcher identified one study by Taylor (1991) that focused on the evaluation of mathematics textbook ancillary assessment materials. In the first part of a dissertation study, Taylor examined the extent to which mathematics teachers in Ohio utilized publisher-provided assessment materials to design teacher-made tests. A survey of 138 algebra and geometry teachers in Ohio found that student grades were based mostly on tests, quizzes, and homework. Over one-third of those teachers used the text-provided assessments for at least 50% of their testing needs. Of particular relevance to the current study, the second part of Taylor’s dissertation evaluated ancillary assessment materials associated with three high school algebra (1 and 2) and geometry textbooks used in Ohio.

Taylor limited evaluation to the chapter tests and final tests of the algebra 1, algebra 2, and geometry texts. The researcher did not disclose reasons for limiting her evaluation to ancillary testing materials of the textbooks. After interrater reliability of the instrument used to collect the data was established, the researcher rated each of the chapter tests in the supplementary resource books of the textbooks. A Chi-square comparison found no significant difference between the rating of the researcher and the average rating of the rating team.
Taylor’s methodology section of her dissertation did not discuss how the data collected using her test evaluation instrument was analyzed. The results section reported average percentages for each textbook based on the collected data for the various categories of the instrument. With regard to processes, the algebra 1 and 2 textbooks showed an emphasis on mathematical procedures, and the geometry texts emphasized mathematical concepts. Most of the test questions were classified at a low cognitive knowledge/skill level. The content of the textbooks rarely deviated from the traditional subject areas of algebra and geometry. Taylor’s study did not include an examination of the use of graphing calculators in the test items.

The Influence of the Standards

Numerous studies have examined textbooks (Gomez, 1993; Irvin, 1993; Martin et al., 2001; River, 1990; Rock, 1992) and test items (Madaus et al., 1992; Romberg et al., 1992; Senk et al., 1997; Taylor, 1991) in terms of whether they reflect the recommendations of the NCTM Standards. Martin et al. (2001), in particular, evaluated five secondary mathematics curricula, funded by the National Science Foundation (NSF) and designed to align with the Standards (NCTM, 1989). The researchers wanted to examine how well the five series measured up against the PSSM (NCTM, 2000), and specifically, the extent to which each of the series addressed the Process and Content Standards. The series examined were: Contemporary Mathematics in Context (Core-Plus), Interactive Mathematics Program (IMP), Math Connections: A Secondary Mathematics Core Curriculum, Mathematics: Modeling Our World (ARISE), and SIMMS Integrated Mathematics: A Modeling Approach Using Technology. Part of the
analysis looked at how the NSF-funded series generally differed from traditional materials. The main difference found was that the content strands such as algebra and geometry in the NSF-funded textbooks were integrated throughout each year of the program to emphasize connections among the strands whereas the traditional textbooks treated each content strand as a separate course.

The NSF-funded curricula were also analyzed and rated with respect to the Process Standards using a detailed list of indicators constructed from the elaborated summary following the statement of each standard. Sample sections were selected from each textbook series and were scoured for these indicators. Descriptions detailing how the sample sections were selected or the nature of the sample sections were not provided. The highest ratings were received by the Core-Plus and SIMMS series.

Overall, Martin et al. found the Process Standards were well represented. “Reasoning and Proof” was the least represented Process Standard across the five series. For the Content Standards, the researchers looked for content in places such as scope-and-sequence charts and tables of contents that matched the Standards’ (NCTM, 2000) sixty-one content expectations. Each series was found to be in general alignment with the sixty-one content expectations, though among the three textbook series of IMP, Math Connections, and ARISE, one or more did not clearly address eleven topics from the content areas. Core-Plus and SIMMS included all sixty-one of the content expectations. Distinctive features were identified and representative examples were provided for each series. Results showed the five series to reflect the PSSM (NCTM, 2000) quite well.

For example, Rivers (1990) considered the influence of the *Standards* (NCTM, 1989) on the context of algebra textbooks. The qualitative, two-part investigation examined first year algebra textbooks adopted for use in South Carolina. The first part of the study analyzed five textbooks adopted for use in 1984. The second part analyzed five textbooks adopted for use in 1990 to determine whether the textbooks were influenced by the *Standards* (NCTM, 1989). Results of the study showed that the 1990 textbooks were indeed influenced by the *Standards* (NCTM, 1989). This influence was evidenced by more thorough integration of information and applications into problem solving activities, promotion of real world mathematics, and problem contexts that described “everyday applications without references to incidental characteristics of people” (Rivers, 1990, p.20).

However, most mathematics textbooks and test items have generally failed to reflect the recommendations of the *Standards* (Gomez, 1993; Irvin, 1993; Madaus et al., 1992; Rock, 1992; Romberg, 1992; Senk et al., 1997; Taylor, 1991). A dissertation study that illustrates this failure was conducted by Rock (1992). Rock examined and reviewed the quality of six mathematics textbooks at the seventh-grade level based on selected key features of their mathematics content. One notable aspect of the dissertation was the construction and use of an auditing tool that was based on a Model of Quality for Middle School/Junior High School Mathematics Curricular Materials. The Model of Quality reflected the reform view of mathematics prescribed by the *Standards* (NCTM, 1989). The main research question of the study sought to determine the extent to which each textbook demonstrated key features in light of current issues in mathematics education.
The six textbooks were selected to represent the variability in seventh-grade mathematics textbooks. Key features of each textbook that were analyzed included: Problem Situations, Organizers (to facilitate student construction of knowledge), Connections, Interrelated Disciplines, Mathematical Content, and Use of Technological Tools (Rock, 1992, p.85). The researcher provided precise, detailed definitions for each feature. Another noteworthy aspect of the study was the sample selection. Textbook pages that contained material related to the content domain of rational numbers were selected for analysis of key features. The whole of each textbook was analyzed for general features such as number of pages in the textbook. After inter-judge agreement was established for the auditing tool, the auditing tool was used to collect data. Results of the study include reports on the quantitative data collected, qualitative descriptions of the construction of each textbook, and qualitative judgments of each book’s contents in terms of reform goals. Rock found that none of the textbooks reflected the key features of reform.

Research analyzing mathematics textbooks published prior to the *Curriculum and Evaluation Standards* (NCTM, 1989) has shown the majority of problems and tasks in the textbooks and the accompanying assessment materials address low cognitive level and do not require higher-order thinking skills (Nicely, Jr., 1985, 1991; Taylor, 1991). Even in textbooks published after 1989, word problems in select mathematics textbook series were found to be low level, emphasizing skills and procedures (Gomez, 1993). Gomez (1993) conducted a study on word problems in three different mathematics textbooks series for grades nine, ten, and eleven. The researcher wanted to determine how the different series defined problem solving and examine the extent to which word
problems in the series were process-oriented (more open-ended) or task oriented (based on algorithms presented in the textbook). The study also sought to answer the question, “Is mathematical knowledge as it relates to problem solving in the textbook compatible with the recommendations of the Standards?” (Gomez, 1993, p.4).

One major finding of Gomez’s study was that the majority of word problems incorporated procedures primarily from the section where they appeared, giving a possible explanation for why students have difficulty in problem situations where problems are in an unfamiliar context, such as on standardized tests. Results of the study showed more than half of the problems emphasized procedural knowledge. Problems tended to request a numeric answer, with less prominence placed on problems in which the objective was to find a conclusion, make an interpretation, or give an explanation. Both examples and exercises focused on skills, procedures, and factual knowledge, with approximately 83% of the word problem exercises providing practice on procedures demonstrated in the book. In light of the Standards (NCTM, 1989), it was concluded that the problem solving related contents of the textbook series examined in the study did not address the recommendations promoted by the Problem Solving standard.

Researchers have found some widely-used assessments in K-12 mathematics lacking in alignment with national standards (Romberg et al., 1992; Stern & Ahlgren, 2002). In the area of science, Stern and Ahlgren (2002) studied the alignment of assessments in a widely-used science curriculum with national science standards. Stern and Ahlgren found the assessment tasks in the curriculum materials were “severely lacking in value” (2002, p.904) and were not helpful in finding out students’ understanding of important ideas of science literacy. More relevant to the current study,
Romberg et al. (1992) examined the extent to which six standardized mathematics tests were aligned with the NCTM *Standards* (1989). The six eighth-grade-level tests that were examined were: SRA Survey of Basic Skills, California Achievement Test, Stanford Achievement Test, Iowa Test of Basic Skills, Metropolitan Achievement Test, and Comprehensive Test of Basic Skills.

Romberg and his colleagues found that all six tests had significantly more procedural (85%) than conceptual (15%) test items. Most of the items, an average of 71%, were in the content area of Number and Number Relations, with the rest of the items distributed fairly evenly among the other six content areas. An average of only 1% of the test items were categorized as problem solving. With regard to process, 79% of the items were classified as Computation/Estimation and 20% of the items were classified as Communication. Though the study categorized each test item into one process category, it is possible for a test item to address more than one process standard category.

The study by Romberg et al. concluded that the six tests inadequately covered the content categories in the standards and placed too much weight on computations and algorithmic processes, as opposed to problem solving, reasoning, connections, and communication. Furthermore, the tests placed too much emphasis on procedures and not enough emphasis on conceptual knowledge. Although exact specifications for the tests were not provided, the conclusions of Romberg et al. implied that coverage of the content and process standards should be more evenly distributed. It was also indicated that since problem solving is “one of the primary content areas of the *Standards*” (Romberg et al., 1992, p.69), more emphasis should be placed on non-routine problem solving. The subject of technology use on the tests was not addressed.
Standards-Based Instruments

Studies have utilized standards-based instruments to examine mathematics test items and textbooks (Harpster, 1999; Madaus et al., 1992; Martin et al., 2001; Rock, 1992; Senk et al., 1997; Taylor, 1991). The researcher carefully examined the various instruments and took them into consideration in the construction of the researcher’s own rubric. One study that is particularly relevant to the current study, conducted by Senk, Beckmann, and Thompson (1997), used a rubric to examine the technology level of teacher-written test questions. The rubric, described as a coding scheme (Appendix C), was constructed to examine the extent to which test items reflect the recommendations of the Standards (NCTM, 1989), with the use of technology as one component. The characteristics in the coding scheme included item format, skill, level (low, other), realistic context, reasoning required, role of diagram, and technology (active, neutral, or inactive). Interrater reliability for the coding scheme was established through calculating a percent agreement for each category on the coding scheme. The mean percent agreement for all of the categories was 89%. Two researchers independently and blindly coded each item. When the two raters disagreed, a third rater resolved the coding. A limitation of the coding scheme is that only one category is utilized to describe an item’s use of technology. Both Senk et al. and Taylor analyzed data by calculating mean percentages for each teacher (or textbook in the case of Taylor) for each category on the instrument.
The dissertation study conducted by Harpster (1999) is noteworthy because of the study’s use of a detailed rubric to examine the cognitive levels of test questions written by teachers. Harpster constructed a rubric based on Bloom’s Taxonomy and Cooney’s Taxonomy, called the Bloom/Cooney Rubric, to categorize the questions submitted by the teachers. Questions submitted by the teachers in Harpster’s study were coded based on four different cognitive levels using the Bloom/Cooney Rubric. Although Harpster’s rubric was used to classify questions into four different levels, questions were described as fitting into one of two levels: those that required lower-order thinking skills and those that required higher-order thinking skills. No conclusions were made based on the four different levels.

In 2003, Harpster revised his rubric with a greater focus on Bloom’s Taxonomy, and renamed it the Harpster/Burke Taxonomy (unpublished). The revised taxonomy has five different cognitive levels: 1. Recall, 2. Algorithm, 3. Transfer, 4a. Analysis, 4b. Synthesis, 5. Evaluation. The five levels fit into the three categorical areas consisting of Lower-order Thinking Skills, Transitional-order Thinking Skills, and Higher-order Thinking Skills. Recall and Algorithm are considered Lower-order Thinking Skills. Transfer is a Transitional-order Thinking Skill. Analysis, Synthesis, and Evaluation are Higher-order Thinking Skills. Both of Harpster’s rubrics were considered by the researcher in the construction of the cognitive levels for the rubric created for the current study. Based on the results of Harpster’s dissertation and for the sake of simplification, the researcher decided to use two cognitive levels: Lower-order Thinking Skills (Recall, Algorithm) and Transitional/Higher-order Thinking Skills (Transfer, Synthesis/Analysis, Evaluation).
Mixed-Methodologies

Studies conducted by Martin et al. (2001), May (1994), and Rock (1992) used a mixed methodology to collect both quantitative and qualitative data on mathematics textbooks. To supplement the quantitative data collected in May’s study, May provided qualitative descriptions of each textbook’s approach to the use of graphing calculators. Features related to graphing calculators that were examined included: dependence on graphing calculator technology, necessity for teacher training, whether the textbook would become antiquated over time, and whether the textbook and its ancillary materials provide for the wealth of experiences promoted by the Standards (NCTM, 1989).

Despite three of the textbooks appearing to be similar in their graphing calculator uses, the textbooks were found to be very different. Using the qualitative data and the cumulative score totals, the textbooks were rated.

Rock (1992) and Martin et al. (2001) also supplemented quantitative data with qualitative data. Rock used a standards-based “auditing tool” to collect quantitative data. Prior to data collection, revisions were made to the tool based on two pilot studies. Rock included qualitative descriptions of the construction of each textbook and qualitative judgments of each book’s contents in terms of reform goals. Regarding graphing calculators, Rock paid particular attention to the textbooks’ dependence on graphing calculator technology.

Martin et al. used a mixed methodology to evaluate five NSF-funded standards-based textbook series, collecting quantitative data on indicators of the PSSM (NCTM, 2000) using a standards-based instrument and qualitative data on the distinctive features of each textbook series. For each Process Standard, each of the five NSF-funded series
was rated using a “star” rating system where the number of stars received was based on the percent range for the presence of the Process Standard indicators. Qualitative data was collected on the distinctive features of each of the five NSF-funded textbook series. The researcher’s method of quantitative data analysis in the current study mirrored those of Martin et al.

Methodological Framework

The methodological framework of this study was grounded in the methodologies of Martin et al., May, Rock, Senk et al., and Taylor as follows:

2. Use of standards-based instrument to collect quantitative data (Martin et al., 2001; Senk et al., 1997; Taylor, 1991), and Rock (1992).
3. Classification system to analyze quantitative data (Martin et al., 2001).

The current study utilized methodologies similar to these researchers for data collection and analysis, with the following substantial differences:

1. Focus was placed on the use of graphing calculators in formal assessments using a rubric based on Senk et al.’s (1997) coding scheme and the recommendations of the PSSM (2000).
2. Formal assessments that accompany mathematics textbooks from both NSF-funded integrated curricula and non-NSF-funded curricula were evaluated in terms of the PSSM (2000).
Summary

Research studies have shown that there is a lack of assessment of higher-order thinking skills and conceptual understanding in test questions (Harpster, 1999; Madaus et al., 1992; Romberg et al., 1992; Senk et al., 1997; Taylor, 1991). The researcher found that various features of mathematics textbooks have been analyzed and that studies have described, in general terms, how calculator technology is used in mathematics textbooks (Martin et al., 2001; Rivers, 1990; Rock, 1992). With regard to graphing calculator technology, studies that have investigated the use of graphing calculator technology in mathematics textbooks (May, 1994) and in teacher-constructed test items (Senk et al., 1997) have been limited. On the subject of the influence of the Standards, the five NSF-funded textbook series were all found to be in alignment with the PSSM (2000) (Martin et al., 2001), and various traditional textbooks have demonstrated some recommendations of the standards (1989) (Chandler & Brosnan, 1994; Rivers, 1990). However, most mathematics textbooks and test items have generally failed to reflect the recommendations of the Standards (Gomez, 1993; Irvin, 1993; Madaus et al., 1992; Rock, 1992; Romberg, 1992; Senk et al., 1997; Taylor, 1991). In light of the PSSM (2000), additional research is needed on the extent and quality of graphing calculator use in formal assessments that accompany secondary mathematics textbooks.

Theoretical Framework

The PSSM (NCTM, 2000) provides expectations for the general use of graphing calculators in the mathematics classroom, which can also be applied to formal
assessments. The researcher summarized the expectations into a framework of six
guiding principles. The six guidelines can be integrated into the theoretical framework of
this study by applying Wiggins and McTighe’s (1998) model “Stages in the Backward
Design Process” (see Figure 1). Though the model is presented as a method, it is in fact a
theory of curriculum design, providing a conceptual framework for the “backward
design” of a curriculum that promotes student understanding. In the backward
curriculum design, goals and standards for student learning are established in the first
stage, followed by determining what evidence of student learning is acceptable (stage
two) through assessment. The final stage (stage three) involves planning classroom
experiences and instruction according to the assessment methods. The model
demonstrates that assessment is intrinsic to the design of a curriculum and that
assessment methods should be determined by goals and standards.

In relation to this study, the six guidelines based upon the *PSSM* (2000) and the
general use of graphing calculators apply to stage one, “Identify desired results.” If
improved student understanding through the use of graphing calculators is a goal of the
curriculum and if the use of graphing calculators as recommended by the *PSSM* (2000) is
truly valued, then assessments such as tests should integrate the use of graphing
calculators as recommended by the *PSSM* (2000) in order to have alignment of the
curriculum.
Figure 1. Stages in the backward design process.

Identify desired results.
(Goals, Standards)

Determine acceptable evidence.
(Assessment)

Plan learning experiences and instruction.
/Instruction)

CHAPTER 3

METHODOLOGY

Research Design

This research was a descriptive and comparative study of the formal assessment materials of NSF-funded and non-NSF-funded high school mathematics curricula as they relate to the use of graphing calculator technology. As discussed in the literature review, algebra 2 courses have many topics that allow for the integration of graphing calculators into the curriculum at the algebra 2 level. For the NSF-funded textbooks, topics in the third year of study (corresponding to the level of algebra 2) were examined. The researcher identified quadratic, exponential, and logarithmic functions as three areas particularly amenable to integrating graphing calculator technology. Consequently, because these areas should have the opportunity to reflect the recommendations of the Principles and Standards for School Mathematics (PSSM) (NCTM, 2000) regarding the use of graphing calculators, the study included the formal assessments provided with the textbook chapters or units that cover these three areas.

Textbook Sample

A purposive sampling technique was used to select the textbooks for this study. The three most widely used textbooks among NSF-funded curricula and the seven most widely used textbooks among non-NSF-funded curricula were identified for evaluation. The NSF-funded curricula include: Core-Plus, Interactive Mathematics Program (IMP),
Math Connections, ARISE, and SIMMS. Gary Bauer, director of the SIMMS project at Montana State University in Bozeman, identified the most widely used standards-based curricula as Core-Plus, IMP and SIMMS (personal communication, October 28, 2003). Bauer’s assertion was based on a discussion about sales with leaders from each of the five NSF-funded curricula. Also, Bauer had access to a report from an outside evaluator, whose name he could not disclose, that confirmed his conclusions. The researcher requested a copy of the third-year book and ancillary assessment materials from the publisher of each of the three curricula. The NSF-funded textbooks and accompanying assessment materials are:


For the non-NSF-funded curricula, the population of textbooks includes high school algebra 2 textbooks and one advanced algebra textbook. The most widely used textbooks were discovered by searching the Web for textbook adoption lists and state textbook depository lists in the states of California, Texas, Florida, and South Carolina. These states were selected because of their large student populations and dominant influence in textbook adoptions nationwide. It was discovered that in California, there is no high school textbook adoption list and textbook adoptions are determined by each district. Publishers most common to the lists from Texas, Florida, and South Carolina were identified. Glencoe/McGraw Hill; Holt, Rinehart, & Winston, McDougal Littell
were common to all three states. Key Curriculum Press and Prentice Hall were common to Texas and South Carolina. Prentice Hall’s *Advanced Algebra* (UCSMP) textbook was on the lists of both Texas and Florida. Saxon was exclusively on Texas’ list (see Figure 2).

Figure 2. Venn diagram illustrating the states of Florida, Texas, and South Carolina and the publishers most common to the textbook adoption lists of these states.

Key:
Glenc = Glencoe
HRW = Holt, Rinehart, & Winston
McDL = McDougal Littell
Key = Key Curriculum Press
PH = Prentice Hall
The researcher found that textbook publishers do not release sales figures on individual textbooks. Furthermore, Association of American Publishers (AAP) representative Kathryn Blough said, “AAP does not have any data on individual companies. All of our reports are in the aggregate” (personal communication, February 2, 2004). Most of the companies’ representatives who were contacted were uncertain how to obtain information on sales figures. Although sales figures were identified online for the K-12 publishing segment of McDougal Littell and the school division of Pearson Education, which houses Prentice Hall, the figures were not comparative. In the end, the researcher chose to accept the K-12 textbook publishers identified by Mike Simpson, Vice President and General Manager of Key College Publishing, a division of Key Curriculum Press, because his information was consistent with the researcher’s findings on the textbook adoption lists. He identified the publishers as follows: Prentice Hall, Glencoe/McGraw Hill, McDougal Littell, Harcourt (Holt, Rinehart, & Winston), Key Curriculum Press, and Saxon Publishing (personal communication, January 21, 2004).

Each publisher was contacted and asked to provide a sample copy of the annotated teacher’s edition and ancillary assessment materials for their most widely used algebra 2 textbook. Prentice Hall’s Advanced Algebra (UCSMP) textbook was also included in the study because it is on both Texas and Florida’s textbook adoption lists. The non-NSF-funded textbooks and accompanying assessment materials are:

Formal Assessment Sample

The current study examined a purposively selected subset of formal assessments, collected from each curriculum, related to the topics of quadratic, exponential, and logarithmic functions. The formal assessments included materials such as chapter tests and end of unit/module assessments, as these materials best represent the population of formal assessments. A CD-ROM with assessment materials accompanies each teacher’s edition textbook of the non-NSF-funded curricula, except the Saxon textbook. For the majority of the curricula, the formal assessments were only on CD-ROM. To be consistent in the selection of materials from the non-NSF-funded curricula, formal assessments for these were selected from the CD-ROM. The population and sample of formal assessment materials are described for each curriculum in the following paragraphs.

The formal assessments of the Saxon (Saxon Publishers, 2003) textbook include 32 tests and a final exam in print. The Saxon method emphasizes review and consequently, each test is cumulative. Quadratic functions are covered in Lesson 71, and exponential and logarithmic functions are covered primarily in Lesson 118. Each test has two forms of the same difficulty level, Form A and Form B. The sample of formal assessments consisted of Form A of Tests 19 and 30, corresponding to Lessons 71 and 118, respectively.
An assessment book with quizzes, chapter tests, and semester exams accompanies the Key Curriculum Press (1998) textbook. A CD-ROM provides an electronic form of the textbook. Each chapter test has two forms, Form A and Form B, at the same difficulty level. The sample included the chapter tests (Form A) for Chapters 7 and 10. Chapter 7 covers exponential and logarithmic functions and Chapter 10 includes material on quadratic functions.

Each chapter of the Glencoe (Glencoe/McGraw-Hill, 2003) textbook is supplemented by a Resource Masters Book that contains quizzes, chapter tests of varying difficulty levels for each of 14 chapters, and open-ended assessments. The CD-ROM contains a Worksheet Builder to create customized tests and worksheets as well as generated chapter tests, including Test 1 and Test 2, for each chapter. Test 1 and Test 2 are the same level. The sample consisted of the CD-ROM chapter tests (Test 1) for Chapter 6, “Quadratic Functions and Inequalities,” and Chapter 10, “Exponential and Logarithmic Relations.”

Holt, Rinehart, and Winston’s (Holt, Rinehart, & Winston, 2004) assessment materials are strictly on CD-ROM and include quizzes, mid-chapter assessments, chapter assessments (for 14 chapters), and alternative assessments. The CD-ROM also includes a worksheet/test builder. Each chapter assessment has two forms, A and B. The two forms cover the same objectives and have the same difficulty level, but form A is multiple choice and form B is free response. Chapter 5 is on quadratic functions and Chapter 6 covers exponential and logarithmic functions. This study analyzed Chapter Assessments (Form B) for chapters 5 and 6. Form B was selected, as opposed to Form A, because the
researcher thought it might give the curriculum a better chance of demonstrating a
Standards-based use of graphing calculators.

