Academic Mathematicians’ Dispositions Toward Software Use in Mathematics

Instruction: What Are the Underlying Reasons?

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Heba Bakr Khoshaim

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This dissertation titled

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Abstract

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Instruction: What Are the Underlying Reasons?

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Academic mathematicians’ opinions are divided regarding software use in undergraduate mathematics instruction. This study explored these opinions through interviews and a subsequent survey of mathematicians at PhD-granting institutions in the United States regarding their dispositions and the underlying attitudes. Most prior related work had focused on mathematicians who used software in teaching, thus ignoring skeptics and critics. This investigation studied the full range of views. The research questions were

- What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

- What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

An exploratory sequential research design built, expanded, and tested a model to explain mathematicians’ dispositions toward software use in undergraduate instruction. This model subsumed Fishbein and Ajzen’s attitude framework. The researcher reviewed anecdotal evidence, published opinions, related theories, and research results to add to this framework, thus building an initial model. Next, interview data were used to expand
the model, and the data and expanded model served as bases to develop a survey
instrument. Using a sample of mathematicians from 50 PhD-granting institutions, survey
data tested the factors in the expanded model. The interview data and the survey data
were triangulated with the reviewed literature