A Chapter Resource Book supplements each chapter of the McDougal Littell Textbook (McDougal Littell Inc., 2003) and contains graphing calculator activities, quizzes, chapter tests, and alternative assessments. The CD-ROM has quizzes, chapter tests (for 14 chapters), midterm tests, and an end-of-the-year test. The sample included the chapter tests from the CD-ROM for chapters 5 and 8, on quadratic functions and exponential and logarithmic functions, respectively.

Prentice Hall’s Algebra 2 (Pearson Prentice Hall, 2004) textbook has an ancillary Blackline Masters book of assessments. The assessments are quizzes, 14 chapter tests (Forms A and B), and chapter alternative assessments. The CD-ROM contains quizzes and chapter tests. This study examined the CD-ROM chapter tests 5 and 8, on quadratic functions and exponential and logarithmic functions, respectively.

UCSMP’s (Prentice Hall, 2002) textbook has an Assessment Sourcebook on CD-ROM. The Assessment Sourcebook includes quizzes, chapter tests (for 13 chapters), cumulative tests for each chapter, comprehensive tests, and alternative assessments. The chapter tests consist of two types: Test Forms (A and B) and Performance Tests (C and D). To be as consistent as possible with the tests selected from the other curricula, Test Form A was analyzed for Chapter 6 and 9, on quadratic functions and exponential and logarithmic functions, respectively.

Since the NSF-funded curricula integrate various mathematical subjects such as algebra, geometry, and statistics over the course of four years, it was necessary to identify the units or modules in the textbooks that cover the topics of quadratic, exponential, and
logarithmic functions. Through analysis of scope and sequencing charts, units or modules that emphasize quadratic and exponential/logarithmic functions were identified. Formal assessments were selected from these units or modules. To be consistent with the non-NSF funded curricula sample, the study examined those formal assessments that are to be used in-class as more traditional assessments, as opposed to those that are take-home, more open-ended assessments. A description of the formal assessments that were analyzed for each curriculum follows.

Course 3 of the Core-Plus (Glencoe/McGraw-Hill, 2003) curriculum consists of seven units plus a capstone. Formal assessments consist of quizzes for each lesson within a unit, in-class exams (Forms A and B) and take-home exams for each unit, and a final exam. Unit 3 focuses on quadratic expressions and relations. Unit 6 emphasizes exponential expressions and relations. The in-class exams (Form A) from Units 3 and 6 were included in this study. Since logarithmic expressions and relations are not covered until Course 4, this topic was not included in the examination of the Core-Plus assessments.

Year 3 of the IMP (Key Curriculum Press, 1999) curriculum contains five units. Assessments include in-class and take-home final assessments as well as supplemental problems for each unit. This study evaluated the in-class assessments for Unit 1 “Fireworks” and Unit 4 “Small World, Isn’t It?” Unit 1 focuses on quadratic expressions, equations and functions, whereas Unit 4 covers exponential and logarithmic functions.

The third year of the SIMMS (Kendall/Hunt, 1997) curriculum has two options, Level 3 or Level 4, depending on student career path. Level 4, geared towards students planning careers in math and science, contains 16 modules. Each module has one
summary assessment and one module assessment. The summary assessments are more open-ended and the module assessments are to be used in-class as traditional assessments. The module assessments for the modules entitled “It’s All in the Family,” “Log Jam,” and “Drafting and Polynomials” were examined. In “It’s All in the Family,” students investigate exponential and logarithmic functions. “Log Jam” requires students to examine the properties of exponents and to develop the properties of logarithms. In “Drafting and Polynomials,” students study polynomial functions, including quadratic functions.

Measures

To analyze the formal assessments, a rubric called the *Graphing Calculator Use Rubric* (Appendix A) was constructed based on Senk et al.’s (1997) coding scheme (Appendix C). Senk et al.’s coding scheme was modified by the researcher based on the findings of the literature review and the framework of recommendations (see p.15) of the *PSSM* (NCTM, 2000) about assessment and graphing calculator technology. The *Graphing Calculator Use Rubric* includes eight categories: Indication of Graphing Calculator Use, Graphing Calculator Technology Level, Cognitive Level, Reason for Graphing Calculator Use, Simplification, Request for Justification, Real-world Context, and Role of Graph.

The following paragraphs provide background information on the construction of the rubric and explain reasons for the inclusion of the various categories in the rubric. The researcher conducted preliminary testing of the rubric by coding chapter tests that accompany mathematics textbooks not included in the study sample. In this initial
testing, the researcher discovered some limitations in the prior studies reported in the review of literature and some complex issues associated with the analysis of test items in terms of graphing calculator technology. For example, Senk et al. (1997) categorized test items as technology active, neutral, or inactive; and, independent of this technology categorization, they coded items for cognitive level (low or other). However, the cognitive level of an item may be different depending on whether or not a graphing calculator is used. Thus, in the researcher’s rubric, cognitive level is based on the indication of graphing calculator use.

Another complex issue in the construction of the rubric arose from Harvey (1992). Harvey defined an item as calculator acceptable if the objective(s) and difficulty of the item are the same whether or not a calculator is used (p.144). Harvey’s definition could not be directly incorporated into the researcher’s rubric. In the examination of assessment items outside of the context of actual classrooms, the objectives that an item intends to test may be unclear. Furthermore, the objectives may change if a graphing calculator is used to solve an item. Harvey’s definition was written for a scientific calculator and does not reflect more recent technology such as the graphing calculator. Instead of using Harvey’s calculator acceptable designation, the researcher created the Simplification category on the rubric. The Simplification category addresses the issue that assessment items could be simplified by the use of a graphing calculator and deals strictly with items that are rated none on the Indication of Graphing Calculator Use and neutral on Graphing Calculator Technology Level.

In developing the rubric, the researcher also took into consideration a general framework based upon the PSSM (NCTM, 2000). This framework is divided into six
guidelines for the general use of graphing calculators, and is reflected in the categories of the rubric:

1. Graphing calculators should be incorporated into teaching, learning, and doing mathematics (NCTM, 2000, p.24).

2. The graphing calculator should be used to facilitate the connection between conceptual understanding and procedural skills (NCTM, 2000, p.23).

3. Graphing calculators should be used for mathematical modeling, studying changes in parameter and classes of functions, formulating and exploring conjectures, and representing and studying the behavior of functions (NCTM, 2000, p.25, p.26, p.297, p.299).

4. Graphing calculators should be used for the study of many cases, of more complex problems, and of real-world problems (NCTM, 2000, p.25, p.26, p.297).

5. Students should be able to justify and explain their solutions to problems that are solved using a graphing calculator (NCTM, 2000, p.342).

6. The graphing calculator should be used to facilitate translating and making connections between multiple representations (algebraic, numeric, and graphic) (NCTM, 2000, p.354, p.360, p.363).

Categories in the Rubric

The following paragraphs describe each category of the rubric, indicate the research studies that pertain to the category, and explain how each category is connected to the six guidelines.
Indication of Graphing Calculator Use (Anderson et al., 1999) determines the extent to which each textbook’s formal assessments explicitly or implicitly indicate that a graphing calculator should be used on the assessment items. The category provides information, relevant to guideline #1, on the textbook’s intention for graphing calculator use in assessments.

Graphing Calculator Technology Level (Forster & Mueller, 2002; Harvey, 1992; Senk et al., 1997) is also connected to guideline #1. The category establishes the extent to which the assessment items are active or neutral. Because graphing calculators are essential tools for teaching, learning, and doing mathematics, assessments should have items that are active.

Cognitive Level (Goldenberg, 2000; Harpster, 1999; Madaus et al., 1992; NCTM, 2000; Romberg et al., 1992; Senk et al., 1997; Taylor, 1991) relates to guidelines #2 and #4. The category determines whether the active or neutral assessment items include more complex items and items that require students to use higher-order thinking skills.

Reason for Graphing Calculator Use (May, 1994; NCTM, 2000) is associated with guidelines #3 and #4. The category ascertains whether assessment items require the use of a graphing calculator for visualization purposes, i.e., problems of the type recommended by the PSSM (NCTM, 2000) for graphing calculator use.

Simplification (Goldenberg, 2000; Harvey, 1992) addresses the issue of items where the use of a graphing calculator could simplify or significantly change the intended objective(s) of the item. This categorization pertains only to those items that are rated none on Indication of Graphing Calculator Use and neutral on Graphing Calculator Technology Level.
Request for Justification (NCTM, 2000; Senk et al., 1997) reflects guideline #5. The category indicates whether students are expected to justify or explain their solutions to assessment items that could be solved using a graphing calculator.

Real-World Context (NCTM, 2000; Senk et al., 1997) is connected with guideline #4. The category shows the percentage of the assessment items that use a graphing calculator to solve real-world problems.

Role of Graph (NCTM, 2000; Senk et al., 1997) is associated with guideline #6. The category establishes the percentage of assessment items that require students to make or interpret a graph, making connections between the graph and either algebraic or numeric representations.

Preliminary testing of the rubric enabled the researcher to create a list of instructions with examples called the *Instructions for Graphing Calculator Use Rubric* (Appendix B) that explains the rubric in detail and how to utilize it for coding. An example of how one item would be categorized with the *Graphing Calculator Use Rubric* is also provided in the *Instructions for Graphing Calculator Use Rubric* (Appendix B, p.168). In order to pilot the instrument, the researcher and her committee Chair (Dr. Maurice Burke) trained by using the rubric to classify items using assessment materials from the NSF-funded curriculum, *Mathematics: Modeling Our World, Course 3* (ARISE) (South-Western Educational Publishing, 1998). Additionally, the training employed more traditional curricular materials, including chapter tests from algebra 1 and algebra 2 textbooks. None of the materials were part of the study sample.

Based on a discussion of the results, modifications were made to both the rubric and the *Instructions for Graphing Calculator Use Rubric* and a second round of piloting
was conducted. Additional modifications were made. Interrater reliability of the rubric was established using methods similar to those of Senk et al. (1997). The researcher paid and trained another rater, a graduate student in mathematics education, using the *Instructions for Graphing Calculator Use Rubric* as a training tool. The two raters, the researcher and the other trained rater, used the rubric to independently code each item on two randomly selected assessments; one selected from the NSF-funded sample and one selected from the non-NSF-funded sample. For those categories on the rubric with two classification levels, the percent agreement was determined. For those categories with three classification levels, to account for chance agreement between raters, Coefficient Kappa was calculated using the statistical software *SAS*. The process of making modifications to the rubric followed by coding was repeated until the Kappa and overall mean percentage agreement on coding were sufficiently high.

According to Payne (1992), Kappa should be above 0.70. A percent agreement level of 80% or higher is acceptable in most situations (Lombard, Snyder-Duch, & Bracken, 2004). The overall mean percent agreement was 96%, with the following percent agreements for each category: Cognitive Level (100%), Reason for Graphing Calculator Use (92%), Simplification (89%), Request for Justification (100%), and Real-World Context (100%). The overall mean Kappa was 0.82, with the following Kappa values for each category: Indication of Graphing Calculator Use (0.68), Graphing Calculator Technology Level (0.78), and Role of Graph (1.00). Based on an analysis of the items in the Indication of Graphing Calculator Use category where the two raters disagreed, the researcher did not find a consistent pattern. However, the researcher made one minor clarification on the *Instructions for Graphing Calculator Use Rubric* based on
one of the items. After the interrater reliability of the rubric was confirmed, the researcher coded the remaining assessments.

The researcher also established the content validity of the rubric. Content validity, described by Popham (2000) as content-related validity evidence, is defined as “Evidence indicating that an assessment suitably reflects the content domain it represents” (Popham, 2000, p.96). Based on the pilot study, the close ties to other researchers’ rubrics, and the reviews by mathematics educators at Montana State University, the researcher concluded that the rubric measures what the researcher purports the rubric to measure: extent of graphing calculator use and quality of graphing calculator use in formal assessments.

Methodology

The following section describes the methods used for data collection and analysis pertaining to each of the three research questions.

Research Question 1

To what extent do formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula incorporate graphing calculator technology? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of extent of graphing calculator use?
Research Question 2

What is the quality of graphing calculator use in formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula, as measured by a rubric based on Senk, Beckmann, and Thompson’s (1997) coding scheme and the recommendations of the Principles and Standards (NCTM, 2000)? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of quality of graphing calculator use?

Method of Data Collection for Research Questions 1 and 2

The Graphing Calculator Use Rubric was used to collect quantitative data on each textbook’s formal assessments. After the researcher established the interrater reliability and validity of the Graphing Calculator Use Rubric, it was utilized to examine the sample of formal assessments. Assessments from each textbook of the NSF-funded curricula and of the non-NSF-funded curricula were measured independently using the rubric. The rubric was used to code each item on the select assessments. In order to keep track of the various assessments, each assessment was given an identification letter and number, and each question on the assessment was given an item number. For each assessment, a table (Appendix D) was used to record the coding of each item by characteristics on the rubric.

To determine the extent of graphing calculator use as requested in research question 1, items were first coded for the indication of intended graphing calculator use (explicit, implicit, or none) and for graphing calculator level (active, neutral, or inactive). To examine the quality of graphing calculator use in the assessments as asked for in
research question 2, those items that were active or neutral were further coded for cognitive level (lower-order thinking skills or transitional/higher-order thinking skills), reason for graphing calculator use (computation, visualization), request for justification, real-world context, and role of graph (interpret/make, superfluous, or none). Those items that were coded as both none and neutral, were further coded by the simplification category.

Method of Data Analysis for Research Questions 1 and 2

The results of coding with the Graphing Calculator Use Rubric were tabulated (see Appendix D) and organized using matrices. For each textbook, percentages were calculated using all of the items in the sample from that textbook. First, the total number of items analyzed was recorded. Second, based on the number of items in each level, percentages were calculated for each level of the Indication of Graphing Calculator Use category. Next, percentages were calculated for the Graphing Calculator Technology Levels and Simplification categories. Finally, for those items that had a technology level of either active or neutral, a table was used to record percentages for the remaining categories. Part of the data analysis combined neutral items with active items because a graphing calculator could possibly be used for neutral items. Table 1 provides an example of the data and percentage tabulation.
Table 1. Example of data collected from the ARISE curriculum using the *Graphing Calculator Use Rubric*.

Total number of items analyzed: 30

**Indication of Graphing Calculator Use**

- Explicit 0% (0/30)
- Implicit 53% (16/30)
- None 47% (14/30)

**Graphing Calculator Technology Level**

- Active 37% (11/30)
- Neutral 30% (9/30)
- Inactive 33% (10/30)

**Simplification**

Total number of items both None and Neutral: 3
- Yes 67% (2/3)
- No 33% (1/3)

**Graphing Calculator Technology Level Active or Neutral Items**

Total number of active or neutral items: 20

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive level – Transitional/Higher-order thinking skills</td>
<td>100% (20/20)</td>
<td></td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
<td>80% (16/20)</td>
<td></td>
</tr>
<tr>
<td>Request for Justification – Yes</td>
<td>50% (10/20)</td>
<td></td>
</tr>
<tr>
<td>Real-World Context – Yes</td>
<td>75% (15/20)</td>
<td></td>
</tr>
<tr>
<td>Role of Graph – Interpret/Make</td>
<td>75% (15/20)</td>
<td></td>
</tr>
</tbody>
</table>

In order to describe and analyze the percentage outcomes for the specified levels of each of the eight rubric categories (see Table 2), the percentage outcomes were given a frequency of occurrence classification (see Table 3). The specified levels in Table 2 were chosen to gather information on what might be considered most representative of a
Standards-based extent and quality of graphing calculator use. Note that the first two categories were used to answer research question 1 and categories three through eight were used to answer research question 2. For example, using the ARISE assessment data shown in Table 1, the Indication of Graphing Calculator Use – Explicit or Implicit percentage was 53% and the Graphing Calculator Technology Level – Active percentage was 37%. Thus, the frequency of occurrence was described as “Frequent” for an Explicit or Implicit Indication of Graphing Calculator Use and was described as “Somewhat Frequent” for an Active Graphing Calculator Technology Level. The frequency classifications were used by the researcher to describe the extent and quality of graphing calculator use in the assessments.

Table 2. Outcomes.

1. Indication of Graphing Calculator Use – Explicit or Implicit
2. Graphing Calculator Technology Level – Active
3. Simplification – No
5. Reason for Graphing Calculator Use – Visualization
6. Request for Justification – Yes
7. Real-World Context – Yes
8. Role of Graph – Interpret/Make
Table 3. Percent frequency of occurrence scale defined by researcher.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent</td>
<td>0%– 24%</td>
</tr>
<tr>
<td>Somewhat Frequent</td>
<td>25% – 49%</td>
</tr>
<tr>
<td>Frequent</td>
<td>50% – 74 %</td>
</tr>
<tr>
<td>Very Frequent</td>
<td>75% – 100%</td>
</tr>
</tbody>
</table>

The second part of both research questions 1 and 2 compares the NSF-funded curricula to the non-NSF-funded curricula. The second part of question 1 was answered by creating a scatterplot to represent the relationship between the two variables: Indication of Graphing Calculator Use and Graphing Calculator Technology Level. A cluster analysis was conducted to look for patterns in the data (Everitt, 1993). The second part of question 2 was answered by looking for similarities and differences in the data.

Research Question 3

How do the textbooks mentioned in questions 1 and 2 make use of graphing calculator technology in the instructional materials that support their formal assessments? How do the textbooks from the NSF-funded curricula compare to the textbooks from the non-NSF-funded curricula in terms of graphing calculator use in the instructional materials that support their formal assessments?
Method of Data Collection for Research Question 3

The qualitative data collected for research question 3 supplements the quantitative data by describing the goals and practices related to graphing calculator technology embodied in the textbooks, providing information on the context of the formal assessments. The textbook’s goals and practices regarding the use of graphing calculators assist in examining the alignment of the curriculum; specifically between goals and assessments (Wiggins & McTighe, 1998). Data were collected by taking notes on each textbook, using the following Qualitative Data Checklist as a guide. References are provided for each item on the checklist to indicate sources for the item.

2. To what extent is the textbook dependent on graphing calculator technology? (Rock, 1992; May, 1994).
3. Do the textbook and the textbook’s ancillary materials (such as alternative assessments) reflect the PSSM (2000) with regard to the use of graphing calculators? (May, 1994; Rock, 1992).
4. What is included in the Teaching Notes of the textbook regarding graphing calculators? (May, 1994).

Note that for questions 3 and 4 on the checklist, the questions were used to examine only those chapters and units/modules that cover the topics of quadratic, exponential, and logarithmic functions. In question 3, the researcher paid particular attention to the following key features:

1. Request for justification (Martin et al., 2001).
2. Use of real-world context (Martin et al., 2001; Rock, 1992).


4. Translation between various representations – algebraic, numeric, graphic (Martin et al., 2001).

The researcher also noted any other distinguishing features regarding the use of graphing calculators.

Method of Data Analysis for Research Question 3

Using the information gathered with the Qualitative Data Checklist, the researcher wrote qualitative descriptions of each curriculum, addressing each question on the checklist. To compare the NSF-funded instructional materials to the non-NSF-funded instructional materials, using methods similar to those of May (1994) and Rock (1992), the researcher searched for trends, similarities, and differences in the data gathered for each question on the checklist.
CHAPTER 4

RESULTS

Introduction

This chapter presents the results of the analysis of data for the three research questions. Data were collected using the Graphing Calculator Use Rubric for research questions 1 and 2 and using the Qualitative Data Checklist for research question 3. Three NSF-funded curricula and seven non-NSF-funded curricula were analyzed. The italicized words reference formally defined terms in the study whose applications are dictated by rubrics.

Results for Research Question 1

1. To what extent do formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula incorporate graphing calculator technology? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of extent of graphing calculator use?

To answer the first part of this question, the researcher, assisted by another trained rater, assigned frequency of occurrence classifications for assessment items that had an explicit or implicit Indication of Graphing Calculator Use and for items with an active Graphing Calculator Technology Level. Explicit items are those for which graphing calculator use is explicitly stated in the item. For implicit items, graphing calculator use is not explicit, but the use of a graphing calculator is implicit in the language or symbols used in the item. Active items require the use of a graphing calculator for all practical purposes. The Instructions for Graphing Calculator Use Rubric (Appendix B) provides
more detailed descriptions with examples of explicit, implicit, and active. The frequency
of occurrence classifications were described in Chapter 3 (Table 3) as follows: Infrequent
(0% - 24%), Somewhat Frequent (25% - 49%), Frequent (50% - 74%), and Very
Frequent (75% - 100%). Results are shown for these two categories in Tables 4 and 5.
Overall, the extent of graphing calculator use for eight of the ten curricula was Infrequent
or Somewhat Frequent. Of the ten curricula, Key Curriculum Press (Key) and Holt,
Rinehart, & Winston (HRW) had the highest frequency (Frequent) of explicit or implicit
Indication of Graphing Calculator Use (see Table 4). Key had the highest frequency
(Frequent) of graphing calculator active items, followed by HRW, McDougal Littell
(McDL), and SIMMS (see Table 5). Six of the ten curricula had an Infrequent
occurrence of active items.

In order to illustrate the percentages that the frequency classifications were based
upon, the researcher also constructed bar graphs for the Indication of Graphing Calculator
Use and Graphing Calculator Technology Level categories (see Figures 3 and 4). In each
of the bar graphs, the textbooks were listed on the horizontal axis in the following order:
Saxon, Key, Glencoe, HRW, McDL, Prentice Hall (PH), UCSMP, Core-Plus (Core),
Interactive Mathematics Program (IMP), and SIMMS. For the Indication of Graphing
Calculator Use, Figure 3 shows that four of the textbooks were rated Somewhat Frequent
in the occurrence of explicit or implicit items, with two textbooks virtually just above and
four textbooks virtually just below the cutoff for Somewhat Frequent. The three
textbooks of Key, HRW, and SIMMS stood out as having the highest percentages. Figure
4 shows Graphing Calculator Technology Level active items. Although none of the
textbooks had a Very Frequent occurrence of active items, Key, HRW, and SIMMS again stood out with the highest percentages. The actual numbers used to compute the percentages are provided in Appendix E.
Figure 3. Percentages for indication of graphing calculator use as explicit or implicit.

Table 4. Indication of graphing calculator use (explicit or implicit).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Saxon, Glencoe, UCSMP, Core-Plus</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>McDL, Prentice Hall, IMP, SIMMS</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>Key, HRW</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
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</tr>
</tbody>
</table>
Figure 4. Percentages for graphing calculator technology level as active.

Table 5. Graphing calculator technology level (active).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Saxon, Glencoe, Prentice Hall, UCSMP, Core-Plus, IMP</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>HRW, McDL, SIMMS</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>Key</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
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</tbody>
</table>
To answer the second part of research question 1, the researcher constructed a scatterplot using percentages from those items that were explicit or implicit in the Extent of Graphing Calculator Use category and active in the Graphing Calculator Technology Level category (see Figure 5). As explained in the *Instructions for Graphing Calculator Use Rubric* (Appendix B), it is implied that an item rated as active is also rated as explicit or implicit. Therefore, the set of active items is a subset of the set of explicit or implicit items, and the set of explicit or implicit items may also contain items that have a *neutral* Graphing Calculator Technology Level, depending on the curriculum.

The researcher looked for clusterings (Everitt, 1993) of the ten data points. The scatterplot suggests three different clusters of points set apart roughly by the dotted lines in the scatterplot. The clusters do not reveal any significant differences in the extent of graphing calculator use between the NSF-funded curricula (indicated by the black-filled squares in Figure 5) and the non-NSF-funded curricula. However, two of the three NSF-funded curricula are in the lowest cluster. There also seems to be a trend – as there are more active items for a given curriculum, there are more frequent explicit or implicit items. This trend was not entirely unexpected because every active item is also explicit or implicit (see Figure 6). What is interesting to note, nonetheless, are the vertical gaps. For example, the lowest cluster has two sub-clusters, separated by a vertical gap. The gap is due to the fact that the curricula in the higher sub-cluster had a greater portion of explicit or implicit items that were active. Because a greater number of active items increases dependence on a graphing calculator, the curricula in the higher sub-cluster have a greater dependence of these curricula’s assessment items on graphing calculators as compared to the curricula in the lower sub-cluster. Figure 6 shows the portion of
active items that are explicit or implicit. For Key, for example, every explicit or implicit item was active, indicating the heavy dependence of Key’s assessment items on graphing calculators. In contrast, Saxon had a larger gap between the number of active items and the number of explicit or implicit items, demonstrating a lesser dependence of Saxon’s assessment items on graphing calculators.

Figure 5. Scatterplot of indication of graphing calculator use (explicit or implicit) and graphing calculator technology level (active). The dotted lines correspond to the frequency classification boundaries.
Figure 6. Active items as a portion of explicit or implicit items.

Results for Research Question 2

2. What is the quality of graphing calculator use in formal assessments that accompany third-year textbooks used in NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula, as measured by a rubric based on Senk, Beckmann, and Thompson’s (1997) coding scheme and the recommendations of the Principles and Standards (NCTM, 2000)? How do the NSF-funded curricula compare to the non-NSF-funded curricula in terms of quality of graphing calculator use?

To assist in describing the quality of graphing calculator use in the formal assessments accompanying the textbooks, the researcher, assisted by another trained
rater, assigned frequency of occurrence classifications to the remaining six categories of the *Graphing Calculator Use Rubric*. The six categories used to describe the quality of items, a measure independent from the extent of graphing calculator use, were applied to graphing calculator active or neutral items. As compared to the pool of items analyzed for the extent of use (i.e., all formal assessment items, including inactive items), the pool of items that were active or neutral had a reduced sample size. However, it should be understood that the size of the pool of active or neutral items will always be greater than the size of the pool of items that are explicit or implicit, thus representing a larger subset of the total number of formal assessment items. Therefore, in examining quality of graphing calculator use, the researcher wanted to be an inclusive as possible and thus had a sample size that expanded on the number of explicit or implicit items by including all neutral items, items for which it is possible to use a graphing calculator. For the curricula of Glencoe, HRW, McDL, PH, and UCSMP, the sample sizes for the total number of active or neutral items were noticeably larger. Thus, the percentage outcomes for each category are relative to the sample sizes as they are discussed in the results.

The Simplification category was utilized to classify a subset of this same pool of active or neutral items: items that were neutral in Graphing Calculator Technology Level but rated *none* in the Indication of Graphing Calculator Use category, and so were disjoint from the explicit or implicit items. Of the total of 393 formal assessment items analyzed in the study, only two of the items (from UCSMP) specifically stated that a calculator should not be used at all. Otherwise, none of the assessment items explicitly restricted the use of a graphing calculator. Therefore, the Simplification category was included in the analysis of quality because it addresses the issue that a curriculum may
not indicate (or is unclear) that a graphing calculator should be used for an assessment item, but that because the item is neutral, a graphing calculator could be used and consequently simplify or change the objective of the item.

It should also be noted that all six quality attributes (corresponding to the six categories on the Graphing Calculator Use Rubric) can validly be applied to the topics in the chapters/units examined by the researcher because those topics were chosen based on their amenability to the use of graphing calculators. For example, in the context of the chapters examined by the researcher, one would expect the use of a graphing calculator for visualization purposes. Beyond the descriptions provided in the following paragraphs, more detailed definitions of the various levels of the six categories of the Graphing Calculator Use Rubric are given in the Instructions for Graphing Calculator Use Rubric (Appendix B).

Regarding the percentage of active or neutral assessment items with a cognitive level requiring transitional/higher-order thinking skills, Saxon, Key, Core-Plus and SIMMS were all Somewhat Frequent and had the highest frequencies (see Table 6). Transitional/higher-order thinking skills include skills such as transfer, synthesis, analysis, and evaluation. Five non-NSF-funded curricula and IMP were rated Infrequent on this attribute.

Glencoe, Core-Plus, and SIMMS’ graphing calculator active or neutral items frequently used a graphing calculator for visualization. Uses of a graphing calculator for visualization include solving equations graphically and graphing functions. Saxon and HRW’s active or neutral items infrequently used a graphing calculator for visualization, implying that when used, graphing calculators were most likely used for computation.
It should be noted that HRW’s actual number of items that used a graphing calculator for visualization (8/42) was comparable to Key, Core, and SIMMS, but was rated Infrequent because the percent (19%) is relative to the total number of active or neutral items.

The Request for Justification category (Yes level) is defined by items that request justification, explanation, or proof. For graphing calculator active or neutral items that requested justification, Core-Plus had the highest frequency (Frequent), followed by Key and IMP (Somewhat Frequent) (see Table 8). The other seven curricula infrequently requested justification on active and neutral items.

For graphing calculator active or neutral items set in a real-world context, IMP had the highest frequency at Very Frequent (80%), followed by Saxon, Key, HRW, and Core-Plus at Somewhat Frequent (see Table 9).

For assessment items in which the Role of Graph was interpret/make, SIMMS’ items had the highest frequency (Frequent) and Saxon, Key, McDL, Prentice Hall, and Core-Plus were Somewhat Frequent (see Table 10). Interpret/make describes items for which a graph must be constructed, interpreted, or both constructed and interpreted. The remaining curricula were Infrequent. None of IMP’s assessment items called for students to interpret or make a graph or table. It should be noted that the sample of assessment items for IMP was small compared to the other nine curricula, as the grain size of IMP’s assessment items was generally larger than a typical formal assessment item from the non-NSF curricula. For IMP, only eight assessment items were examined in total and of these, only five were graphing calculator active or neutral.
Finally, the Simplification category (*No* level) assists in describing the pool of items rated neutral (Graphing Calculator Technology Level) and none (Indication of Graphing Calculator Use) such that the use of a graphing calculator does not simplify (or significantly change) the intended, main objective(s) of the item. Saxon, Key, Glencoe, McDl, and Prentice Hall all had an Infrequent occurrence of items that were *not* simplified by the use of a graphing calculator. In other words, they had a high percentage of items such that the use of a graphing calculator simplified or significantly changed the intended, main objective(s) of the item. SIMMS (Very Frequent) and IMP (Frequent) were the two curricula for which a graphing calculator most frequently did not simplify items (see Table 11). In other words, SIMMS and IMP had a low percentage of items such that the use of a graphing calculator simplified the item or significantly changed the intended, main objective(s) implied by the item.

The researcher created bar graphs to illustrate the percentages that the frequency classifications were based upon for the six quality categories (see Figures 7, 8, 9, 10, 11, and 12). In interpreting the six bar graphs, it should first be noted that there was large variation in the number of items (sample items) analyzed for each curriculum and, due to the selection criteria, there was also large variation in the number of items (pool sizes) analyzed for the extent of use and quality of use categories.

Figure 7 shows the results for items that require transitional/higher-order thinking skills in the Cognitive Level category. The textbooks separate into two distinctive groups based on the percentages. Glencoe, HRW, McDl, Prentice Hall, and UCSMP had the lowest percentages at 2% (43), 2% (42), 5% (42), 0% (47), and 4% (50), respectively. The numbers in parentheses following the percentages represent the sample sizes, n,
where n represents the total number of active or neutral formal assessment items examined for each curriculum. Saxon, Key, Core-Plus, IMP, and SIMMS had the highest percentages at 29% (28), 33% (21), 33% (18), 20% (5), and 27% (15), respectively. The lower percentage group had larger sample sizes and the higher percentage group had smaller sample sizes. The actual numbers used to compute the percentages for all textbooks and categories are provided in Appendix E.

Figure 8 shows results for the Reason for Graphing Calculator Use category. The majority of the textbooks had between 32% and 54% of the items as visualization. However, there was quite a bit of variation in the sample sizes for the various textbooks due to the selection criteria. For example, UCSMP had 38% of the items as visualization and IMP had 40% of the items as visualization. The UCSMP percentage was based on a sample of 50 items and the IMP percentage was based on a sample of only five items. Standing out in the percentages of items classified as visualization, Saxon had a relatively low percentage (11%) and SIMMS had a relatively high percentage (68%).
Figure 7. Percentages for cognitive level as transitional/higher-order thinking skills.

Table 6. Cognitive level (transitional/higher-order thinking skills).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
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<td>---</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>---</td>
</tr>
</tbody>
</table>
Figure 8. Percentages for reason for graphing calculators use as visualization.

Table 7. Reason for graphing calculator use (visualization).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Saxon, HRW</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>Key, McDL, Prentice Hall, UCSMP, IMP</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>Glencoe, Core-Plus, SIMMS</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>---</td>
</tr>
</tbody>
</table>
Results for the Request for Justification category are illustrated in Figure 9. The textbooks that conspicuously had the lowest percentages were Saxon, Glencoe, HRW, McDl, Prentice Hall, and UCSMP. The respective percentages and sample sizes were: 0% (28), 0% (43), 0% (42), 0% (42), 6% (50). The textbooks that stood out with the highest percentages were Key and all of the NSF-funded textbooks (Core-Plus, IMP, and SIMMS). The respective percentages and sample sizes were: 33% (21), 50% (18), 40% (5), and 20% (15). It should be noted that the textbooks with the lower percentages had large sample sizes and that the textbooks with higher percentages had relatively smaller sample sizes.

Figure 10 displays the results for the Real-World Context category. Salient features of the bar graph include Glencoe’s low percentage (5%) of real-world items and IMP’s high percentage (80%) of real-world items. Glencoe’s sample size was 43 items and IMP’s was five items. The other textbooks percentages ranged between 13% and 48%.

The bar graph for the Role of Graph as interpret/make is shown in Figure 11. All of the textbooks’ percentages ranged between 10% and 33% with the following exceptions: IMP had the lowest percentage of 0% and SIMMS had the highest percentage of 53%. Figure 12 displays the results for items that were both neutral and none and were not simplified by the use of a graphing calculator. The NSF-funded textbooks noticeably had the highest percentages, with percentages as follows: Core-Plus (45%), IMP (75%), and SIMMS (87%). Percentages for the non-NSF-funded textbooks ranged between 0% and 27%. Sample sizes for all of the textbooks varied considerably with a low of four items for IMP and a high of 33 items for UCSMP.
Figure 9. Percentages for request for justification as yes.

![Request for Justification Diagram](image)

Table 8. Request for justification.

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Saxon, Glencoe, HRW, McDL, Prentice Hall, UCSMP, SIMMS</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>Key, IMP</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>Core-Plus</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>---</td>
</tr>
</tbody>
</table>

Figure 10. Percentages for real-world context as yes.
Table 9. Real-world context.

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Glencoe, McDL, Prentice Hall, UCSMP, SIMMS</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>Saxon, Key, HRW, Core-Plus</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>---</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>IMP</td>
</tr>
</tbody>
</table>

Figure 11. Percentages for role of graph as interpret or make.
Table 10. Role of graph (interpret/make).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Glencoe, HRW, UCSMP, IMP</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>Saxon, Key, McDL, Prentice Hall, Core-Plus</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>SIMMS</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>---</td>
</tr>
</tbody>
</table>

Figure 12. Percentages for simplification as no.
Table 11. Simplification (no).

<table>
<thead>
<tr>
<th>Frequency of Occurrence</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrequent (0-24%)</td>
<td>Saxon, Key, Glencoe, McDL, Prentice Hall</td>
</tr>
<tr>
<td>Somewhat Frequent (25-49%)</td>
<td>HRW, UCSMP, Core-Plus</td>
</tr>
<tr>
<td>Frequent (50-74%)</td>
<td>IMP</td>
</tr>
<tr>
<td>Very Frequent (75-100%)</td>
<td>SIMMS</td>
</tr>
</tbody>
</table>
With regard to both research questions 1 and 2, Figures 13 through 22 not only illustrate the combined results for both extent and quality of graphing calculator use for each of the ten curricula, but also show the number of sample items and pool sizes for the various analyses of formal assessment items. The graphs emphasize that the percentage outcomes based on the extent and quality categories are relative to the sample size of each curriculum. For example, Figure 13 shows the results for Saxon. The horizontal axis gives the pool sizes for the various categories analyzed as a percentage of Saxon’s sample size. A total of 42 (sample) items were analyzed for the extent and level of use. Ten were explicit or implicit (24%) and of these, 5 were active (12%). These percentages are illustrated by the horizontal bars originating at the base of the vertical axis. The vertical axis displays Saxon’s percentages for the six quality categories using the short horizontal bars that appear directly above their respective pool size percentages. Of the 42 items sampled, 28 items (68%) were rated as active or neutral, and 18 items (45%), were rated as none and neutral. As mentioned previously, five of the six categories apply to the same pool of assessment items, those identified as active or neutral. The sixth category, Simplification, was a subset of this same pool of items, i.e., those items that were neutral but rated none in Indication of Graphing Calculator Use. Thus, directly above 68%, five short horizontal bars appear corresponding to Saxon’s percentages in the five quality categories of Justification (0%), Visualization (11%), InterpretMake (25%), TransHi (29%), and RealWorld (36%). Directly above 45%, a short horizontal bar appears on the horizontal axis representing Saxon’s 0% in the NoSimplification category. The following paragraphs explain the six quality categories in more detail and present results for each category.
Figure 13. Saxon’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.

**Saxon**

![Quality Percentages Chart](chart.png)

**Percentages Based on Pool Sizes**

- RealWorld
- TransHi
- InterpretMake
- Visualization
- Justification

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>E/I</th>
<th>None &amp; N</th>
<th>A or N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Percentages</td>
<td>12%</td>
<td>24%</td>
<td>45%</td>
<td>68%</td>
</tr>
<tr>
<td>Pool Sizes</td>
<td>(5/42)</td>
<td>(10/42)</td>
<td>(18/42)</td>
<td>(28/42)</td>
</tr>
</tbody>
</table>
Figure 14. Key’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.
Figure 15. Glencoe’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.
Figure 16. HRW’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.

Holt, Rinehart, & Winston

<table>
<thead>
<tr>
<th>None &amp; N</th>
<th>28%</th>
<th>42%</th>
<th>51%</th>
<th>79%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(15/53)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Quality Percentages

0% 25% 50% 75% 100%

NoSimp
RealWorld
Visualization
InterpretMake
TransHi
Justification (0%)

Percentages Based on Pool Sizes
Figure 17. McDL’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.
Figure 18. Prentice Hall’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.

<table>
<thead>
<tr>
<th>Pool Size</th>
<th>Quality Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100%</td>
</tr>
<tr>
<td>A or N</td>
<td>85%</td>
</tr>
<tr>
<td>None &amp; N</td>
<td>33%</td>
</tr>
<tr>
<td>E/I</td>
<td>24%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Prentice Hall

Quality Percentages

Percentages Based on Pool Sizes

Visualization
InterpretMake
NoSimp
RealWorld

TransHi (0%)
Justification (0%)

0 24% 33% 44% 85% 100%
A E/I None & N A or N
(13/55) (18/55) (24/55) (47/55) (55/55)
Figure 19. UCSMP’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.
Figure 20. Core Plus’ extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.
Figure 21. IMP’s extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.

Interactive Mathematics Program

Quality Percentages

RealWorld

NoSimp

Visualization

Justification

TransHi

InterpretMake (0%)

Percentages Based on Pool Sizes

0 13% 25% 50% 63% 100%

A E/I None & N A or N

Figure 22. SIMMS’ extent and quality of graphing calculator use, taking into account pool sizes for active items (A), explicit or implicit items (E/I), none and neutral items (None & N), and active or neutral items (A or N). Pool sizes are in parentheses below.

SIMMS

Percentages Based on Pool Sizes

<table>
<thead>
<tr>
<th>Quality Percentages</th>
<th>RealWorld</th>
<th>InterpretMake</th>
<th>Visualization</th>
<th>Justification</th>
<th>TransHi</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>83% (18/18)</td>
<td>44% (8/18)</td>
<td>39% (7/18)</td>
<td>25% (15/18)</td>
<td>0% (8/18)</td>
</tr>
<tr>
<td>75%</td>
<td>83% (18/18)</td>
<td></td>
<td>44% (8/18)</td>
<td>39% (7/18)</td>
<td>25% (15/18)</td>
</tr>
<tr>
<td>50%</td>
<td>83% (18/18)</td>
<td></td>
<td></td>
<td>39% (7/18)</td>
<td>25% (15/18)</td>
</tr>
<tr>
<td>25%</td>
<td>83% (18/18)</td>
<td></td>
<td></td>
<td></td>
<td>25% (15/18)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pool Sizes</th>
<th>NoSimp</th>
<th>A, E/I</th>
<th>None &amp; N</th>
<th>A or N</th>
</tr>
</thead>
<tbody>
<tr>
<td>(7/18)</td>
<td>0% (8/18)</td>
<td>39% (7/18)</td>
<td>44% (8/18)</td>
<td>83% (18/18)</td>
</tr>
<tr>
<td>(8/18)</td>
<td>44% (8/18)</td>
<td>39% (7/18)</td>
<td>44% (8/18)</td>
<td>83% (18/18)</td>
</tr>
<tr>
<td>(15/18)</td>
<td>83% (18/18)</td>
<td>44% (8/18)</td>
<td>39% (7/18)</td>
<td>83% (18/18)</td>
</tr>
<tr>
<td>(18/18)</td>
<td>100%</td>
<td>44% (8/18)</td>
<td>39% (7/18)</td>
<td>83% (18/18)</td>
</tr>
</tbody>
</table>
An examination of each individual curriculum represented in a bar graph for all six categories (used to examine the quality of graphing calculator use) provided additional results used to address the first part of research question 2 (see Figure 23). The following paragraphs describe the results for the individual curricula based on an analysis of Figure 23.

Saxon had the two categories of Justification and NoSimplification at 0%, with the other four categories ranging between 11% and 36%. Saxon’s highest percentage of 36% was in the RealWorld category.

Key had one category at 0% (NoSimplification), with the other five categories ranging between 33% and 48%. Key’s highest percentage of 48% was in the RealWorld category.

Glencoe had one category, NoSimplification, at 0%. The categories of TransHi and Justification were also very low with percentages of 2% and 5%, respectively. Percentages for the other three categories fell between 10% and 54%. Visualization stood out with the highest percentage at 54%.

HRW had one category, Justification, at 0%. The TransHi category was also quite low with a percentage of 2%. The remaining four categories had percentages ranging between 10% and 27%. The highest percentage was 27% in the NoSimplification category.

McDL also had 0% in the Justification category. Two other categories with low percentages were TransHi (5%) and NoSimplification (4%). The remaining three categories had percentages between 24% and 41%. McDL’s highest percentage of 41% was in the Visualization category.
Figure 23. Quality of graphing calculator use for all six categories combined.
Prentice Hall had 0% in two categories: Justification and TransHi. Otherwise, the four categories of Visualization, RealWorld, InterpretMake, and NoSimplification ranged between 19% and 32%. The highest percentage of 32% was in the Visualization category.

UCSMP had no categories at 0% and three categories in the reasonably balanced range: Visualization, RealWorld, and NoSimplification. The lowest percentage for UCSMP was 4% in TransHi and the highest percentage was 38% in Visualization.

Core-Plus had no categories at 0%. All six of the quality categories ranged between 28% and 50%. The high percentage for Core-Plus at 50% was in two categories: Visualization and Justification.

IMP had one category, InterpretMake at 0% with the other five categories ranging between 20% and 80%. IMP’s highest percentage of 80% was in RealWorld, and NoSimplification also stood out as being high with a percentage of 75%.

SIMMS’ lowest percentage was in RealWorld (13%) with the other five categories between 20% and 87%. The highest percentage of 88% was in the NoSimplification category, followed by 68% in the Visualization category.

For the second part of research question 2, the researcher compared the quality of the NSF-funded curricula’s assessment items to the non-NSF-funded curricula’s assessment items. For each category, the NSF-funded group had at least two of the three curricula classified as Somewhat Frequent, Frequent, or Very Frequent, whereas the non-NSF-funded curricula were almost always classified as Infrequent or Somewhat Frequent. Although Core-Plus and SIMMS were in the “highest” frequency levels in both the Cognitive Level category and the Reason for Graphing Calculator Use category
(see Tables 6 and 7), the three NSF-funded curricula were otherwise spread out amongst three levels of frequency classifications. For example, in the Real-World context category, the frequency classifications were as follows: IMP – Very Frequent, Core-Plus – Somewhat Frequent, and SIMMS – Infrequent (see Table 9), with SIMMS having the second lowest percentage (13%) of all ten curricula (see Figure 10). In the Simplification category, although the NSF-funded curricula were spread out amongst three levels of frequency classifications (see Table 11), the group stood out as having percentages well above the non-NSF-funded group (see Figure 12).

In addition, the two groups were compared according to the number of categories most consistently falling above 0% in the bar graph of all six categories used to examine the quality of graphing calculator use (see Figure 23). Among the non-NSF-funded curricula, all of the curricula except UCSMP had at least one category at 0%. Key Curriculum Press had the highest percentages overall. Among the NSF-funded curricula, Core-Plus and SIMMS had no categories at 0% and IMP had one category at 0%. Otherwise, all categories for the three curricula had percentages of at least 13% or higher.

The researcher also examined the percentage of active items that required transitional/higher-order thinking skills for each textbook. The results are shown in Table 12, with the actual numbers used to compute the percentages following each percentage. Although IMP had the highest percentage (100%), the percentage was based on a sample of only one active item. Core-Plus (86%) and SIMMS (57%) had the next highest percentages, both based on samples of seven active items. With the exception of Key, all of the non-NSF-funded curricula had an Infrequent occurrence of active items that required transitional/higher-order thinking skills.
Table 12. Active items that require transitional/higher-order thinking skills (number of items, total number of items reviewed).

<table>
<thead>
<tr>
<th>Textbook</th>
<th>Percentage</th>
<th>(number of items)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saxon</td>
<td>20%</td>
<td>(1/5)</td>
</tr>
<tr>
<td>Key</td>
<td>33%</td>
<td>(5/15)</td>
</tr>
<tr>
<td>Glencoe</td>
<td>9%</td>
<td>(1/11)</td>
</tr>
<tr>
<td>HRW</td>
<td>5%</td>
<td>(1/22)</td>
</tr>
<tr>
<td>McDL</td>
<td>6%</td>
<td>(1/16)</td>
</tr>
<tr>
<td>Prentice Hall</td>
<td>0%</td>
<td>(0/13)</td>
</tr>
<tr>
<td>UCSMP</td>
<td>8%</td>
<td>(1/12)</td>
</tr>
<tr>
<td>Core-Plus</td>
<td>86%</td>
<td>(6/7)</td>
</tr>
<tr>
<td>IMP</td>
<td>100%</td>
<td>(1/1)</td>
</tr>
<tr>
<td>SIMMS</td>
<td>57%</td>
<td>(4/7)</td>
</tr>
</tbody>
</table>

In summary, although the NSF-funded curricula were spread out amongst the frequency classification levels, indicating variability amongst the curricula in individual categories, the NSF-funded curricula more consistently had most categories falling well above 0%. Also, the NSF-funded curricula had the highest percentages of active items that required transitional/higher-order thinking skills. In contrast, the non-NSF-funded curricula had more low percentages overall and less consistency of categories falling well above 0%.
Results for Research Question 3

3. How do the textbooks mentioned in questions 1 and 2 make use of graphing calculator technology in the instructional materials that support their formal assessments? How do the textbooks from the NSF-funded curricula compare to the textbooks from the non-NSF-funded curricula in terms of graphing calculator use in the instructional materials that support their formal assessments?

Part 1 of Research Question 3

The researcher addressed the first part of research question 3 by collecting information on all ten curricula using the *Qualitative Data Checklist*. The first two items on the *Qualitative Data Checklist* are related to textbook goals for and extent of graphing calculator use. For these two items, the researcher looked at each textbook in its entirety. For the remaining items on the checklist, the researcher examined only those chapters or units that covered quadratic, exponential, and logarithmic functions. The third item on the checklist examines the request for justification in items that use a graphing calculator. Recall that the request for justification is specific to the type of question asked and applies if the question calls for justification, explanation, or proof. Based upon the data gathered, the following paragraphs highlight the salient features of each curriculum to provide a qualitative description of each curriculum.

**Saxon**

1. The Saxon textbook had no goals explicitly stated for graphing calculator use.

2. The extent of graphing calculator use in the textbook was infrequent. Of the textbook’s 129 lessons, eight of the lessons used a scientific calculator, with computation the only reason for calculator use.

3. No justification was requested on the problems that used a calculator.
4. Approximately the first five problems of every 30-problem exercise set were real-world, some of which employed a calculator for computation and required transitional/higher-order thinking skills.

5. The textbook examples were mostly procedural.

6. In general, some examples and exercises in the textbook required translation between different representations, but none that involved a graphing calculator.

7. With respect to teaching notes, the text included examples of how to use keystrokes for computation.

8. Saxon had no alternative assessments.

Key Curriculum Press

1. The Key textbook’s goals for graphing calculators were to fully integrate graphing calculators into its mathematical processes.

2. Graphing calculators were used extensively throughout the textbook, with every section of each chapter structured by hands-on investigations that employed a graphing calculator.

3. The request for justification was quite prevalent. Students were often asked to “provide a real-world meaning” for an answer.

4. Graphing calculator problems were usually set in a real-world context and were included in investigations, exercises, and projects.

5. The use of transitional/higher-order thinking skills was frequently required in investigations, examples, and exercises, as well as in the Teacher Resource Book’s open-ended and group problems.
6. The textbook used a graphing calculator for both computation and visualization, with investigations often involving translation between representations.

7. The teaching notes, included in the *Teacher’s Guide and Answer Key* (Key Curriculum Press, 1998), were mainly suggestions for when to use a graphing calculator, what features to use, and what to be aware of. For example, the notes suggested using the Table feature to explore and check answers.

8. Key’s textbook was also accompanied by *Blackline Masters for Calculator Notes TI-82 and TI-83* (Key Curriculum Press, 1998) which provided notes on the specifics of how to use a graphing calculator. For example, one note described how to program the calculator to use the quadratic formula.

**Glencoe**

1. Glencoe’s textbook had no specific goals for the use of graphing calculators, but stated simply that it “includes opportunities to use graphing calculators” (p.T22).

2. The overall extent of graphing calculator use in the textbook was infrequent. Graphing calculators were most typically used in examples to graph functions in order to check solutions to equations that were obtained using a paper-and-pencil method. Each chapter of the textbook had approximately one to two Graphing Calculator Investigations.

3. None of the exercises, examples, or investigations that utilized a graphing calculator specifically requested any kind of explanation. Investigations did ask questions like “Describe the relationship between the graphs” (p.524).
4. Two of the five graphing calculator investigations examined in Chapters 6 and 10 had a real-world context. Of the examples in Chapter 6, 12\% had a real-world context and integrated the use of a graphing calculator.

5. Chapter 6 (on quadratic functions and inequalities) employed a graphing calculator mainly for visualization (for checking answers) and Chapter 10 (on exponential and logarithmic relations) primarily for computation.

6. Chapters 6 and 10’s Graphing Calculator Investigations required transitional-higher order thinking skills and involved translation between representations.

7. Glencoe’s teaching notes related to graphing calculators were mainly associated with the Graphing Calculator Investigations. The notes included things to be aware of such as window dimensions and tips for additional classroom discussions or to clarify expectations for answers. Keystrokes were provided in the textbook.

Holt, Rinehart, & Winston

1. The textbook claimed to incorporate graphing calculators so that their use was “appropriate and promotes mathematical reasoning.” HRW viewed the graphing calculator as a powerful visualization tool.

2. Graphing calculators were heavily integrated throughout text via examples, activities, and pictures of what the graphing calculator screen is expected to look like.

3. Although justification was called for in both general activities and graphing calculator activities, it was rarely required in examples and exercises.

4. Each exercise set had numerous application problems that had a real-world context and required the use of a graphing calculator.
5. The use of transitional/higher order thinking skills in graphing calculator problems was expected in the activities and on occasion, in examples.

6. The textbook’s examples emphasized the use of a graphing calculator for visualization purposes, especially to graph functions in order to check solutions to equations that were obtained using a paper-and-pencil method. Examples typically showed two methods for solving a problem: graphic and numeric (table) or algebraic and graphic.

7. Regarding the teaching notes, an “Interleaf” for each chapter included a page on technology that indicated how a graphing calculator could be used for each lesson of the chapter and included ideas for questions to ask students. In addition, “Teaching Tips” on how to use a TI-82 or TI-83 graphing calculator to do things such as check maximum and minimum values accompanied some examples.

McDougal Littell

1. The textbook had no explicit goals for the use of graphing calculators.

2. The textbook’s use of graphing calculators (extent of use) was occasional, with each chapter of the textbook having approximately two Graphing Calculator Activities.

3. Very few examples and exercises that integrated a graphing calculator requested students to justify their reasoning.

4. An icon of the earth appeared next to real-world problems in the exercise sets, many of which required a graphing calculator for computation. A graphing calculator icon appeared next to approximately one to two examples and exercises per section that
explicitly wanted students to use a graphing calculator for visualization, and not solely to check an answer.

5. Students had to use transitional/higher-order thinking skills in some graphing calculator examples and word problem exercises, and in graphing calculator Activities in both the textbook and in the Chapter Resource Book.

6. Although infrequent, the most common translation between representations was the use of a graphing calculator to go from an algebraic to a graphic representation; namely to graph functions in order to check solutions to equations that were obtained using a paper-and-pencil method.

7. The textbook had very few teaching notes related to the use of graphing calculators. The blackline masters in the Chapter Resource Books included keystroke guides. Each Chapter Resource Book also had a “Tips for New Teachers” section, but the notes were limited to briefly mentioning that students might use a calculator to incorrectly evaluate the quadratic formula in Chapter 5. There were no tips in Chapter 8.

Prentice Hall

1. Prentice Hall’s textbook had no explicit goals for the use of graphing calculators. Graphing calculators were never mentioned at the beginning of the textbook.

2. The use of graphing calculators was not an integral part of the textbook and seemed like an optional appendage. A graphing calculator icon appeared next to some exercises and some examples that used a graphing calculator.
3. Overall, the textbook required very little justification. Technology Activities 5.1 and 8.1 each had one question that requested justification. The examples rarely requested justification.

4. The textbook claimed to have “abundant real-world connections” (p.T4) and the researcher found that, in general, many examples and exercises had a real-world context. The percentages of the examples that integrated a graphing calculator in a real-world context were as follows: 4% in Chapter 5 and 12% in Chapter 8.

5. The use of transitional/higher-order thinking skills was called for in the Technology Activities, and in some word problems in the exercises and examples.

6. Graphing calculators were used for both computation and visualization in the exercises and examples.

7. Translation between representations in the exercises occurred mostly between graphic and algebraic representations. The Extensions and Activities incorporated a numeric representation as well.

8. Prentice Hall’s teaching notes included Technology Tips for the exercises. For example, one tip on the CALC feature suggested how to select left and right bounds. The teaching notes for the (graphing calculator) Technology Activities and Extensions included ways to prevent calculator error, suggestions for how to use the graphing calculator, and tips on things to be aware of.

UCSMP

1. UCSMP believed students should have access to graphing calculators at all times.
2. Regarding the extent of graphing calculator use, graphing calculators were incorporated throughout the textbook. However, the use was not very obvious or explicit.

3. The textbook required very little justification. In fact, none of the textbook examples or In-class Activity items requested justification. In the ancillary Technology Sourcebook (on CD), Computer Master 10 on Fitting a Quadratic Model to Data had one “Explain your response.”

4. In Chapters 6 and 9 (on quadratic functions and on exponential and logarithmic functions, respectively), about one out of three in-class activities, about 10% of the exercises, and about half of the shorter activities had a real-world context and used a graphing calculator. About 25% of the examples in Chapter 6 and about 50% of the examples in Chapter 9 incorporated a graphing calculator in a real-world setting.

5. The use of transitional/higher-order thinking skills was required occasionally in-class activities and in examples and exercises.

6. Graphing calculators were used for both computation and visualization in examples and exercises. Furthermore, some examples incorporated a combination of the two.

7. Translation between representations with the graphing calculator was mainly to graph functions in order to check solutions to equations where the solutions were obtained using a paper-and-pencil method. The textbook also used tables (numeric representation).

8. The teaching notes in UCSMP provided some suggestions for when and how to use a graphing calculator. Also, the notes highlighted things to be aware of related to
graphing calculators. None of the notes were specifically labeled as “Technology Tips.”

Core-Plus

1. Core-Plus stipulated that graphing calculators should be used in an appropriate manner throughout the curriculum and that calculators should be available for assessments.

2. The textbook’s extent of graphing calculator use depended on the topic. The small group investigations called “Explore” used a graphing calculator for computations with real data and for explorations using the graphing (visualization) capabilities of a graphing calculator.

3. With regard to the request for justification in graphing calculator problems, students were frequently required to “explain the meaning” in small group investigations that structure each lesson, in the independent assignments, and in the MORE (Modeling, Organizing, Reflecting, Extending) section.

4. For the most part, real-world contexts were frequently used in all parts (investigations, independent assignments, MORE) of the textbook’s units. The real data necessitated the use of a graphing calculator.

5. Items that required the use of transitional/higher-order thinking skills were prevalent in the investigations and independent assignments.

6. Graphing calculators were utilized throughout the textbook for both computation and visualization.
7. Core-Plus frequently used the graphing calculator’s TABLE feature to translate between numeric and graphic representations. The following example demonstrates an investigation problem on vertical stretching and shrinking that engaged three different representations: Use your calculator to compare graphs and tables of values for these four functions: \( c(x) = \cos x \), \( d(x) = 5\cos x \), \( e(x) = 0.5\cos x \), \( f(x) = 5\cos x - 2 \), and then describe how the functions are similar and different for \(-2\pi \leq x \leq 2\pi\) (p. 450).

8. Core-Plus’ teaching notes were quite thorough and detailed for each unit. The notes provided explanations for things such as graph behavior, and suggestions for what to look out for and make sure students do. For matters related to facilitating graphing calculator use, the notes showed what graphs and tables should look like, gave tips on window selection, and offered suggestions for questions to ask.

IMP

1. The IMP curriculum stated that graphing calculators are an integral part of the development of mathematical ideas that allow students to focus on ideas rather than on computation. Furthermore, graphing calculators should be available to students at all times, including assessments.

2. The use of graphing calculators was definitely part of IMP’s textbook, but the extent of use was not heavy and was not very explicit. Many of the textbook’s problems were graphing calculator neutral, making graphing calculator use appear to be optional.
3. The textbook’s “Classwork” problems that integrated graphing calculators requested students to explain their reasoning.

4. Regarding graphing calculator items set in a real-world context, the Fireworks unit’s Classwork was not real-world, but the Small World unit’s Classwork was real-world. The homework mirrored the Classwork.

5. The Classwork problems and Supplemental problems involved transitional/higher-order thinking skills, whereas these skills were less extensively required in the homework.

6. IMP used graphing calculators for both computation and visualization.

7. The most typical translation between representations was algebraic to graphic.

8. The teaching notes, provided in the Teacher’s Guide, included suggestions for discussing and going over homework, questions to ask, limitations of the graphing calculator, and what to expect. None of the notes were specifically labeled as “technology tips”; rather the notes related to the use of technology were embedded in the teaching notes.

SIMMS

1. The SIMMS curriculum professed to take full advantage of the appropriate use of technology and believed technology is necessary to achieve curricular goals. In addition, a graphing calculator must be readily accessible to students.

2. Regarding SIMMS’ extent of use, all of the activities in the three modules the researcher closely examined had a graphing calculator on the required materials list. However, the graphing utility was not heavily utilized in the activities. Some of the
problems in each module explicitly said to use a graphing utility and for some, it was unclear whether or not a graphing utility should be used.

3. Some of the activities and associated assignments called for justification, but inconsistently. Justification was requested more in the Discussions part of the activity.

4. About 50% of the assignment problems were real-world and were often science applications. It was not uncommon for activity, assignment, and summary assessment problems to start out in a real-world context, but then the actual questions based on these problems were not framed in a real-world context.

5. Activity Explorations and Discussions, homework problems, and Summary Assessments typically entailed the use of transitional/higher-order thinking skills.

6. The SIMMS textbook referred to the graphing calculator as a graphing utility and used it noticeably more for visualization (graphing, modeling) than for computation. The textbook rarely utilized the graphing calculator for computation.

7. The curriculum frequently translated between all three different representations with the assistance of a graphing utility.

8. The teaching notes had no specific section of technology tips. The “Teacher Note” part of the Teacher Edition had general notes on each activity, including things to point out to students, but very little about the use of a graphing calculator. One example of a note follows: “When using a graphing utility, students should plot points so that both a scatterplot and a function can be illustrated simultaneously.” (Drafting & Polynomials, p.129).
Part 2 of Research Question 3

The following results address the second part of research question 3, comparing the instructional materials of the NSF-funded curricula to those of the non-NSF funded curricula by pointing out trends, similarities, and differences based on each question of the checklist.

**Goals for Graphing Calculator Use** For the non-NSF-funded curricula, with the exception of Key, HRW, and UCSMP, four of seven curricula had no explicit or specific goals regarding the use of graphing calculators. Each of the NSF-funded curricula along with Key, HRW, and UCSMP claimed to incorporate the use of graphing calculators throughout the textbook. All three NSF-funded curricula described graphing calculators as an integral part of the curriculum to assist in the development of mathematical thinking and believed that graphing calculators should be available to students at all times, including on assessments. Three of the non-NSF curricula and all of the NSF curricula had some kind of goals for graphing calculator use.

**Extent of Graphing Calculator Use** The non-NSF-funded curricula of Key, HRW, and UCSMP integrated graphing calculators throughout the text, and in fact, Key and HRW heavily used graphing calculators. For UCSMP, graphing calculators were used throughout the textbook but their use was not as explicit, indicated by a lack of graphing calculator icons and screen pictures. For the other four non-NSF curricula, the use was more incidental, appearing in separate activities like an appendage. For the NSF-funded curricula, the graphing calculator use by Core-Plus depended on the topic, the use by IMP seemed to be treated more as an option, and the use by SIMMS was not required
extensively within the activities and homework. For UCSMP and the NSF-funded curricula, the actual use of graphing calculators was not as extensive as the goals may have indicated.

**Request for Justification in Graphing Calculator Problems** Among the non-NSF curricula, Key extensively requested justification. HRW called for justification in graphing calculator activities, but rarely requested it in examples and exercises. Otherwise, for the other five non-NSF curricula, very little or no justification was required. For the NSF curricula of Core-Plus and IMP, the use of justification was frequently requested. For SIMMS, the primary requests for justification were in the Discussions and in the activities and their associated assignments. In general, SIMMS’ call for justification was inconsistent. The majority of the non-NSF textbooks did not request justification in problems that used a graphing calculator whereas all of the NSF textbooks frequently requested justification.

**Graphing Calculator Problems Set in a Real-World Context** All seven of the non-NSF curricula utilized a graphing calculator for real-world problems. However, the reason for use and the extent of use depended on the curriculum. Saxon had some real-world problems that used a scientific calculator for computation. McDL included many real-world problems in which a graphing calculator was used for computation. HRW had numerous real-world exercises that integrated a graphing calculator. Key consistently took advantage of using a graphing calculator where the use of technology was beneficial, and this usually involved a real-world problem situation. Finally, Prentice Hall had many problems set in a real-world context, but a low percentage of those
problems incorporated the use of a graphing calculator. For the NSF curricula, Core-Plus frequently had real-world problems that used a graphing calculator. For IMP, the Fireworks unit had none and the Small World unit had some. Regarding SIMMS, about 50% of the activities, exercises, and summary assessment items were initially presented in a real-world context, but the questions were not framed in a real-world context.

**Use of Graphing Calculator for Computation or Visualization** The use of a graphing calculator for computation and/or visualization depended on the curriculum. The curricula that used a graphing calculator for both computation and visualization were Key, Glencoe, McDL, Prentice Hall, UCSMP, Core-Plus, and IMP. Saxon used a graphing calculator (scientific) for computation only whereas, HRW and SIMMS emphasized its use for visualization. There were no distinct differences between the NSF and non-NSF curricula on whether a graphing calculator was used for computation or visualization.

**Translation between Different Representations** With the exception of Saxon, all of the non-NSF and NSF curricula utilized a graphing calculator to translate between different representations. For Glencoe, HRW, McDL, and UCSMP, the use was often to graph functions in order to verify solutions to equations that were obtained using a paper-and-pencil method. Core-Plus often used the TABLE feature to go between numeric and graphic representations. IMP typically translated from an algebraic to a graphic representation, and SIMMS utilized all three representations as a routine part of mathematical modeling. The non-NSF curricula most commonly translated from an
algebraic to a graphic translation, whereas the NSF curricula were more likely to translate between all three representations.

**Teaching Notes** The teaching notes varied between each curriculum. The following numerals highlight the trends that were discovered in the teaching notes amongst select curricula.

i. Things to be aware of regarding graphing calculator use: Key, Glencoe (Graphing Calculator Investigations), McDL (only one item in Ch. 5), Prentice Hall, UCSMP, Core-Plus, and IMP.

ii. Keystroke guidelines for how to use a graphing calculator to perform certain operations: Saxon, Key (in “Calculator Notes” book for TI-82, 83), Glencoe, HRW (“Teaching Tips” on how to use TI-82, 83 accompanied some examples), and McDL (Chapter Resource Books).

iii. Suggestions for when and how to use a graphing calculator: Key, HRW, Prentice Hall, UCSMP, and Core-Plus.

iv. No notes or section specifically labeled as technology tips: Saxon, UCSMP, IMP, and SIMMS.

Overall, HRW and Core-Plus had the most extensive teaching notes. HRW had an “Interleaf” page on the use of technology and how a graphing calculator could be used for each section of a chapter as well as ideas for questions to ask students. HRW also had “Teaching Tips” for things such as how to check a maximum/minimum value or how to set a viewing window. Core-Plus had an elaborate Teaching Notes section for each unit that included very specific notes such as explanations for graph behavior and what graphs
and tables should look like, tips for window selection, suggestions for facilitating
graphing calculator use, and questions to ask. Overall, there were no striking similarities
or differences between the non-NSF and NSF curricula’s teaching notes.

**Miscellaneous** With the exception of Key, for the non-NSF group, there was very
little or only some use of transitional/higher-order thinking skills in the exercise sets and
examples. For HRW, McDL, and Prentice Hall, transitional/higher-order thinking skills
were more commonly called for in the graphing calculator activities. For the NSF group,
the use of transitional/higher-order thinking skills was prevalent for all three curricula;
more so for Core-Plus and SIMMS than for IMP.

Regarding ancillary assessment materials for the textbooks, all curricula (except
Saxon, IMP, and SIMMS) had some type of Assessment or Chapter Resource Book.
IMP had Supplemental problems that typically required the use of transitional/higher-
order thinking skills. Overall, as compared to the textbooks, the non-NSF group’s
ancillary materials that incorporated graphing calculators required slightly more
justification and transitional/higher-order thinking skills. Otherwise, the ancillary
materials for both groups did not stand out as being dramatically different from the
textbooks.

**Summary of Results**

The following summarizes the results of all three of the research questions and
connects the qualitative data to the quantitative data. Explanations are included about
how the qualitative data gathered for research question 3 shed light on the quantitative
data collected for research questions 1 and 2. Each of the ten curricula is discussed initially to address the first part of the three research questions, followed by a comparison of the NSF group to the non-NSF group to address the second part of the first two research questions. The second part of the third research question is addressed in Chapter 5 in the discussion on curriculum alignment.

The Ten Curricula

Of the ten curricula examined in the study, Saxon least frequently incorporated graphing calculator technology into its formal assessments, with an Infrequent occurrence of both active and explicit/implicit items. However, these results were not unexpected because the Saxon textbook had no goals for the use of graphing calculators, with only eight of its 129 lessons using a scientific calculator (for computation). Although the percentages for the six categories used to examine the quality of graphing calculator use on Saxon’s formal assessments were quite low overall, these results were actually higher than the qualitative data from the textbook might predict. However, a 0% in the Request for Justification category could be explained by the fact that the Saxon textbook required no justification on the problems that used a calculator. A notable weakness was the NoSimplification category at 0% (0/18), possibly suggesting a need for Saxon to attend to whether a graphing calculator inappropriately simplifies formal assessment items. Taking into account sample sizes, Saxon had the greatest number of items (8) that required transitional/higher-order thinking skills, despite the fact that Saxon’s percentage (29%) was not the highest in this category. Saxon had a low percentage (11%) in the
Visualization category, but had 3 (of 28) items in this category, a higher number of items than did IMP (2/5) at 40%.

Of all ten curricula, Key had the most frequent incorporation of graphing calculators into its formal assessments, with a Frequent occurrence classification for both active and explicit/implicit items. This frequent graphing calculator use followed logically from the extensive integration of graphing calculators throughout the textbook. Five of the six categories that looked at the quality of graphing calculator had percentages at 33% or higher. These high percentages could be explained by the textbook’s frequent requests for justification, real-world contexts, and transitional/higher-order thinking skills in problems that utilized a graphing calculator. Key’s only weakness was a 0% (0/6) in the NoSimplification category, possibly indicating a need to consider whether a graphing calculator inappropriately simplifies formal assessment items.

Glencoe’s textbook had no specific goals for graphing calculator use and the main use of graphing calculators in the textbook was in one to two Graphing Calculator Investigations per chapter. These facts might help explain why the curriculum had an Infrequent occurrence classification for both active and explicit/implicit items. Glencoe’s most notable quality was the Visualization category, with 23 out of 43 items (54%), the largest number of items in this category of any of the ten curricula. The textbook most typically used a graphing calculator to visually check solutions to equations that were obtained using a paper-and-pencil method and this might help to account for the higher percentage in the Visualization category. Otherwise, percentages in the other quality categories were quite low. A 0% in the Request for Justification category could be explained by the fact that none of the exercises, examples, or investigations in the
textbook that utilized a graphing calculator specifically requested any kind of explanation. The requirement of transitional/higher-order thinking skills was limited to the Graphing Calculator Investigations, giving some indication as to why the TransHi category had a low percentage. Keep in mind that although Glencoe had a low percentage (2%) in the TransHi category as compared to IMP (20%), the 1 item (out of 43) in this category was the same as IMP (1 out of 5).

The widespread integration of graphing calculators by the HRW textbook shed light on why the curriculum had a frequent extent of graphing calculator use in the formal assessments. HRW, in the highest cluster of Figure 5, had a Somewhat Frequent occurrence of active items and a Frequent occurrence of explicit/implicit items. The textbook viewed the graphing calculator as a powerful visualization tool. HRW had detailed and thorough teaching notes related to the use of graphing calculators that provided ideas for how to use a graphing calculator for each lesson and for questions to ask students, further indicating the textbook’s attention to the appropriate use of graphing calculators. However, of the six categories used to measure quality, HRW’s highest percentage was 27% in the NoSimplification category. The low percentage of 0% in the Request for Justification category might follow from the fact that the textbook rarely requested justification in exercises and examples, although some justification was called for in graphing calculator activities. Given that HRW viewed the graphing calculator as a powerful visualization tool and emphasized its use for visualization purposes, one might expect a classification higher than Infrequent (19%) in the Visualization category. Furthermore, because each exercise set had numerous application problems that had a real-world context and that required the use of a graphing calculator, one might anticipate
a percentage higher than 26% in the Realworld category. Similarly to Glencoe, HRW also had a low percentage (2%) in the TransHi category as compared to IMP (20%), although both HRW and IMP had 1 item in this category.

Given that McDL’s extent of use was relatively frequent, with the Indication of Graphing Calculator Use and Graphing Calculator Technology Level both having Somewhat Frequent classifications (see Figure 5), it was surprising that the textbook had no explicit goals for the use of graphing calculators, with only occasional use of graphing calculators. McDL’s highest percentage was 41% (17/42) in the Visualization category. A low percentage of 5% in the TransHi category might be explained by the fact that students had to use transitional/higher-order thinking skills in the textbook only for some graphing calculator examples and word problem exercises, and for graphing calculator activities. A Somewhat Frequent occurrence of items (28% or 13/47) in the InterpretMake category was higher than expected given that the textbook infrequently used a graphing calculator for translations between representations. It should be noted that although McDL had a low percentage (5%) in TransHi, McDL had 2 (out of 50) items in this category, a greater number of items than IMP’s 1 item.

Prentice Hall’s textbook had no explicit goals for the use of graphing calculators and the use of graphing calculators was not an integral part of the textbook. Thus, with a Somewhat Frequent occurrence of explicit/implicit items, the extent of graphing calculator use in formal assessments was slightly higher than anticipated. Although Prentice Hall had a total of four quality categories in the reasonably balanced range, the percentages in these four categories ranged between 19% (in RealWorld) and 32% (in Visualization). Prentice Hall had 0% in two categories: Request for Justification and
The low percentage in the Request for Justification category could be accounted for by the fact that the textbook seldom requested justification of answers. However, because the Technology Activities and some word problems in exercises and examples in the textbook called for transitional/higher-order thinking skills, one would expect the percentage in the TransHi category to be higher than 0% (0/47).

Because UCSMP believed students should have access to graphing calculators at all times and because graphing calculators were incorporated throughout the textbook, though not explicitly, the extent of graphing calculator use in the formal assessments was lower than expected. The Indication of Graphing Calculator Use and Graphing Calculator Technology Level categories both had Infrequent classifications. UCSMP had no categories at 0%. It should be noted that although the percentages in the categories of Visualization, Real-World, and NoSimplification were not among the highest, the number of items in each of the three categories was high. For example, UCSMP had 24% in the RealWorld category, with the highest number of items (12) in this category of any curriculum. A percentage of 24% in the RealWorld category aligned with the textbook’s use of graphing calculator exercises, examples, and activities that had a real-world context. A high percentage of 38% in the Visualization category followed from the textbook’s use of graphing calculators for both computation and visualization. The textbook had very few requests for justification of answers, which helped to account for the low percentage of 6% in the Request for Justification category. Given that some of the in-class activities, exercises, and examples in the textbook called for transitional/higher-order thinking skills, a 4% in the TransHi category was lower than anticipated. Taking into account sample sizes, despite the fact that UCSMP had low
percentages in the TransHi (4%) and Request for Justification (6%) categories, due to UCSMP’s larger sample of items, UCSMP had a larger number of items in these categories as compared to IMP. UCSMP had 2 items (out of 50) in TransHi as compared to IMP’s 1 item (out of 5), and UCSMP had 3 items in Request for Justification whereas IMP had 2 items.

Although the Core-Plus textbook stipulated that graphing calculators should be used throughout the curriculum and that calculators should be available for assessments, the textbook’s extent of graphing calculator use depended on the topic. Indeed, the extent of graphing calculator use in the formal assessments, with both the Indication of Graphing Calculator Use and Graphing Calculator Technology Level categories at 24% (Infrequent), was lower than expected. Regarding the quality of graphing calculator use, however, Core-Plus had all six quality categories with percentages at 28% or higher. The high percentages in each category were consistent with the textbook’s treatment of the matters related to each category. Furthermore, the teaching notes related to graphing calculator use were extensive, demonstrating the curricula’s attention to the use of graphing calculators in an appropriate manner.

Despite the IMP textbook’s belief that graphing calculators were an integral part of student learning and that graphing calculators should be available to students at all times, the use of graphing calculators in the textbook was not widespread. Both the occurrence of active items and of explicit/implicit items was Infrequent. Many of the textbook’s problems were graphing calculator neutral, which helps to explain why only 13% of the formal assessment items were graphing calculator active. In spite of the low
extent of graphing calculator use in the textbook and the formal assessments, five of the six quality categories had percentages at 20% or higher.

It should be noted that the number of formal assessment items examined might have been a factor in the results for IMP. The formal assessments for the two units examined contained a total of only eight items. Although the grain size of these assessment items was generally larger than a typical formal assessment item from the non-NSF curricula, the grain size was not larger than formal assessment items from the other NSF curricula. The highest percentage was 80% in the RealWorld category, but this was based on a sample of only five items. Of the two units examined, one was set in a real-world context and four out of five of the unit’s assessment items had a real-world context. IMP’s next highest percentage, 75% (3/4), was in the NoSimplification category. The percentages in the other categories were consistent with the textbook’s handling of the issues related to each category, with the exception of the InterpretMake category. The percentage in the InterpretMake category was 0%, inconsistent with the textbook’s inclusion of translation between algebraic and graphic representations.

SIMMS’ extent of graphing calculator use in the formal assessments was the highest overall for the three NSF curricula, with a percentage of 39% (Somewhat Frequent) in both the Indication of Graphing Calculator Use and Graphing Calculator Technology Level categories. This relatively frequent extent of use was supported by the SIMMS textbook’s profession to take full advantage of the appropriate use of technology and belief that technology is necessary to achieve curricular goals. SIMMS’ highest percentage was 88% in the NoSimplification category. The second highest percentage of 68% in the Visualization category went hand-in-hand with the fact that the textbook used
a graphing calculator much more for visualization purposes than for computation. The lowest percentage was 13% in the RealWorld category and this could be explained by the fact that the textbook problems were often presented in a real-world context, but then actual questions were not framed in a real-world context. The SIMMS textbook’s frequent translations between all three different representations using a graphing calculator might help to explain why the InterpretMake category percentage was 53%, the highest percentage of all ten curricula in this category.

Comparison of NSF-Funded Group to Non-NSF-Funded Group

The following comparison of the NSF-funded group to the non-NSF-funded group addresses the second part of the first two research questions. Regarding the first research question, the overall extent of graphing calculator use for the two curricular groups was different than what the researcher expected. The extent of use was lower than anticipated for the NSF-funded curricula and higher than expected for the non-NSF-funded curricula. The researcher’s expectations were based on the fact that although there is some leeway in how one interprets the overall intentions of the *Principles and Standards for School Mathematics (PSSM)* (NCTM, 2000) regarding the use of graphing calculators, when it comes to the topics specifically considered in this study, there should be no doubt that the stance of the *PSSM* is on the strong side of graphing calculator usage. Thus, given that the NSF-funded curricula are all explicitly *Standards-based*, the researcher expected a greater frequency of graphing calculator use within this group. In the cluster analysis of the scatterplot (see Figure 5) of the categories used to examine the extent of use, the NSF-funded curricula were clustered in two different clusters; the
lowest cluster and the middle cluster, set apart roughly by the dotted lines on the scatterplot. The researcher expected the NSF-funded curricula to be grouped together in the highest cluster.

In the overall comparison of the quality of graphing calculator use in formal assessments between the two curricular groups, of the six categories employed to measure quality of graphing calculator use, the NSF-funded curricula had fewer categories with low percentages and more categories with higher percentages. Furthermore, although based on smaller sample sizes, the NSF-funded curricula had the highest percentages of active items that required transitional/higher-order thinking skills (see Table 12). These facts demonstrated a greater consistency in the NSF-funded curricula’s quality of graphing calculator use. However, when the Frequency Classification Levels are factored in, there is still room for improvement in certain categories for each of the three curricula.

In contrast, on the whole, the non-NSF group had more categories with low percentages and fewer categories with high percentages. Key was an exception in this group with five of the six categories having higher percentages. All of the curricula in the non-NSF group had lower percentages in the NoSimplification category than the NSF group. Overall, the non-NSF-funded curricula showed a difference from the NSF group in the quality of graphing calculator use, with less consistency and lower percentages.
CHAPTER 5

CONCLUSIONS

Introduction

The purpose of this chapter is to present conclusions and implications, discuss limitations and delimitations of the study, and provide recommendations for further research.

Conclusions

A detailed analysis of the results in order to draw conclusions based on the three research questions posed in this study demonstrates that the issue of analyzing and comparing curricula on the extent and quality of graphing calculator use in formal assessments does not present a clear picture. In fact, the issue is very complex with many variables involved, and is further complicated by the fact that the *PSSM* (NCTM, 2000) does not provide detailed, quantifiable statements about the appropriate use of graphing calculators in teaching and learning mathematics, and specifically in formal assessments. Thus, an analysis of the results of this study raises many tough questions, with answers that are not clean cut. Some of the questions raised include the following: “What is considered ‘enough’ for the extent and quality of graphing calculator use?”, “To what degree should we request justification in problems where a graphing calculator could be used?”, “What percentage of formal assessment items (where a graphing calculator could be used) should require a student to use transitional/higher-order thinking skills?”, and “If we want to have a ‘reasonable balance’ of items (graphing calculator active or neutral) in
each of the quality categories, what does that mean?” In particular, “What is meant by a Standards-based used of graphing calculators?” Answers to these questions will vary, depending on curricular goals and how the PSSM (NCTM, 2000) is interpreted.

The following paragraphs hypothesize three cases, where each case uses a different quantitative descriptor of what might constitute a Standards-based use of graphing calculators. For each case, conclusions based on the results of this study are presented.

Case 1: Suppose we believe that “some” is sufficient to represent a Standards-based use of graphing calculators regarding the extent and quality of graphing calculator use in the formal assessments. If we believe that “some” is sufficient, then the extent of graphing calculator use was Standards-based for all ten curricula because all ten curricula had percentages of more than 0% for active items and for explicit/implicit items. The ten curricula also demonstrated an overall Standard-based use of graphing calculators with respect to the quality of use, with the following exceptions, quality categories where the curricula had 0%: TransHi – Prentice Hall; Request for Justification – Saxon, Glencoe, HRW, McDL, and Prentice Hall; InterpretMake – IMP; NoSimplification – Saxon and Key (see Figure 23). In comparing the NSF group to the non-NSF group, the extent of use was comparable but the NSF group demonstrated a higher quality of use with fewer 0%’s relative to the number of curricula in the group.

Case 2: Suppose we believe that a percentage of 15% or higher in the extent and quality of use categories represents what we think is a “reasonable balance” of quality and sufficiently demonstrates a Standards-based use of graphing calculators. Then, all of the curricula except Saxon and IMP demonstrated a Standards-based extent of use. For
the quality of use of the NSF-funded curricula, Core-Plus had a Standards-based use in all categories, IMP showed a Standards-based use in all categories except InterpretMake, and SIMMS had a Standards-based use in all categories except RealWorld. For the quality of use of the non-NSF-funded curricula, Key demonstrated a Standards-based use in all categories except for NoSimplification. Otherwise, the remaining curricula had a Standards-based use in two to four categories (see Figure 23). Overall, there was no significant difference in the extent of use for the two groups, but the NSF group had more categories (relative to the number of curricula in the group) exhibiting a Standards-based quality.

Case 3: Suppose we believe that a percentage of 50% or higher in the extent and quality of use categories represents what we think is a “reasonable balance” of quality and sufficiently demonstrates a Standards-based use of graphing calculators. Regarding extent of use, Key was the only curriculum that demonstrated a Standards-based extent of use for both active and explicit/implicit items. HRW had a Standards-based extent of use for explicit/implicit items, but not active items. For the NSF group, Core-Plus, IMP, and SIMMS all had a Standards-based quality of use in two or three categories. In contrast, for the non-NSF group, only Glencoe had one category (Visualization at 54%) with a Standards-based quality (see Figure 23).

The three different cases illustrate that depending on what is believed to represent a Standards-based use of graphing calculators with respect to extent and quality of use, conclusions will vary. In addition, the three cases show that because of the many factors involved, it is not clear exactly how to justify a rigid definition of Standard-based use of graphing calculators. For example, are Saxon’s formal assessments Standards-based?
The answer depends on the degrees to which value is placed on extent of use and the various qualities of use. If a 0% in the Justification and NoSimplification categories or the fact that only 11% of the active or neutral items utilized a graphing calculator for visualization purposes are considered compatible with Standards-based, then Saxon’s formal assessments could be considered Standards-based.

Another issue related to the lack of clarity of what is considered “enough” for the extent and quality of graphing calculators use is that research has not answered this question in order to justify recommendations to teachers. Therefore, teachers really have very little to go on regarding graphing calculator use in the classroom and on formal assessments. Should the PSSM (NCTM, 2000) be more explicit? More research is needed to shed light on what is most beneficial for student learning in the classroom.

In spite of these issues, this study has provided a rubric (the Graphing Calculator Use Rubric) and a method for collecting and analyzing data to provide a basis for conducting a somewhat objective evaluation. An important and significant outcome of this study is that it reveals, in spite of the complex issues involved, that the curricula are not that same in terms of graphing calculator use and that there are differences, not only between the ten curricula, but also between the NSF group and the non-NSF group. This finding of differences in graphing calculator use between the curricula is similar to May (1994), who found significant differences between four pre-calculus textbooks and their uses of graphing calculators.
Implications for Curriculum

The results of this study, combined with findings from the related research and a reasonable reading of the *PSSM*, suggest some implications for the curricula from both the NSF-funded and non-NSF-funded groups. A rubric constructed by the researcher and based on the recommendations of the *PSSM* (NCTM, 2000) was used to collect data for researcher questions 1 and 2 of this study. The researcher purposively examined formal assessments from the chapters or units/modules in the textbooks that covered the topics of quadratic, exponential, and logarithmic function; topics identified as particularly amenable to the use of graphing calculators. Thus, the formal assessment sample consisted of items where graphing calculators could most likely be incorporated.

The *PSSM* recommends that graphing calculators should be integrated into teaching, learning, and doing mathematics (NCTM, 2000, p.24). Research question 1 addressed the extent to which formal assessments that accompany third-year NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF-funded curricula incorporate graphing calculator technology. The results of the study suggest that if even a 15% usage rate is considered Standards-based for the extent of graphing calculator use, Saxon and IMP should include more active items in their formal assessments.

To answer the second research question, the rubric was used to analyze the quality of graphing calculator use in formal assessments that accompany third-year NSF-funded curricula and that accompany algebra 2 textbooks used in non-NSF funded curricula. According to the *PSSM*, graphing calculators should be used to facilitate the connection between procedural skills and conceptual understanding (NCTM, 2000, p.23) and to solve more complex problems (NCTM, 2000, p.26). The *PSSM* recommendations, along
with research related to the cognitive level of test items (Goldenberg, 2000; Harpster, 1999; Madaus et al., 1992, Romberg et al., 1992; Senk et al., 1997; Taylor, 1991), precipitated the researchers’ examination of transitional/higher-order thinking skills in assessment items involving calculators. Five of the seven non-NSF funded curricula infrequently required transitional/higher-order thinking skills in graphing calculator active or neutral items. Upon closer examination of items that were strictly graphing calculator active, the researcher found that the non-NSF-funded curricula infrequently required transitional/higher-order thinking skills and that the NSF-funded curricula frequently or very frequently required transitional/higher-order thinking skills. To increase the likelihood of being considered Standards-based, these findings suggest a need for the non-NSF-funded curricula to work on increasing the number of active or neutral items in formal assessments that call for transitional/higher-order thinking skills.

The PSSM recommends that graphing calculators be used for mathematical modeling, studying changes in parameter and classes of functions, formulating and exploring conjectures, and representing and studying the behavior of functions (NCTM, 2000, p.25, p.26, p.297, p.299). These are all examples of using a graphing calculator for visualization purposes as opposed to computation. Numerous other researchers, including Kennedy, Vasquez, and Huber (2003), Lindsay (2000), and Taylor and Miitag (2001) also provided examples of using a graphing calculator for visualization purposes. If a Standards-based quality of use for visualization purposes is considered to be higher than 11%, Saxon should place more emphasis on using a graphing calculator for visualization purposes.
The instrument used to collect data on test items in the study by Senk et al. (1997) included a “Reasoning required” category (see Appendix C). In problems that are solved using a graphing calculator, students should be able to justify and explain the reasoning behind their solutions (NCTM, 2000, p.342). The researcher found six of the seven non-NSF-funded curricula requested very little or no justification at all. Again, to be considered Standards-based, these results suggest that with the exception of Key, the non-NSF-funded curricula should request students to provide more justification of answers on assessment items in which students might use a graphing calculator.

The PSSM calls for the use of graphing calculators to study real-world problems. Senk et al. (1997) also examined whether test items had a real-world context. The researcher examined graphing calculator active or neutral assessment items that had a real-world context. The results suggest that Glencoe and SIMSS might increase the number of graphing calculator problems set in a real-world context in their formal assessments.

Assessment items that required students to interpret or make a graph (or table) in the Role of Graph category on the researcher’s rubric addressed the PSSM’s recommendation for use of the graphing calculator to facilitate translating and making connections between multiple representations (algebraic, numeric, and graphic) (NCTM, 2000, p.354, p.360, p.363). The researcher found that IMP had a 0% in the InterpretMake category. This result suggests that IMP should create more formal assessment items in which students have to interpret or make a graph or table.

The Simplification category dealt with the issue of assessment items where the use of a graphing calculator simplified or significantly changed the intended objective(s)
of the item (Goldenberg, 2000; Harvey, 1992). This categorization pertained only to those items that were coded none on Indication of Graphing Calculator Use and neutral on Graphing Calculator Technology Level. In the Simplification category, both Saxon and Key had a 0%, and McDl had a 4%. These results suggest the need for the assessment items of these three curricula to be written with increased awareness of the fact that students will most likely have access to a graphing calculator and that the use of a graphing calculator could simplify or significantly change the intended objective of the item.

In the overall comparison the two curricular groups, the NSF-funded curricula stood out as having a better chance of reflecting the recommendations of the *PSSM* (NCTM, 2000) related to quality of graphing calculator use. Among the non-NSF-funded curricula, Key Curriculum Press had categories most consistently demonstrating higher percentages. However, because of the textbook’s focus on the integration of graphing calculators, this was not unexpected. The lack of consistency in some of the NSF-funded curricula’s individual categories demonstrated that there is still room for improvement in certain categories. For example, IMP could include some assessment items in which students are required to make or interpret a graph or table. SIMMS could increase its percentage of graphing calculator-appropriate assessment items set in a real-world context.

On the whole, although the non-NSF-funded curricula’s extent of use was higher than expected and the quality reflects some recommendations of the *PSSM* (NCTM, 2000) regarding the use of graphing calculators, these findings suggest the need for an improvement in the non-NSF-funded curricula’s quality of graphing calculator use in
multiple categories, with the categories depending on the curriculum. These findings were similar to the findings of studies by Madaus et al. (1992), Senk et al. (1997), and Taylor (1991); studies that found that test items associated with non-NSF-funded high school mathematics textbooks do not fully reflect the recommendations of the NCTM Standards (1989, 2000). Despite the NSF-funded curricula’s extent of use being lower than expected, the NSF-funded curricula’s formal assessment quality has a better chance of satisfying the recommendations of the PSSM (NCTM, 2000) regarding the use of graphing calculators. Martin et al. (2001) found the five NSF-funded textbook series were in alignment with the PSSM (NCTM, 2000). The findings associated with the NSF group’s quality of graphing calculator use in the current study were compatible with the findings of Martin et al. (2001).

Curriculum Alignment

To supplement the quantitative data collected from the formal assessments, the third research question qualitatively examined how the textbooks made use of graphing calculator technology. According to Wiggins and McTighe (1998), assessments should be determined by goals and standards. In order to examine the alignment of the curricula between goals and assessments as part of the theoretical framework for this study, the researcher identified each curriculum’s explicitly stated goals for graphing calculators use in the textbooks and each curriculum’s practices in the textbooks related to the extent and quality of graphing calculator use.

The stated goals on the use of graphing calculators varied between each curriculum. The non-NSF-funded curricula of Saxon, Glencoe, McDougal Littell, and
Prentice Hall had no explicit goals regarding the use of graphing calculators and for the latter three curricula, graphing calculator use seemed optional. The interpretation of the results for these four curricula must take this fact into account. If a curriculum does not explicitly claim to integrate graphing calculators, as was the case for Saxon, Glencoe, McDougal Littell, and Prentice Hall, then one cannot expect a high extent or quality of graphing calculator use in the formal assessments of these curricula. The non-NSF-funded curricula of Key, HRW, and UCSMP and the three NSF-funded curricula stated explicit goals for graphing calculators and incorporated graphing calculators throughout their textbooks. The stated goals and assessments for these curricula appeared to be in general alignment for all ten curricula.

The majority of the curricula in both groups demonstrated a general consistency between the extent of use in the textbook and the extent of use in formal assessments. The most transparent inconsistency was shown by UCSMP with fairly frequent use in the textbook but an infrequent use in the formal assessments relative to the other curricula. The quality of use of graphing calculators in the formal assessments was also in general alignment with the quality of use of graphing calculators in the textbooks for both groups, with some inconsistencies in the TransHi, RealWorld and InterpretMake categories. An inconsistency was determined by a conspicuous difference between the quality related to the category in the textbook and the quality (based on the category percentage) in the formal assessments. In the NSF group, SIMMS had one inconsistency in the RealWorld category and IMP had one inconsistency in the InterpretMake category. In the non-NSF group, Saxon and Prentice Hall each had inconsistencies in the TransHi category, Prentice Hall had an inconsistency in the RealWorld category, and Saxon, Glencoe,
HRW, and McDL all had inconsistencies in the InterpretMake category. Most of the inconsistencies were related to quality of use.

How the textbooks and their ancillary materials reflected the goals of the *PSSM* (NCTM, 2000) regarding the use of graphing calculators varied depending on the curriculum. The request for justification was consistent between textbooks and formal assessments. If textbooks did not request justification, then the formal assessments did not use request justification. Although HRW, McDougal Littell, and Prentice Hall had some graphing calculator activities that called for transitional/higher-order thinking skills, the non-NSF-funded curricula need more problems that require these skills in both the textbooks (example and exercises) and the formal assessments. One possible explanation for this lack of problems that require transitional/higher-order thinking skills in the non-NSF-funded curricula might be time constraints. It is possible that formal assessments in the traditional context inhibit authors from using these types of problems, which tend to take more time. Saxon’s low percentage in the Visualization category relative to the other curricula could be explained by the fact that the textbook did not use a graphing calculator at all but rather used a scientific calculator strictly for computation.

The findings related to the teaching notes provide information on what a curriculum should ideally include in the teaching notes associated with graphing calculator use. On the whole, HRW and Core-Plus had the most comprehensive teaching notes regarding graphing calculator use. In order for teaching notes to be as thorough and as helpful as possible, the notes should be labeled clearly and should include the following: a “things to be aware of” section regarding graphing calculator use, keystroke guidelines for how to use a graphing calculator to perform certain operations, suggestions
for when and how to use a graphing calculator for each section, explanations for interpreting graphing calculator output, and ideas for questions to ask students to encourage student thinking and classroom discussion.

Other Observations

Although the researcher focused on formal assessments in the current study, it should be noted that a curriculum may not be designed to rely heavily on testing (or formal assessments) for assessment. A curriculum may emphasize alternative assessments. For instance, in the curricula examined in this study, the NSF-funded curricula included take-home assessments. The non-NSF-funded curricula typically included chapter “alternative assessments” or “open-ended assessments”, and many of the curricula incorporated graphing calculator investigations or activities in the text proper.

Another factor in this study is that the rubric used to collect data was based on the recommendations of the PSSM (NCTM, 2000). Only the curricula of Glencoe, HRW, McDl, Prentice Hall, and Core-Plus specifically correlate their curricula with the PSSM. The curricula of Saxon, Key, and UCSMP did not explicitly claim to be based on the PSSM or on the Curriculum and Evaluation Standards (NCTM, 1989). The curricula of IMP and SIMMS, were written based on the Curriculum and Evaluation Standards (NCTM, 1989).

A notable outcome of this study is that it produced a significant tool, the Graphing Calculator Use Rubric, constructed by the researcher for analyzing comparing the extent and quality of graphing calculator integration in formal assessments. The
rubric is well-founded in that it’s construction was based not only on the recommendations of the *PSSM* (NCTM, 2000), but also incorporated components and ideas from other researchers including the following: Anderson et al. (1999), Forster and Mueller (2002), Goldenberg (2000), Harpster (2000), Harvey (1992), Madaus et al. (1992), May (1994), Romberg et al. (1992), Senk et al. (1997), and Taylor (1991). Furthermore, the rubric is useful beyond employing it to examine the extent and quality of graphing calculator use in formal assessments in that it could also be utilized to analyze examples, exercises, and other types of assessments such as alternative assessments.

**Summary of Conclusions**

This study demonstrated that the issue of analyzing and comparing curricula on the extent and quality of graphing calculator use in formal assessments is very complex with many factors involved. The *PSSM* (NCTM, 2000) provides general guidelines on the use of graphing calculators in teaching and learning mathematics, but lacks specifics regarding the extent to which graphing calculators should be incorporated and the degree to which each quality attribute should be emphasized. The study raised many questions, including “What is meant by a *Standards-based* use of graphing calculators?” The answer is not clear cut and depends on what is valued. However, this study not only produced a rubric and a method for analyzing and comparing curricula, but also found that there were differences between the ten curricula examined. The researcher found that regarding the use of graphing calculators, the goals and assessments were in general alignment for the ten curricula. The extent and quality of graphing calculator use was
also generally aligned between the textbooks and their formal assessments, with some inconsistencies associated with the quality of use.

Limitations

Because the *PSSM* (NCTM, 2000) does not provide detailed, quantifiable statements about the appropriate use of graphing calculators in teaching and learning mathematics, including formal assessments, it is difficult to interpret the exact intentions of the *PSSM* for graphing calculator implementation. Therefore, the researcher’s interpretation of the data and conclusions based on the data were intrinsically subjective in so far as they judged a text to conform with the *PSSM* (NCTM, 2000). The researcher’s conclusions must be qualified by the fact that it is not easy to satisfy the *PSSM* due to the many variables involved and the obscurity of the exact intentions of the *PSSM* regarding graphing calculators. Also, what is valued in terms of the use of graphing calculators depends on the individual school using a curriculum. Though the study found a difference between the NSF-funded curricula and the non-NSF funded curricula, no general judgments or value statements can be made about this difference.

Also, due to varying teacher beliefs and teaching environments, the intended curriculum can be significantly different than the enacted curriculum (Cronin-Jones, 1991). The study did not look at the actual classroom assessment practices of teachers who use the textbooks evaluated in this study.

Another limitation of this study was the variation in the sample sizes, determined by the number of items on the formal assessments examined for each of the ten
curricula. If the sample sizes were more homogeneous, more rigorous comparisons could have been conducted between the curricula.

**Delimitations**

The researcher did not look at formal assessments from all of the chapters and units in the curricular materials. Only those formal assessments from chapters and units that covered quadratic, exponential, and logarithmic functions were included in the study sample.

In addition, there are a total of five NSF-funded curricula. The researcher’s sample was limited to the top three most widely used of these curricula. Therefore, the results of this study may not be completely representative of the NSF-funded curricula.

**Recommendations for Research**

The formal assessment materials examined by the researcher represent part of the intended curriculum for each of the ten curricula. What takes place in the classroom can be different than what was proposed by a curriculum (Cronin-Jones, 1991). One recommendation for further research is to follow the current study with an examination of actual classroom assessment practices regarding the use of graphing calculators by teachers who use the textbooks evaluated in this study. This would provide a more complete picture of how teachers truly use the formal assessments that accompany each of the ten curricula.

Additional research could evaluate the alternative assessments that accompany the ten curricula. Alternative assessments included take-home assessments, chapter
“alternative assessments” or “open-ended assessments,” and graphing calculator investigations or activities.

Another suggestion for further research is to use the researcher’s rubric to examine a larger sample of formal assessment items from the ten curricula, including chapters and units that covered topics that are amenable to the use of graphing calculators besides quadratic, exponential, and logarithmic functions. The rubric could also be used to examine examples and exercises in the textbooks, and alternative assessments that accompany the textbooks.

Finally, additional research is needed to determine more specifically how graphing calculators can be incorporated into teaching and learning mathematics in a way that is most beneficial to student learning.


National Council of Teachers of Mathematics. (2000). Results from the seventh mathematics assessment of the National Assessment of Educational Progress.


APPENDICES
APPENDIX A

GRAPHING CALCULATOR USE RUBRIC
Graphing Calculator Use Rubric

Item Characteristic Categories

Indication of Graphing Calculator Use
- Explicit – Graphing calculator use is explicitly stated in the problem (or in the directions for a set of problems or in the directions for the test/assessment.)

- Implicit – Graphing calculator use is not explicit. However, use of a graphing calculator is implicit in the language/symbols used, suggesting the author intends that a student use a graphing calculator.

- None – There is no explicit or implicit evidence that a graphing calculator should be used, or it is unclear whether or not the use of a graphing calculator is intended.

Graphing Calculator Technology Level
- Active – An item for which the use of a graphing calculator is necessary for all practical purposes to obtain a solution.

- Inactive – An item for which the use of a graphing calculator is not possible for all practical purposes.

- Neutral – An item for which it is possible to use a graphing calculator to obtain a significant part or all of the solution, but the item could be reasonably answered without a graphing calculator.

Cognitive Level
(Active or Neutral items only)
- Lower-order Thinking Skills – Recall, Algorithm
  Recall – Recall a mathematical fact, definition, one-step process, or the steps in a process (Harpster, 2003).
  Algorithm – Item employs a step-by-step algorithm that can be executed in a specific sequence of steps (Hiebert and Lefevre, 1986).

  Transfer – The application of familiar mathematical operations, properties, algorithms, theorems, or concepts to a new situation or type of problem (Harpster, 2003).
  Analysis – The breakdown of a mathematical entity into its constituent elements or parts so that the relations between the mathematical components are made explicit (Harpster, 2003).
Synthesis – The putting together of mathematical components so as to form a whole (Harpster, 2003).
Evaluation – Judgments about the value of mathematical models for given purposes. Open-ended mathematical problems that require problem solving and/or modeling (Harpster, 2003).

Reason for Graphing Calculator Use
(most reasonable, straightforward use - *Active or Neutral* items only)
• Computation (C)
• Visualization (V)

Simplification
(Indication of Graphing Calculator Use *None* and Graphing Calculator Technology Level *Neutral* items only)
• Yes – Use of a graphing calculator simplifies or significantly changes the intended, main objective(s) of the item.
• No – Use of a graphing calculator does not simplify or significantly change the intended, main objective(s) of the item.

Request for Justification
(*Active or Neutral* items only)
• Yes – Item requests justification, explanation, or proof.
• No – No justification, explanation, or proof is requested.
(By itself, “Show your work” is not considered a request for justification.)

Real-World Context
(*Active or Neutral* items only)
• Yes – The item is set in a context outside of mathematics (e.g. art, food, science, sports).
• No – There is no context outside of mathematics.
Role of Graph
(Active or Neutral items only, based on Indication of Graphing Calculator Use – if None, assume no graphing calculator is used, otherwise assume a graphing calculator is used)
• Interpret/Make
Interpret – A graph, diagram, or table is given (or provided in a multiple choice item) and must be interpreted (or identified) to answer the question, or a graph must be constructed and interpreted to answer the question.
Make – Student is required to draw a graph from some non-graphical representation (algebraic, numeric, verbal description). A graphing calculator could be used to assist.
• Superfluous – A graph, diagram, or table is given but is not needed to answer the question.
• None – No graphical representation is given or required.
APPENDIX B

INSTRUCTIONS FOR

GRAPHING CALCULATOR USE RUBRIC
General Notes

(1) For an item with multiple parts (parts (a), (b), (c), etc...) that are related to one another, treat each part as a separate item. Since each part usually has its own objective(s), each part can be treated independently. However, tasks completed in previous items may need to be taken into consideration. 

Example: Suppose that the graph of \( y = 2x^2 \) is translated 4 units to the left and 5 units up.
(a) Write an equation in vertex form for the image. 
(b) Write an equation for the image in standard form.
In the example, although a graphing calculator could be used in part (a) to use a “guess & check” method to write an equation, and assuming that this had been done, part (b) entails rewriting the equation found in part (a), making part (b) inactive with respect to the Technology Level.

(2) If the item separately asks for some sort of explanation, still treat this as one item. 

Example: At first sight, the franchise fee contract does not look better. However, it is a better choice if the owner uses enough gallons of Swift Currant soft drink. How many? Explain how you got your answer.

(3) To categorize an item by Indication of Graphing Calculator Use, the rater should take into account the answer key (intended) answer of the item. The answer key provides information about the author’s intentions for whether or not a graphing calculator should be used for the item. If the answers are in exact form, then it is intended that the item should be done by hand. An exception to this is if the item involves the simplification of large numbers (greater than double digit) under a radical. 

Example: Solve \( 3\sqrt{y} - 7y - 5 = 0 \) using the quadratic formula.
In the example, the answer key gives the solutions as \( \frac{7 \pm \sqrt{109}}{6} \), an exact format, indicating that the item should be done by hand.

(4) To categorize an item by Graphing Calculator Technology Level, the rater should take into account whether the item is multiple choice. 

Example: Solve \( x^2 - 5x + 1 = 0 \) using the quadratic formula.
In the example, the item is multiple choice with the following answer choices: 
(A) \( \frac{-5 + \sqrt{21}}{2}, \frac{-5 - \sqrt{21}}{2} \) (B) \( \frac{-5 + \sqrt{29}}{2}, \frac{-5 - \sqrt{29}}{2} \)
(C) \( \frac{5 + \sqrt{21}}{2}, \frac{5 - \sqrt{21}}{2} \) (D) \( \frac{5 + \sqrt{29}}{2}, \frac{5 - \sqrt{29}}{2} \)
The answer choices are in an exact format, indicating the item should be done by hand. However, because the item is multiple choice, it could also be solved using a “guess & check” solution method with a graphing calculator, making the Technology Level Neutral.
(5) *Explicit* or *Implicit* Indication of Graphing Calculator Use does not imply that an item has an *Active* Technology Level.

**Example:** Graph the model for the concentration of acid in the solution, 
\[ y = \frac{1+x}{2+x} \]. Explain the meaning of any asymptotes in this context.

In the example, the answer key shows a graph with the viewing window specified as [0,10] x [0,1], indicating that \( x \) is shown between values of 0 and 10 and \( y \) is shown between values of 0 and 1, and that a graphing calculator should be used to graph the model. Thus, the Indication of Graphing Calculator Use is *Implicit*. However, a graphing calculator is not necessary to graph the model, making the item *Neutral* with respect to the Technology Level. Note that if the answer key did not specify a viewing window, then the Indication of Graphing Calculator Use would be *None*.

(6) An *Active* Technology Level implies *Explicit* or *Implicit* Indication of Graphing Calculator Use.

**Example:** The following table shows the records of price charged and monthly sales of a non-seasonal product. Model the relationship between price and sales.

\begin{tabular}{|c|c|}
\hline
Price & Sales \\
\hline
$55 & 1270 \\
$75 & 850 \\
$68 & 1004 \\
$52 & 1356 \\
\hline
\end{tabular}

In the example, the Technology Level is *Active* and the Indication of Graphing Calculator Use is *Implicit* (because of the use of large numbers).

(7) The Reason for Graphing Calculator Use (*Computation* or *Visualization*), independent of the Technology Level, should be the most reasonable, straightforward use that entails the fewest number of steps.

**Example 1:** Solve the equation \( 5x^2 = 75 \). Give solutions to the nearest tenth when necessary.

In example 1, using a graphing calculator to solve graphically would entail more steps than using it for computation.

**Example 2:** Find the \( x \)-intercepts, to the nearest hundredth, for the parabola 
\[ y = -\frac{1}{2}(x - 3)^2 + 4 \].

In example 2, the most straightforward method to solve this item would be to use a graphing calculator to solve graphically. The item could also be solved using the quadratic formula, but this would entail quite a few more steps.

(8) For items that could employ a graphing calculator to graph a function, assume one starts with a standard viewing window, [-10,10] x [-10,10], unless the item specifies otherwise. If a student was required to select a viewing window other than a standard
viewing window in order to determine the solution, the Cognitive Level of the item could change from *lower-order thinking skills* to *transitional/higher-order thinking skills*.

**Example:** In 1971, the population of a country was estimated at 5 million. For any subsequent year, the population, \( P(t) \) (in millions), can be modeled using the equation \[ P(t) = \frac{250}{5 + 44.99e^{-0.0208t}} \], where \( t \) is the number of years since 1971. Use a graphing calculator to estimate the year when the population will be 37 million.

In the example, the item cannot be solved by simply graphing \( y_1 = \frac{250}{5 + 44.99e^{-0.0208t}} \) and \( y_2 = 37 \) and directly using the calculator’s “intersect” function.

**Example of How to Categorize an Item with the Graphing Calculator Use Rubric**

**Example:** In 1971, the population of a country was estimated at 5 million. For any subsequent year, the population, \( P(t) \) (in millions), can be modeled using the equation \[ P(t) = \frac{250}{5 + 44.99e^{-0.0208t}} \], where \( t \) is the number of years since 1971. Use a graphing calculator to estimate the year when the population will be 37 million.

1. Indication of Graphing Calculator Use – Explicit
2. Graphing Calculator Technology Level - Active
3. Cognitive Level – Transitional/Higher-order Thinking Skills
4. Reason for Graphing Calculator Use – Visualization
5. Simplification – Does not apply
6. Request for Justification – No
7. Real-word context – Yes
8. Role of Graph – Interpret/Make

**The Categories of the Rubric**

1. Indication of Graphing Calculator Use

**Explicit** – Graphing calculator use is explicitly stated in the item (or in the directions for a set of items or in the directions for the test/assessment.)

- The item explicitly states to use a graphing calculator (or calculator) to solve it. **Example:** In 1971, the population of a country was estimated at 5 million. For any subsequent year, the population, \( P(t) \) (in millions), can be modeled using the equation \[ P(t) = \frac{250}{5 + 44.99e^{-0.0208t}} \], where \( t \) is the number of years since 1971. Use a graphing calculator to estimate the year when the population will be 37 million.

- There is a graphing calculator (or calculator) symbol/icon next to the item.
Implicit – Graphing calculator use is not explicit. However, use of a graphing calculator is implicit in the language/symbols used, suggesting the author intends that a student use a graphing calculator.

- The item requires computation or graphing where decimals are used in the item or in the answer to the item. This is also dependent on the context of the item and the basic/significant concepts covered in the chapter(s) that the item is associated with. If the basic/significant concepts are other than performing computations with decimals by hand and the use of decimals adds significantly to the computational load of the item, then this suggests a graphing calculator should be used for items with decimals. Note that the use of simple decimal numbers such as 0.5, that a student could work with mentally or by hand, may be an exception.

Example 1: A T-shirt company estimates that the average cost per shirt can be approximated by the function \( A(x) = \frac{4.25x + 150}{x} \), where \( x \) is the number of T-shirts made. Find the average cost per T-shirt when the company makes 10 shirts.

Answer choices: (A) $19.25 (B) $5.75 (C) $415.43 (D) $4.27

Example 2: Graph \( y = 0.65x^2 + 10.13x - 41.25 \). Make a sketch of the graph.

- The item specifies the number of decimal places for the answer. In the context of the chapters examined in the current study, the fundamental ideas do not include performing computations with decimals, implying that a graphing calculator should be used to state answers to a specified number of decimal places.

Example: Find the local maximum and minimum values of the function \( f(x) = 2^{(1/x)} \) and the values of \( x \) at which they occur. State your answers correct to two decimal places.

- The item uses large (greater than double digit) or very small (decimal) numbers. In the context of the chapters the current study examined, the basic concepts do not require the use of large or very small numbers. Thus, the presence of large or very small numbers implies that a graphing calculator should be used.

Example: The consumer demand for Swift Currant soft drink is related to the price \( p \) per gallon in this way: \( d = -800p + 10,000 \). What is the range for the demand (in gallons) that corresponds to the given range in price?

- The item requires calculation of values involving a non-simple exponential or logarithmic function.

Note: “Non-simple” means that the calculation involves decimal numbers and/or a base \( e \) exponential function.
Example: Complete the table and use it to graph the function $f(x) = 2e^x$.

<table>
<thead>
<tr>
<th>$x$</th>
<th>$f(x) = 2e^x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>-1.5</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>-0.5</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

None – There is no explicit or implicit evidence that a graphing calculator should be used, or it is unclear whether or not the use of a graphing calculator is intended.

- There is no indication (explicit or implicit) that a graphing calculator should be used to answer the item.
  Example: Describe the difference between a graph of exponential growth and a graph of logistic growth. Illustrate your description with a graph of each type of growth.

- It is unclear whether or not the use of a graphing calculator is intended.
  Example: Graph the logarithmic function $f(x) = \log_3 x$.

- The answer format (given in the answer key) of the item is exact.
  Example: Solve $3y^2 - 7y - 5 = 0$ using the quadratic formula. Answer: $(7 \pm \sqrt{109}) / 6$.

- The item specifically states that a graphing calculator or calculator should not be used.

- The item has an inactive Technology Level.

- The item requires calculation of values involving a relatively simple exponential or logarithmic function.
  Example: Evaluate $\log(1000)$. 
2. Graphing Calculator Technology Level

**Active** – An item for which the use of a graphing calculator is necessary for all practical purposes to obtain a solution.

Note: “For all practical purposes” takes into account the context of the assessment items; a testing situation in which the assessment must be completed within a certain time frame and assumes limits to the number of steps required in the solution process as well as to the cognitive complexity of the task.

**Example 1:** Find all local extrema of the polynomial \( y = 4x^3 - 2x + 3 \) correct to two decimal places.

**Example 2:** You decide to buy a boat that costs $9100. The normal depreciation for such a boat is 17% per year. If you pay for the boat with a 3-year loan, how much less will the boat be worth after you have paid off the loan?

**Example 3:** Graph the profit formulas \(-800p^2 + 14800p - 60000\) and \(-800p^2 + 14320p - 55000\) in the same diagram.

**Inactive** – An item for which the use of a graphing calculator is not possible for all practical purposes.

**Example 1:** Which property is shown by the following statement?
\[ 5 \times (4 + 11) = 5 \times 4 + 5 \times 11. \]

**Example 2:** A sum of $10,000 is invested at an interest rate of 8% per year compounded semiannually. Find the value \( A(t) \) of the investment after \( t \) years.

**Example 3:** Find a quadratic function that has a maximum value of 3 and \( x = -2 \) as the line of symmetry for its graph.

- If a graphing calculator were used, it would significantly increase the number of steps required to solve the item and it would assume a depth of understanding beyond what is intended by the item.

**Example:** Find the inverse of the function \( f(x) = (x + 2)/4 \).

In the example, one could create a table of values, switch the \( x \) and \( f(x) \) values, and use a graphing calculator to perform a linear regression. However, solving the problem by this method increases the number of steps and the cognitive level.

- The item specifies a traditional, by hand solution method.

**Example:** Solve \( 3x^2 + 24x + 36 = 0 \) by completing the square.

In the example, although a graphing calculator could be used to check the answers, the graphing calculator would *not* be used for a *significant part* of the specified solution process.
Neutral – An item for which it is possible to use a graphing calculator to obtain a significant part or all of the solution, but the item could be reasonably answered without a graphing calculator.

- Evaluating or factoring expressions.
  Example 1: Evaluate the expression \((64 \cdot 4^2 - 4 \cdot 7^2)/(7 + 4^2)\).
  Example 2: If \(c = 2i - 1\) and \(d = 5 - 3i\), what is \(c - 2d\)?
  Example 3: Factor the expression \(36y^2 - 49\).

- Despite the request of a non-graphing calculator solution method in the item’s directions, a graphing calculator could be used to assist significantly in solving the item.
  Example 1: Consider the equation \(y = 2x^2 - 8x + 7\). Use the Discriminant Theorem to determine the nature of the roots.
  In example 1, a graphing calculator could be used to graph the equation to determine the nature of the roots.
  Example 2: Use the properties of logarithms to evaluate the expression \(\log \log \log 33 392 78 1\).

- Item could be done either using a traditional method (algorithm) or it could be done using a graphing calculator. The use of a graphing calculator includes a “guess & check” solution method.
  Example 1: Write the equation of the function that results from performing the following transformations on the parent function \(f(x) = x^2\): a translation -4 units vertically, a translation of -3 units horizontally, a reflection about the x-axis, and a vertical stretch by 7.
  Example 2: Solve the equation. Check your answer. \(\ln x - \ln 6 = 0\)
  (Item would have to have a multiple choice format.)
  Answer choices: (A) \(\ln 6\)   (B) \(e^6\)   (C) 6   (D) 6e.
  In example 2, note that the directions specify “Check your answer.” A graphing calculator could be used for computation with a “guess & check” solution method.

3. Cognitive Level
   (Active or Neutral items only)

Notes: Cognitive level should be based on the Indication of Graphing Calculator Use. If the Indication of Graphing Calculator Use is None, assume a traditional paper-and-pencil method is used to obtain the solution.

Lower-Order Thinking Skills – Recall, Algorithm
Recall – Recall a mathematical fact, definition, one-step process, or the steps in a process (without actually doing the process). Recognize, name, or use a mathematical symbol or object. (Harpster, 2003).
• Read information from charts, graphs, or tables.

Algorithm – Item employs a step-by-step algorithm that can be executed in a specific sequence of steps (Hiebert and Lefevre, 1986).

• Interpret, interpolate, or extrapolate from tables, charts, or graphs.

• Use an algorithm to solve a system of equations.
  **Example:** Use the elimination method to solve the following system of equations:
  
  \[
  \begin{align*}
  3x - y &= 5 \\
  x + 2y &= -1 
  \end{align*}
  \]

• Given a function and the value of either the independent or dependent variable, determine the value of the one not given.
  **Example:** The distance \( h \) traveled in \( t \) seconds by an object dropped from a height is \( h = 16t^2 \). If an object is dropped from a height of 180 feet, how long will it take before the object hits the ground? Round your answer to the nearest 0.01 second.

• Graph functions where the \( x \)- and \( y \)-intercepts can be found using algorithms (paper-and-pencil methods). Includes associating roots and factors.
  **Example:** Graph \( y = x^2 - 4x - 5 \). Identify the vertex and any \( x \)- or \( y \)-intercepts. In the example, the quadratic function could be factored to find the roots/\( x \)-intercepts. The \( x \)-coordinate of the vertex could be found using \( x = -b/2a \).

• Graph simple functions.
  **Example 1:** Graph \( y = 2^x \).
  **Example 2:** Graph \( y = (1/3)^x \).

• Transformations of functions.
  **Example 1:** Graph \( y = -(x - 3)^2 + 2 \).
  **Example 2:** Write the equation of the function that results from performing the following transformations on the parent function \( f(x) = x^2 \): a translation 4 units vertically, a translation of -3 units horizontally, a reflection about the \( x \)-axis, and a vertical stretch by 7.

• Use a graphing calculator’s CALC functions (with a standard viewing window) to directly find \( x \)- and \( y \)-intercepts, maxima and minima of functions.
  **Example 1:** Find the local maximum and minimum values of the function \( f(x) = (2x)^{1/x} \) and the values of \( x \) at which they occur. State your answers correct to two decimal places.
  **Example 2:** Solve \( 4x^2 - 5x = 17 \). Round answers to nearest hundredth.
  In example 2, the item could be solved by graphing \( y_1 = 4x^2 - 5x \) and \( y_2 = 17 \) and then using the calculators “intersect” function to determine where the two graphs intersect.
Construct an equation (linear, quadratic, exponential) to represent a relationship where the relationship has been specified verbally or with a formula as linear, quadratic, or exponential.

**Example 1:** The half-life of carbon-14 is 5700 years. Write the exponential decay model for a 290-mg sample. To the nearest hundredth, find the amount of carbon-14 remaining after 3051 years.

**Example 2:** A biologist is conducting an experiment using a colony of bacteria that contains 2500 bacteria. The bacteria grow at a rate of 5% per hour. Write an equation in the form $y = ab^x$ for the amount of the bacteria after $x$ hours. How long will it take for the number of bacteria to double?

**Transitional/Higher Order Thinking Skills** – Transfer, Analysis/Synthesis, Evaluation

Transfer – The application of familiar mathematical operations, properties, algorithms, theorems, or concepts to a new situation or type of problem (Harpster, 2003).

Use a graphing calculator (and having to select a window other than the standard viewing window) to find $x$- and $y$-intercepts, maxima and minima of functions. The $x$- and $y$-intercepts, maxima and minima of functions cannot be directly found using the graphing calculator’s CALC functions.

**Example:** In 1971, the population of a country was estimated at 5 million. For any subsequent year, the population, $P(t)$ (in millions), can be modeled using the equation $P(t) = \frac{250}{5 + 44.99e^{-0.0208t}}$, where $t$ is the number of years since 1971. Use a graphing calculator to estimate the year when the population will be 37 million.

Analysis – The breakdown of a mathematical entity into its constituent elements or parts so that the relations between the mathematical components are made explicit (Harpster, 2003).

Synthesis – The putting together of mathematical components so as to form a whole (Harpster, 2003).

Describe a family of functions.

**Example:** Graph the family of polynomials $P(x) = (x + C)^3$ in the same viewing rectangle, using the values $C = -1, 0, 1, 2$. Explain how changing the value of $C$ affects the graph.

Evaluation – Judgments about the value of mathematical models for given purposes. Open-ended mathematical problems that require problem solving and/or modeling (Harpster, 2003).
Example: A statistician performed a map of a city using nine equally spaced concentric rings. He then used random sampling to determine the population density in each of those rings. The results are in the table below.

<table>
<thead>
<tr>
<th>Distance from Center (in miles)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop. density (per Square mile)</td>
<td>8300</td>
<td>6100</td>
<td>4800</td>
<td>3800</td>
<td>2650</td>
<td>1720</td>
<td>1500</td>
<td>800</td>
<td>350</td>
</tr>
</tbody>
</table>

Determine the mathematical model, \( g(x) \), which best fits the data in the table. Demonstrate and explain why that model is the best one. (Note: There are a couple of models that fit the data quite well, but the student must demonstrate and explain why his/her model is best.)

4. Reason for Graphing Calculator Use (most reasonable, straightforward use)  
(Active or Neutral items only)

Computation (C)

Example: Solve the equation \( 5x^2 = 75 \). Give solutions to the nearest tenth when necessary.

Example 2: Solve the equation. Check your answer. \( \ln x - \ln 6 = 0 \)  
(Item would have to have a multiple choice format.)

Answer choices: (A) \( \ln 6 \)  (B) \( e^6 \)  (C) 6  (D) 6e.

Visualization (V)

- Solve graphically.

Example: Use a graphing calculator to solve the inequality \( x^4 - 4x^3 + 5x > 0 \) and express your answer using interval notation.

- Graph functions or identify the graph of a function.

- Explore parameter changes.

Example: Graph the family of polynomials \( P(x) = (x + C)^3 \) in the same viewing rectangle, using the values \( C = -1, 0, 1, 2 \). Explain how changing the value of \( C \) affects the graph.
• Use a graphical method to come up with a model.
Example: The table shows the median price for custom homes in one area of the United States since 1990.

<table>
<thead>
<tr>
<th>Years since 1990</th>
<th>Median price (in dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500,000</td>
</tr>
<tr>
<td>2</td>
<td>600,000</td>
</tr>
<tr>
<td>3</td>
<td>800,000</td>
</tr>
<tr>
<td>4</td>
<td>950,000</td>
</tr>
<tr>
<td>5</td>
<td>1,200,000</td>
</tr>
</tbody>
</table>

Enter the data into a graphing calculator and perform an exponential regression. Find a power function to model the data.

5. Simplification (for all practical purposes)

Notes: The simplification categorization pertains only to those items such that the Indication of Graphing Calculator Use is None AND the Graphing Calculator Technology Level is Neutral. In other words, this categorization deals with items for which graphing calculator use was not intended, but a graphing calculator could be used to solve the item, for all practical purposes, providing information on whether the use of a graphing calculator simplifies or changes the objective of items of this type. This categorization is to be distinguished from the Active definition.

Yes – Use of a graphing calculator simplifies or significantly changes the intended, main objective(s) of the item.
Example 1: Graph \( y = -\frac{1}{4}x^2 + 3 \).
Example 2: What are the coordinates of the vertex of the graph of \( y = -2x^2 - 8 \)?

• Item in which a graphing calculator could be used for computation beyond “simple arithmetic” for a significant part of the solution. “Simple arithmetic” is defined as using one or more of the four arithmetic operations (addition, subtraction, multiplication, division) to conduct operations with single digit numbers.
Example 1: Expand and simplify: \( (2c + 5)^2 - (2c - 5)^2 \).
Example 2: Write the following in \( a + bi \) form: \( \frac{\sqrt{-196}}{\sqrt{-49}} \).

No – Use of a graphing calculator does not simplify or significantly change the intended, main objective(s) of the item.
Example: Write the equation of the function that results from performing the following transformations on the parent function \( f(x) = x^2 \): a translation -4 units vertically, a translation of -3 units horizontally, a reflection about the \( x \)-axis, and a vertical stretch by 7.

- Item such that the computation involves “simple arithmetic” only.
Example: Write \((5 - 2i) - (-3 + 4i)\) in \(a + bi\) form.

6. Request for Justification
(Active or Neutral items only)

Yes
- Item requests justification, explanation, or proof.
- Item requests student to provide evidence of reasoning used to arrive at answer.
Example 1: Graph the family of polynomials \( P(x) = (x + C)^3 \) in the same viewing rectangle, using the values \( C = -1, 0, 1, 2 \). Explain how changing the value of \( C \) affects the graph.
Example 2: Discuss the merits of measuring the success of a business by profit margin instead of total profit.

No
- No justification, explanation, or proof is requested. (By itself, “Show your work” is not considered a request for justification.)
- Item does not request student to provide evidence of reasoning used to arrive at answer.

7. Real-World Context
(Active or Neutral items only)

Yes – The item is set in a context outside of mathematics.
- The context is something like art, food, science, sports, or business.
Example: The pizza chain uses a lot of the soft drink Swift Currant, so the owner wants to know if another type of contract (a franchise fee contract) is a better choice. For this type of contract, the owner pays a certain fixed fee \( f \) once and a price \( p \) per gallon that is 10% lower than the regular price. The regular price is $6 per gallon, and the franchise fee is $1000. Write a formula for the costs according to the franchise contract.

- Item uses terminology that relates to something in the real-world.
Example: Find the amount in a continuously compounded account for the given conditions. Principal: $8000, Annual interest rate: 6.1%, Time: 15 yrs.

No – There is no context outside of mathematics. Example: Describe how the graph of the function $y = f(x) - 6$ can be obtained from the graph of $y = f(x)$.

8. Role of Graph
(Active or Neutral items only)

Notes: This category is based on the Indication of Graphing Calculator Use. If the Indication of Graphing Calculator Use is None, assume no graphing calculator is used. Otherwise, assume a graphing calculator is used.

Interpret/Make
Interpret – A graph, diagram, or table is given (or provided in a multiple choice item) and must be interpreted (or identified) to answer the question, or a graph must be constructed and interpreted to answer the question. Example: Write an equation in the form $y = a(x - h)^2 + k$ for the parabola shown.

Make – Student is required to draw a graph from some non-graphical representation (data, equation, verbal description). A graphing calculator could be used to assist.

Note: In Interpret/Make, the use of a graph, diagram, or table is not optional, rather an integral part of the solution process.

Superfluous – A graph, diagram, or table is given but is not needed to answer the question.

None – No graphical representation is given or required.
APPENDIX C

SENK, BECKMANN, AND THOMPSON’S
“ITEM CHARACTERISTICS AND CATEGORIES”
CODING SCHEME
<table>
<thead>
<tr>
<th>Characteristic Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item format</strong></td>
<td></td>
</tr>
<tr>
<td>Answer given</td>
<td>True or false, yes or no, multiple choice, or matching</td>
</tr>
<tr>
<td>Answer not given</td>
<td>Fill in the blank or longer free response</td>
</tr>
<tr>
<td><strong>Skill</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Solution requires applying a well-known algorithm such as solving equations or inequalities or bisecting an angle. Item does no require translation between representations.</td>
</tr>
<tr>
<td>No</td>
<td>No algorithm is generally taught for answering such questions, or item requires translation across representations.</td>
</tr>
<tr>
<td><strong>Level</strong></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>A typical student in that course would use 1 or 2 steps to solve.</td>
</tr>
<tr>
<td>Other</td>
<td>A typical student in that course would use 3 or more steps to solve, and the content is new to the course.</td>
</tr>
<tr>
<td><strong>Realistic context</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>The item is set in a context outside of mathematics (e.g. art, fantasy, science, sports).</td>
</tr>
<tr>
<td>No</td>
<td>There is no context outside of mathematics.</td>
</tr>
<tr>
<td><strong>Reasoning required</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Item requires justification, explanation, or proof.</td>
</tr>
<tr>
<td>No</td>
<td>No justification, explanation, or proof is required. (By itself, “Show your work” is not considered reasoning.)</td>
</tr>
<tr>
<td><strong>Open-ended</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>The student must generate an example, solution, or explanation for which there are many correct answers.</td>
</tr>
<tr>
<td>No</td>
<td>There are only a small number of correct answers possible.</td>
</tr>
<tr>
<td><strong>Role of diagram</strong></td>
<td></td>
</tr>
<tr>
<td>Interpret</td>
<td>A graph or diagram is given and must be interpreted to answer the question.</td>
</tr>
<tr>
<td>Superfluous</td>
<td>A graph or diagram is given but is not needed to answer the question.</td>
</tr>
<tr>
<td>Make</td>
<td>From some nongraphical representation (data, equation, verbal description) student must make a graph or diagram.</td>
</tr>
<tr>
<td>None</td>
<td>No graphical representation is given or needed.</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>Use of the tool is necessary to obtain a solution or it greatly simplifies the work needed to get a solution.</td>
</tr>
<tr>
<td>Neutral</td>
<td>It is possible to use the tool to obtain part or all of the solution; but the question could be reasonably answered without the tool.</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Inactive</td>
<td>Use of the tool is not possible.</td>
</tr>
</tbody>
</table>

APPENDIX D

TABLE TO COLLECT DATA WITH

GRAPHING CALCULATOR USE RUBRIC
Table to Collect Data with Graphing Calculator Use Rubric

Assessment Number ____________________

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Indicat. of GC Use – Explic, Implic, None</th>
<th>GC Tech Level – Act(A), Inact(I), Neut(N)</th>
<th>Cog. Level – Lower (L), Tran/Hi (T/H)</th>
<th>Reason for GC Use C, V</th>
<th>Does GC simplify item? (None/N only)</th>
<th>Req. for justification Y/N</th>
<th>Real world context Y/N</th>
<th>Role of graph? Interpr/Make, Superf, None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E

QUANTITATIVE DATA
Saxon

Total number of items analyzed: 42

Indication of Graphing Calculator Use

- Explicit: 2.4% (1/42)
- Implicit: 21.4% (9/42)
- None: 76.2% (32/42)

Graphing Calculator Technology Level

- Active: 11.9% (5/42)
- Neutral: 54.8% (23/42)
- Inactive: 33.3% (14/42)

Simplification

Total number of items both None and Neutral: 18

- Yes: 100% (18/18)
- No: 0% (0/18)

Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 28

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive level – Transitional/Higher-order thinking skills</td>
<td>29%</td>
<td>(8/28)</td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
<td>11%</td>
<td>(3/28)</td>
</tr>
<tr>
<td>Request for Justification – Yes</td>
<td>0%</td>
<td>(0/28)</td>
</tr>
<tr>
<td>Real-World Context – Yes</td>
<td>36%</td>
<td>(10/28)</td>
</tr>
<tr>
<td>Role of Graph – Interpret/Make</td>
<td>25%</td>
<td>(7/28)</td>
</tr>
</tbody>
</table>
Key Curriculum Press (Key)

Total number of items analyzed: 30

Indication of Graphing Calculator Use

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit</td>
<td>0%</td>
<td>0/30</td>
</tr>
<tr>
<td>Implicit</td>
<td>50%</td>
<td>15/30</td>
</tr>
<tr>
<td>None</td>
<td>50%</td>
<td>15/30</td>
</tr>
</tbody>
</table>

Graphing Calculator Technology Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>50%</td>
<td>15/30</td>
</tr>
<tr>
<td>Neutral</td>
<td>20%</td>
<td>6/30</td>
</tr>
<tr>
<td>Inactive</td>
<td>30%</td>
<td>9/30</td>
</tr>
</tbody>
</table>

Simplification

Total number of items both None and Neutral: 6

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>100%</td>
<td>6/6</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
<td>0/6</td>
</tr>
</tbody>
</table>

Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 21

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive level – Transitional/Higher-order thinking skills</td>
<td>33%</td>
<td>(7/21)</td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
<td>38%</td>
<td>(8/21)</td>
</tr>
<tr>
<td>Request for Justification – Yes</td>
<td>33%</td>
<td>(7/21)</td>
</tr>
<tr>
<td>Real-World Context – Yes</td>
<td>48%</td>
<td>(10/21)</td>
</tr>
<tr>
<td>Role of Graph – Interpret/Make</td>
<td>33%</td>
<td>(7/21)</td>
</tr>
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</table>
Glencoe

Total number of items analyzed: 50

**Indication of Graphing Calculator Use**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Implicit</td>
<td>24%</td>
<td>12/50</td>
</tr>
<tr>
<td>None</td>
<td>76%</td>
<td>38/50</td>
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</table>

**Graphing Calculator Technology Level**

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
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</tr>
<tr>
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<td>32/50</td>
</tr>
<tr>
<td>Inactive</td>
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<td>7/50</td>
</tr>
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**Simplification**

Total number of items both None and Neutral: 31

<table>
<thead>
<tr>
<th>Option</th>
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<tr>
<td>Yes</td>
<td>90.3%</td>
<td>28/31</td>
</tr>
<tr>
<td>No</td>
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<td>3/31</td>
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</table>

**Graphing Calculator Technology Level Active or Neutral Items**

Total number of active or neutral items: 43

<table>
<thead>
<tr>
<th>Category</th>
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</tr>
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<tbody>
<tr>
<td>Cognitive level – Transitional/Higher-order thinking skills</td>
<td>2%</td>
<td>1/43</td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
<td>54%</td>
<td>23/43</td>
</tr>
<tr>
<td>Request for Justification – Yes</td>
<td>0%</td>
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<tr>
<td>Real-World Context – Yes</td>
<td>5%</td>
<td>2/43</td>
</tr>
<tr>
<td>Role of Graph – Interpret/Mak</td>
<td>19%</td>
<td>8/43</td>
</tr>
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</table>
**Holt, Rinehart, & Winston (HRW)**

Total number of items analyzed: 53

**Indication of Graphing Calculator Use**

| Explicit | 0% | (0/53) |
| Implicit | 50.9% | (27/53) |
| None     | 49.1% | (26/53) |

**Graphing Calculator Technology Level**

| Active | 41.5% | (22/53) |
| Neutral | 37.7% | (20/53) |
| Inactive | 20.8% | (11/53) |

**Simplification**

Total number of items both None and Neutral: 15

| Yes | 73.3% | (11/15) |
| No  | 26.7% | (4/15) |

**Graphing Calculator Technology Level Active or Neutral Items**

Total number of active or neutral items: 42

| Cognitive level – Transitional/Higher-order thinking skills | 2% | (1/42) |
| Reason for Graphing Calculator Use – Visualization | 19% | (8/42) |
| Request for Justification – Yes | 0% | (0/42) |
| Real-World Context – Yes | 26% | (11/42) |
| Role of Graph – Interpret/Make | 10% | (4/42) |
McDougal Littell (McDL)

Total number of items analyzed: 50

**Indication of Graphing Calculator Use**

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<tr>
<td>Implicit</td>
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</tr>
<tr>
<td>None</td>
<td>64%</td>
<td>(32/50)</td>
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**Graphing Calculator Technology Level**

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<tr>
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**Simplification**

Total number of items both None and Neutral: 26

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<td>No</td>
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<td>(1/26)</td>
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**Graphing Calculator Technology Level Active or Neutral Items**

Total number of active or neutral items: 42

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</tr>
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<tr>
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<td>(2/42)</td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
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<td>Real-World Context – Yes</td>
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<td>Role of Graph – Interpret/Make</td>
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Total number of items analyzed: 55

Indication of Graphing Calculator Use

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Graphing Calculator Technology Level

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Simplification

Total number of items both None and Neutral: 24

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Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 47

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<td>(15/47)</td>
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<td>0%</td>
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<td>(9/47)</td>
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<td>Role of Graph – Interpret/Make</td>
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UCSMP

Total number of items analyzed: 58

Indication of Graphing Calculator Use

- Explicit: 0% (0/58)
- Implicit: 24.1% (14/58)
- None: 75.9% (44/58)

Graphing Calculator Technology Level

- Active: 20.7% (12/58)
- Neutral: 65.5% (38/58)
- Inactive: 13.8% (18/58)

Simplification

Total number of items both None and Neutral: 33

- Yes: 72.7% (24/33)
- No: 27.3% (9/33)

Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 50

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<td>6% (3/50)</td>
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<td>Real-World Context – Yes</td>
<td>24% (12/50)</td>
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<tr>
<td>Role of Graph – Interpret/Make</td>
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Core-Plus

Total number of items analyzed: 29

Indication of Graphing Calculator Use

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<td>22/29</td>
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Graphing Calculator Technology Level

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Simplification

Total number of items both None and Neutral: 11

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Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 18

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<td>(6/18)</td>
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<td>Reason for Graphing Calculator Use – Visualization</td>
<td>50%</td>
<td>(9/18)</td>
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<td>Request for Justification – Yes</td>
<td>50%</td>
<td>(9/18)</td>
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<td>Real-World Context – Yes</td>
<td>44%</td>
<td>(8/18)</td>
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<tr>
<td>Role of Graph – Interpret/Make</td>
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<td>(5/18)</td>
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Interactive Mathematics Program (IMP)

Total number of items analyzed: 8

Indication of Graphing Calculator Use

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<tr>
<td>None</td>
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<td>(6/8)</td>
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Graphing Calculator Technology Level

<table>
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<td>Neutral</td>
<td>50%</td>
<td>(4/8)</td>
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<tr>
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Simplification

Total number of items both None and Neutral: 4

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<td>75%</td>
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Graphing Calculator Technology Level Active or Neutral Items

Total number of active or neutral items: 5

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<td>(1/5)</td>
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<td>Reason for Graphing Calculator Use – Visualization</td>
<td>40%</td>
<td>(2/5)</td>
</tr>
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<td>Request for Justification – Yes</td>
<td>40%</td>
<td>(2/5)</td>
</tr>
<tr>
<td>Real-World Context – Yes</td>
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<td>Role of Graph – Interpret/Make</td>
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<td>(0/5)</td>
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SIMMS

Total number of items analyzed: 18

Indication of Graphing Calculator Use
- Explicit 0% (0/18)
- Implicit 38.9% (7/18)
- None 61.1% (11/18)

Graphing Calculator Technology Level
- Active 38.9% (7/18)
- Neutral 44.4% (8/18)
- Inactive 16.7% (3/18)

Simplification
Total number of items both None and Neutral: 8
- Yes 12.5% (1/8)
- No 87.5% (7/8)

Graphing Calculator Technology Level Active or Neutral Items
Total number of active or neutral items: 15

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<td>(4/15)</td>
</tr>
<tr>
<td>Reason for Graphing Calculator Use – Visualization</td>
<td>68%</td>
<td>(10/15)</td>
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<td>Request for Justification – Yes</td>
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<td>Real-World Context – Yes</td>
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<td>(2/15)</td>
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<tr>
<td>Role of Graph – Interpret/Make</td>
<td>53%</td>
<td>(8/15)</td>
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</table>
APPENDIX F

QUALITATIVE DATA
Qualitative Data Recording Sheet  
Curriculum: Saxon

1) Textbook goals for graphing calculator (gc) use:  
General philosophy of text – students learn by doing – emphasis on practice and review – incremental development of concepts (low \( \rightarrow \) higher cognitive level).  
Series of books designed to teach problem-solving skills.  
Specific goals for gc use? Section on scientific calculator – “calculator frees the user from mundane arithmetic chores and permits more emphasis to be placed on understanding”(p.285). However, a calculator cannot be used as a replacement for understanding. Because of the possibility of user error, students should “always estimate before using a calculator.”

2) Extent of textbook dependence on graphing calculator technology:  
Uses the scientific calculators aspect of gc for - (1) scientific notation – simplifying products and quotients of numbers in scientific notation, (2) power and roots involving decimals, (3) solving with exponential equations, functions, and (4) logs. Uses calc for computation – show symbols of calc buttons.  
Of 129 lessons, Lesson 68 on scientific calculator for (1) and (2) above. Lessons 113, 115, and 43 use calc. Lesson 43 on trig functions.

Example from Lesson 68: Estimate first, then simplify \( \frac{40,652 \times 10^{-8}}{0.000324 \times 10^{15}} \)

3) Textbook and ancillary materials (including alternative assessments) reflection of P&S with respect to use of graphing calculator:  
Lessons 50, 62, 71, 110, 112, 113, 115, 118

• Request for justification:  
Not with problems that use gc.  
In fact, in general, there are no problems where student is requested to explain reasoning.

• Use of real-world context:  
In general, text does include real-world problems in homework (HW) and example (some of which use gc for computation). This is the case for approximately the first five problems of every 30-problem exercise set.
• Use of graphing calculator – computation or visualization:
  Computation only.

• Translation b/w various representations – algebraic, numeric, graphic:
  Not with problems using gc.
  In general, few/some problems.

4) What is included in Teaching Notes regarding graphing calculators:
Just includes example of how to use keystrokes for problems that involve computation.

Additional Notes (Misc.):
• No alternative assessments.
• Transitional/higher-order (TH) cognitive level problems – some in initial problems of exercise sets. The examples are mostly procedural.
1) Textbook goals for graphing calculator use:
Technology (especially related to gc) is infused into the curriculum, with the content of
the curriculum anchored in real-world contexts. The text assumes students will have a gc
at home and at school. “Graphing calculators allow students to explore and investigate
algebra.” Technology allows students to look at a lot of examples quickly, to solve
problems involving difficult computation, and to compare results, “to look at situations
from several different perspectives” – with graphic, symbolic, and numeric
representations. The text “fully integrates” gc’s into its mathematical processes. Gc is
used to explore variables and “modeling and functions are at the heart of the course.”
Use technology to check answers.

2) Extent of textbook dependence on graphing calculator technology:
Huge! As was said in 1), the text fully integrates gc. Every chapter includes hands-on
“investigations” that employ the gc as a learning tool. For example, one investigation
used gc to investigate the composition of inverse functions.

3) Textbook and ancillary materials (including alternative assessments) reflection of
PSSM with respect to use of graphing calculator: Chapters 7, 10
• Request for justification:
Yes – quite extensive! Often requests students to “provide a real-world meaning” for an
answer.
Examples: (1) \( f(x) = 480(0.5)^x \) where \( x \) is the number of 25-day periods and \( f(x) \) is the
number of rads. Find \( f(3.2) \) and provide a real-world meaning for it.
(2) “Give a detailed explanation of how you would graph \( f(f^{-1}(x)) \) on your calculator”
(p.337).

• Use of real-world context:
Text seems to use a real-world context wherever appropriate/possible, including
investigations, HW problems, and projects.
• Use of graphing calculator – computation or visualization:
  Both! Chapter 7 is on Exponential and Log. Functions and the Investigations typically
  involve visualization (suggests more time needed for visualization use of gc).

• Translation b/w various representations – algebraic, numeric, graphic:
  Yes! Investigations involve this (again ~ time issue).
  Example: Chapter 10 Investigation is to maximize the area of a triangle and involves all
  three representations (p.228).

4) What is included in Teaching Notes regarding graphing calculators:
Mainly – suggestions for when to use gc and for what features to use. Example: Use
Table feature to explore and check answers for problems 3 and 6 (p.174).
Also, suggestions for what students should be aware of (example of p.228).
In the Teacher’s Guide, the notes are not specific for any type of gc. “Calculator Notes”
book (for TI-82, -83) – notes on specifics re: how to use gc. Example 1: How to graph
composite functions. Example 2: Quadratic formula program.

Additional Notes (Misc.):
• Teacher Resource Book (TRB) – Journal Questions, open-ended problems, more skill
  questions for tests/quizzes, Group Problems (many of which use gc).
  TRB is similar in nature to text re: PSSM issues.
• TH cognitive level – present in Investigations, examples & exercises (frequently see in
  both), also in TRB (open-ended problems, Group Problems).
Qualitative Data Recording Sheet                  Curriculum: Glencoe

1) Textbook goals for graphing calculator use:
In “Teacher Handbook,” acknowledges NCTM PSSM including the Technology Principle – lists the principles – lists the main components of the Standards.
No explicit goals for gc use.

2) Extent of textbook dependence on graphing calculator technology:
Text “includes opportunities to use graphing calculators…in the exploration of Algebra 2 concepts” (p.T22). Most chapters include one or two Graphing Calculator Investigations. Other uses – examples: (1) Use gc visualization method to check computation method. [This is the most typical use of gc.] (2) To find x-intercepts of quadratic function. In Chapter 6, 9 of 33 examples use gc – but keep in mind that Chap. 6 is on quadratic functions which are amenable to gc use. In Chapter 3, 0 of 21 examples use gc. Use of gc’s is not mandatory – seems optional – almost like an appendage. Only occasionally, a gc icon appears next to exercise that is designed for gc use.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Chapters 6, 10

- Request for justification:
In general, some in Writing Exercises, some in word problem exercises (see p.529). For gc, no exercises, examples, investigations that specifically ask for an explanation.
Investigation examples: (1) For \( y = a(x - h)^2 + k \), how does changing the value of \( h \) affect the graph? (p.321)
(2) Describe the relationship between the graphs. (p.524).
(3) Are these good models? Why or why not? (p.540).
More on the use of reasoning is discusses in 4) under Teaching Notes.

- Use of real-world context:
In general, there are real-world problems – mostly in the exercises, occasionally in examples.
For gc, example: p.331 Chapter 6 Example 4 is in the context of football and uses a gc to graph and solve an inequality using a function of the height of the football.
Graphing Calculator Investigations – in Chap. 6 - 1 of 2 investigations has real-world context
- in Chap. 10 – 1 of 3 has real-world context.
In the Examples, in Chap. 6, three are real-world.
• Use of graphing calculator – computation or visualization:
  Both –
  In Chapter 6, mostly visualization – often for checking answers.
  In Chapter 10, mostly computation.

• Translation b/w various representations – algebraic, numeric, graphic:
  Overall, more so in Chapter 6 – re: examples, especially for visually checking answers obtained algebraically. Investigations involve translation b/w various representations as well.
  In Chapter 10, the Investigations deal with this.

4) What is included in Teaching Notes regarding graphing calculators:
For TI-83+
Teaching tips on using technology (gc) are mainly for GC Investigations [This is again indicative of technology/gc as an appendage to the curriculum] –
(1) things to be aware of w.r.t. students such as entering WINDOW dimensions, clearing lists (L1, L2) before entering data. Keystrokes are provided in text.
(2) Tips for exercises – tips for additional discussion and to clarify expectations of answers. Tips re: assessment (Exercises part of Investigations) - for example, make sure students explain why their equation of best fit is a good choice.

Additional Notes (Misc.):
• Ancillary materials – Chapter Resource Masters with tests, quizzes, open-ended assessments – nothing specifically geared towards gc’s. One example in chapter 10 (p.621), graphing calculator use for computation and student is required to explain reasoning.
• CD-ROM problems – similar to Exercises in test & to Chapter 6 and 10 Tests.
• T/H cognitive level – approx. 1~2 Critical Thinking problems in the exercise sets (not necessarily gc active - also in Chap. 10 Open-Ended Assessment and in Chapters 6 and 10 GC Investigations.
1) Textbook goals for graphing calculator use:
HRW “supports instruction that utilizes technology with activities and examples that encourage students to make and test conjectures and to confirm mathematical ideas for themselves” (p.T21).
The classroom as a lab for exploration and experimentation rather than just memorizing isolated facts. Use technology with real-world applications, real data.
In particular, gc as powerful tool for visualization – text incorporates gc’s into instruction so that their use is “appropriate and promotes mathematical reasoning.”

2) Extent of textbook dependence on graphing calculator technology:
Each chapter has an average of six activities – the majority of which use gc and are investigations.
Gc – common uses – to check answers in examples – to solve a problem with more than one solution method.
There is a keystroke guide for students in each chapter. In the Chapter Interleaf (for teacher) – there is a Technology page that explains how gc used in chapter. There is also a Student Technology Guide in the ancillary materials.
The use of gc is heavily integrated throughout the textbook via examples, activities, and pictures of what the gc screen looks like.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Chapters 5, 6

• Request for justification:
Yes – in the Activities (including gc activities).
In the exercises – rare. One example – p.312 #51 (Connection problem) - students are required to “Explain.”
In the examples – rare. One example – p. 387, Example 2: “Compare the intensity of this running vacuum cleaner with the threshold of hearing.” *Also see Additional Notes section.

• Use of real-world context:
Each exercise set has numerous Applications problems that have a real-world context and require the use of a gc for computation and/or visualization.
• Use of graphing calculator – computation or visualization:
  Visualization – often used in examples, especially to check answers obtained algebraically. The examples emphasize a visual use of gc.

• Translation b/w various representations – algebraic, numeric, graphic:
  The examples show two methods – one involving graphic/numeric (table) – one involving algebraic/graphic.

4) What is included in Teaching Notes regarding graphing calculators:
Nice!
Chapters 5 and 5 – “Interleaf” includes a page on technology – how gc could be used for each section/lesson of chapter and ideas for questions to ask students. For example, ask students how they might solve the equation $\log x = 10^{-3}$ using a graphical approach.
“Teaching Tips” on (1) how to use gc (specifically for TI-82 or TI-83) accompany some of the examples that use technology in the text. For example, how to check max/min values, how to set the viewing window for a particular problem in an example.

Additional Notes (Misc.):
• * Chapter Resource Masters (on CD) – includes Alternative Assessments – in Chapter 5, gc use is optional and reasoning is required.
• T/H cognitive level required in:
  - Method 2 of some examples (using gc)
  - 1–2 “Challenge” problems in the exercises (but typically do not use gc)
  - GC Activities
1) Textbook goals for graphing calculator use:
There is nothing explicit w.r.t goals for gc use at the beginning of the text.
For each chapter and lesson, the goals are listed – the Technology Activities that require a gc are listed under some of these goals.
Also, there is a written paragraph on the goals for each chapter – the paragraph does not explicitly mention the use of gc’s.

2) Extent of textbook dependence on graphing calculator technology:
In the “Pacing the Chapter” section, there are “Teaching Options” for each day and GC Activities/Technology Activities are given here – as an option.
Technology/gc’s are not heavily integrated into the chapter examples – Activities that use gc are given separately at the end of some sections. On average, there are about two Tech/GC Activities per chapter. The integration of gc’s depends on the topic – some sections have none and some have 1~2 activities.
Some “Developing Concepts” Activities use gc. For example, Chapter 5 p.259 activity involves investigating transformations of parabolas.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Chapters 5, 8

- Request for justification:
  Very few examples, exercises in text that use gc.
  Examples:
  8.1 p.471 – one “Logical Reasoning” problem required explanation – gc could be use for computation.
  8.2 p.479 – one Challenge problem with the heading “Critical Thinking” required a justification of the answer
  – one Writing problem required students to explain – gc could be used.
  For 8.1, 8.2, some justification requested in Challenge problems – some of which could use gc. [But Challenge problems are most likely not going to be on tests.]
  Another example in an Investigating Parabolas Activity (p.249) – students asked to “Describe the effect of a on the graph of y = ax^2.”

- Use of real-world context:
  Icon of the earth next to real-world problems in the exercise sets, many of which required a gc for computation.
• Use of graphing calculator – computation or visualization:
  Computation – in real-world exercises, example
  Both Chapter 5 (Quadratic) and Chapter 8 (Exponential) use gc for modeling/regression.
  Visualization – gc icon next to examples and exercises that explicitly want students to use gc (for visualization) – this is true for the majority of the problems – this is not the case where a gc could be used for optional checking of answers. In Chapters 5 and 8, for the exercises, approximately 1~2 per section use gc for visualization, on average and for the examples, ~1 per section.

• Translation b/w various representations – algebraic, numeric, graphic:
  Some examples involve translations using a gc with the most common translation from algebraic to graphic. Activities 5.3 and 8.5 involve translations from algebraic to graphic using a gc.
  Although, due to a lack of examples with gc’s, translations are not heavily emphasized – many of the examples that use a gc use it to graphically check an algebraically obtained answer. The use of numeric representations is rare.

4) What is included in Teaching Notes regarding graphing calculators:
In the Chapter Resource Books (CRB), there are Keystroke blackline masters.
The CRB also has “Tips for New Teachers” – Chapter 5 briefly mentions that students might use a calc to incorrectly evaluate the quadratic formula – Chapter 8 has nothing. Overall – very little!

Additional Notes (Misc.):
• The Chapter Resource Book (CRB) has a GC Lesson Opener for some sections (for 5.1, 8.6), GC Activities in some sections (5.1, 5.6, 8.2, 8.6, 8.8), and a Keystroke Guide for Activities and exercises for various gc’s including the TI-82 and TI-83. Overall, the request for justification in the CRB is rare, no real-world context, use of gc is for visualization, and translation b/w rep’s is from algebraic to graphic.
• T/H cognitive level – yes in GC Activities (both in text and CRB) – some in examples, word problems in exercises.
Qualitative Data Recording Sheet  

1) Textbook goals for graphing calculator use:
No explicit goals for gc use. P.T7 – under Program Components – Reaching All Students – lists “Technology Activities.”
Pp. T13-T26 – under some sections – Technology Activities (~1 per chapter, however, Chapter 8 has 3!)
“Math Background” for each chapter – p.420B – using gc for complex calculations with logs.
Text lists NCTM Standards as related to the book (Alg.2) → Algebra Strand (p.T37) – use technology to “study residuals as an indicator of the most appropriate model for data.” [Technology is only mentioned one time and there is no mention of gc.]
“Instant Check System”
PH School website – GC “Procedures”

2) Extent of textbook dependence on graphing calculator technology:
Depend on the topic – (1) there are some examples that use gc – the first one is Chapter 2 Example 2 and includes a “Graphing Calculator Hint” on how to use the ZOOM feature. (2) there are some exercises that have an icon of a gc.
There are Technology Activities. For example, finding the line of best fit (p.85) uses the LinReg feature/function button on the gc.
“Extensions” – Chapter 5 Section 5 – uses gc to graph inequalities and solve systems of quadratic inequalities. Chapter 8 Section 5 – uses gc for Linear and Exponential Models
Overall, gc’s are not an integral part of curriculum – seem more optional, like more of an appendage.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Chapters 5, 8

- Request for justification:
  Very little.
  Technology Activity in 5.1 says “Justify your reasoning” - in 8.1 “Fitting Exponential Curves to Data” asks student to “Explain why this happens” as part of a writing exercise associated with the Technology Activity.
  In some exercises - Sect. 5.1: 31, 38. Sect. 8.2: 49.
  In the Extensions – 8.5 (yes), 5.5 (no)
  Rarely in Examples. Sect. 8.6 Example 2 does not explicitly request justification, but does ask a question that requires an explanation.
- Use of real-world context:
  In general, p.T4 says there are “abundant real-world connections” and this is true – there are lots of examples and exercises that are real-world.
  Out of a total of 45 Examples in Chapter 5, the following Examples use a gc: 5.1 Example 4, 5.5 Example 5, 8.3 Example 1, 8.5 Example 5, 9.6 Examples 2 and 5 (both for computation).
  Out of a total of 33 Examples in Chapter 8, the following Exercises use a gc: Sect. 5.1: 21, 22, 31, 38. Sect.5.8: 68. Sect. 8.1: 45b, 59c. Sect. 8.2: 49. Sect. 8.6: 65.
• Use of graphing calculator – computation or visualization:
Both! For computation – Examples (8.3 Example 1, 8.6 Example 2) and Exercises, one Investigation on the properties of logs.
For visualization, Example and Exercises. Examples from the Exercises: (1) Solve an equation by graphing. (2) 8.3 #'s 18-23, use of graph of \( y = e^x \) to evaluate the expression. (3) 8.6 #65.

• Translation b/w various representations – algebraic, numeric, graphic:
Exercises – mostly graphic \( \leftrightarrow \) algebraic (use graph to solve).
Extensions – 5.5 – algebraic \( \rightarrow \) graphic, 8.5 – numeric \( \rightarrow \) graphic \( \rightarrow \) algebraic.
Activities – 5.1 – numeric \( \rightarrow \) algebraic, 8.1 – numeric \( \rightarrow \) algebraic \( \rightarrow \) graphic, 8.3 – algebraic \( \rightarrow \) graphic.

4) What is included in Teaching Notes regarding graphing calculators:
Technology Tips for Exercises. For example, p. 266 - tip on using CALC feature and includes a suggestion for how to select left and right bounds.
Teaching Notes for Technology (GC) Activities and Extensions: (1) includes “Error prevention” – things to look out for. (2) suggestions re: how to use gc and what to expect. (3) includes Technology Tips - things to be aware of re: using gc.

Additional Notes (Misc.):
• Ancillary materials – Computer Test Generator on CD-ROM - in line with textbook.
• T/H cognitive level – present in GC Technology Activities, in some word problems in exercises, and in some examples.
Qualitative Data Recording Sheet

1) Textbook goals for graphing calculator use:
The curriculum claims to implement the latest technology.
P. T9 – Applications using technology (including gc’s) enhances mathematical understanding and strengthens problem solving skills. Technology is “incorporated throughout the text.” Students should have a gc throughout the year, including for tests and quizzes. The use of a gc makes it easier to approach functions. Gc’s are “required because they are used throughout (the textbook) as a patter-finding, concept-developing, and problem-solving tool” (p.v).

2) Extent of textbook dependence on graphing calculator technology:
Gc technology is definitely used throughout text, but lack of gc icons, pictures of gc screen make use not as explicit or obvious. “In-class Activities” that use “automatic graphers” – there are 1–3 per chapter. Two examples: 1.2 – Introduction to some of function key on calc. 1.8 – Recursive formulas on calculators. Gc is often used in examples for computation and/or visualization. There are some short activities that use gc mixed in with Examples. For example, p.584, calc is used to evaluate logarithmic functions involving.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Chapters 6, 9

• Request for justification:
Very little in Example, Activities (short), and Exercises, and none in In-class Activities. Examples – Chapter 6 – very little. For example, p.365 Example 2 (b) “Explain what each pair (b, h) tells you about height of ball.” Chapter 9 – none. Activities (short) – Chapter 6 – very little. For example - Section 6 p.379 – Re: models, asks “Why or why not?” Chapter 9 – none. Exercises – Chapter 6 – Some in “Exploration” exercises. Chapter 9 – very little. For example, Section 9.8 #27 asks “Why?” regarding a problem where a gc is used for visualization.

• Use of real-world context:
Present in “Applying the Mathematics” (Exercises) and some in “Review” Exercises and in “Exploration.” Exercises – Approximately 2 problems per section in “Applying the Mathematics” and approx. 1 problem per section in the “Review” exercises. Each section has about 30 exercises in total, on average. Examples – in Chapter 6 – about 25%. – in Chapter 9 – about 50%. Of the In-class (long) Activities (6.2, 6.9, 9.2), only 9.2 real-world. Approximately 50% of the short Activities are real-world.
• Use of graphing calculator – computation or visualization:
Both. In Examples and Exercises, usually used for computation only, or for a combination of computation and visualization. Two examples in Chapter 6 are for graphically (visualization) checking solutions that were obtained algebraically.

• Translation b/w various representations – algebraic, numeric, graphic:
One example of this is Sect. 6.6 Example 2: Numeric $\rightarrow$ graphic $\rightarrow$ algebraic.
Another example – Sect. 6.7 Example 2: For graphically checking solutions that were obtained algebraically.
Use of tables (numeric) is fairly common.

4) What is included in Teaching Notes regarding graphing calculators:
Provide some suggestions for when and how to use gc. For example, Chapter 6 opener suggests that teacher might have students graph $y = x^2$ on gc and zoom in and out to become familiar with the shape of a parabola.
Another suggestion – to use gc as another way to show the Absolute Value – Square Root Theorem.
For an In-class Activity – suggestion to use gc to check prediction.
Point out things to be aware of, to look out for such as having a limited view of graph depending on the viewing window.
Note: There are no notes that are specifically labeld as “Technology Tips.”

Additional Notes (Misc.):
• Ancillary materials on CD-ROM include: Activity Sourcebook, Assessment Sourcebook (Quizzes, Chapter Tests), and Technology Sourcebook (activities for use with calculators and computers – some real-world, some requests for justification). One example in Technology Sourcebook is for Chapter 6 on Quadratic Modeling with real data –Computer Master 9 – The Graph Translation Theorem – not real-world and a lot of “check your work by graphing.” – Computer Master 10 – Fitting a Quadratic Model to Data – real-world – some reasoning “Explain your response.”
Chapter 9 – Computer Master 13 – The Number e – not real-world, some requests for justification.
• T/H cognitive level – some (light) in In-class Activities, example (to “check”), and exercises.
Overall – some justification, some real-world, some T/H cognitive level.
Qualitative Data Recording Sheet      Curriculum: __Core-Plus________________

1) Textbook goals for graphing calculator use:
For assessments, calculators are required in most cases and are intended to be available to students. Graphing calculators are "assumed and appropriately used throughout the curriculum" (p.xiii).
Also, technology permits emphasis on multiple representations (verbal, numerical, graphical, symbolic) and "to focus on goals in which mathematical thinking and problem solving are central."

2) Extent of textbook dependence on graphing calculator technology:
Has Explore- Small Group Investigations that involve: 1) computations using real data and 2) explorations using calc’s graphing/visualization capabilities.
Unit 4, however, has very little gc use – gc’s are used some for computation and are not used at all for visualization.
The extent of gc use depends on the topic.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Units 3,6

  • Request for justification:
    Students are frequently required to “explain the meaning” in both small group Investigations and in independent assignments. The Investigations are a big part of each lesson and there are usually 2 to 3 investigations per lesson.
    Request for justification in the “MORE” section (Modeling-Organizing-Reflecting-Extending).

  • Use of real-world context:
    For the most part, frequently used in all parts (Investigations, independent assignments, MORE) of the units of the text - b/c of real data, gc’s are needed.
    Investigations – typically have a real-world context.
    However, overall, it depends on the topic – in some units more so than in others. For example, Unit 6 (on Families of Functions) – Lesson 2 Investigations on “Vertical Translation” and “Reflection across the x-axis” do not have a real-world context (though both use a gc.)
• Use of graphing calculator – computation or visualization:
  Both!

• Translation b/w various representations – algebraic, numeric, graphic:
  Frequent use of gc Table feature (graphic \(\leftrightarrow\) numeric). Also, use of translation between
  all three different representations. For example, Unit 6 Investigation 3 “Vertical
  Stretching and Shrinking” (p. T449) #3 – Use your calculator to compare the graphs and
  tables of values for these four functions:
  \[ c(x) = \cos x \]
  \[ d(x) = 5\cos x \]
  \[ e(x) = 0.5\cos x \]
  \[ f(x) = 5\cos x - 2 \]
  Then describe how they are similar and different.

4) What is included in Teaching Notes regarding graphing calculators:
  Teaching Notes are excellent! In general, for each unit, the Teaching Notes section is
  quite extensive. Not only are they present in the answer key provided for all problems,
  but the Teaching Notes (TN) give/provide explanations for stuff such as graph behavior
  and suggestions for what to look out for, make sure of, and what to make sure the
  students do.
  Specific to gc use, the Teaching Notes show: what graphs should look like, window
  selection (give recommended values for xmin, xmax, ymin, ymax, xscl, yscl), what tables
  should look like, suggestions for “step size” on table. TN suggest to teachers to be sure
  students explain concepts related to gc graphs. Also, TN provide suggestions for
  questions teachers should ask to facilitate gc use.

Additional Notes (Misc.):
• Ancillary – Assessment Resources book – has Projects, Quizzes, Take-Home
  Assessments. In general, for problems that use gc – Justification is requested, context is
  not real-world, translation between rep’s is algebraic\(\leftrightarrow\)graphic, and gc is used for
  visualization.
• T/H cognitive level – prevalent in Investigations and independent assignments.
1) Textbook goals for graphing calculator use:
“Each IMP student should have a graphing calculator within arm’s reach at all times during class” (p.28 of Teaching Handbook for the IMP). Students are allowed to use gc’s on assessments. “The IMP curriculum incorporates graphing calculators as an integral part of the development of mathematics ideas” (p.10, Introduction and Implementation Strategies for the IMP). Students decide when to use gc as a tool. Technology allows students to focus on ideas, not getting bogged down by computation. Use technology to create simulations, models, and graphics. Technology allows students to examine mathematical topics in depth.

2) Extent of textbook dependence on graphing calculator technology:
Gc use is definitely there but is not heavy and is not explicit and seems to be treated as more of an option. Text does not specifically address (or have icons/sections dedicated to) use of gc’s. Gc use is not often explicit in the text as far as icons, pictures of gc graphs and viewing windows, although many of the problems are designed for gc use and problems will occasionally mention gc. For example, one item says “Adjust the viewing window of your graphing calculator so you get a good view of the graph” (p.11). A lot of the problems in the text are gc neutral.

3) Textbook and ancillary materials (including alternative assessments) reflection of PSSM with respect to use of graphing calculator: Fireworks, Small World Isn’t It?

- Request for justification:
  Fireworks – Classwork sections that use gc are entitled “The Same but Different” and “The Ups and Downs of Quadratics.” Both of these request justification of answers. Regarding the Homework, for problems that explicitly use gc, some justification is requested.
  Small World Isn’t It? – Classwork sections that use gc are called “Photo Finish”, “Zooming Free-For-All”, “ZOOOOOM”, and “How Much for Broken Eggs?” All of these request justification.
  The Homework mirrors the classwork
  For Problems of the Week (POWs), these are more open-ended and use of gc is up to the student. Justification (explanation) is requested in the write-up of the solution.
- Use of real-world context:
  Fireworks – Classwork sections that use gc are entitled “The Same but Different” and “The Ups and Downs of Quadratics.” Neither of these has a real-world context.
  Small World Isn’t It? – Classwork sections that use gc are called “Photo Finish”, “Zooming Free-For-All”, “ZOOOOOM”, and “How Much for Broken Eggs?” All of these have a real-world context.
POWs typically have a real-world context.
• Use of graphing calculator – computation or visualization:
  Both!

• Translation b/w various representations – algebraic, numeric, graphic:
  Most typical is algebraic → graphic.

4) What is included in Teaching Notes regarding graphing calculators:
Teaching Notes (TN) are included in the Teacher’s Guide which includes Discussion of
Classwork and Homework problems. TN include: suggestions for discussing, going over
HW, questions to ask, restraints of gc (such as limitation of gc screen/viewing window),
what to expect. To provide an example - Fireworks (p.39) says “Raise the issue of
whether a quadratic function might not have some intercepts that are not visible in the
viewing window of the graphing calculator.” This statement is followed by suggestions
for corresponding questions to ask.
None of the notes are specifically called “Technology Tips.” The technology related
notes are embedded in the rest of the notes. There are no keystroke guides.

Additional Notes (Misc.):
• Supplemental problems – 11 total for Fireworks – one of which is gc active – it is not
  real-world, requires justification, and gc is used for computation.
- 17 total for Small World Isn’t It – one of which is gc active – is is not real-world,
  requires justification, and gc is used for computation.
• T/H cognitive level – Classwork – yes, and also in Homework.
Not as extensive as in Core-Plus.
1) Textbook goals for graphing calculator use:
The SIMMS curriculum “takes full advantage of the appropriate use of technology.”
Technology is necessary to achieve the goals of the curriculum.
Graphing calculators must be readily accessible to students.

2) Extent of textbook dependence on graphing calculator technology:
All of the activities in the three modules closely examined by the researcher have a
graphing utility on the materials required list, but graphing utilities are not extensively
required in the activities.
Specifically where/when to use gc can be explicit such as a problem stating “Use a
graphing utility to…”
Some problems are explicit. However, for some, it is unclear whether gc use is intended
or not.

3) Textbook and ancillary materials (including alternative assessments) reflection of
PSSM with respect to use of graphing calculator:
(A) It’s All in the Family, (B) Drafting and Polynomials, (C) Log Jam
• Request for justification:
Note: Each activity includes Exploration, Discussion, and Assignment Questions.
Some justification is requested in the Activities and Assignments, but it is inconsistent.
Justification is required more so in the Discussions.

• Use of real-world context:
On average, approximately 50% of the Activities and associated Assignment problems
are set in a real-world context. The problems are often science applications. It is
common for some problems to start out in a real-world context, but the actual questions
are not posed in a real-world context.
• Use of graphing calculator – computation or visualization:
  Computation – some (very little)
  Visualization – more so - heavy emphasis on use of gc for graphing, modeling. SIMMS refers to it as a “graphing utility.”

• Translation b/w various representations – algebraic, numeric, graphic:
  Translation between all three different representations.
  In (A) and (B) modules, graphic → algebraic is emphasized.
  In (A) module, modeling uses numeric → graphic → algebraic.
  Overall, most often, numeric → algebraic, or algebraic → graphic.

4) What is included in Teaching Notes regarding graphing calculators:
There is no specific section of Teaching Tips.
There is a “Teacher Note” part of the Teacher’s Edition that for each Activity, includes general notes on the activity and things to point out to students, but very little re: the use of a gc.
Specific to gc use, one example from the Teacher Notes of the (B) module says “When using a graphing utility, students should plot points so that both a scatterplot and a function can be illustrated simultaneously” (p.129).
For the most part, the Teacher’s Edition includes sample responses and an answer key, but not a lot of specifics regarding the use of a gc/graphing utility.

Additional Notes (Misc.):
• Summary Assessments - follow each module are more open-ended – are real-world, allow for gc use (2 out of the 3 require a gc), and requests justification in 2 out of 3 examined.
• T/H cognitive level –
  Activity Explorations and Discussions – yes.
  Homework – combines procedural (more so in (C) Log Jam), but otherwise yes.
  Summary Assessments – yes.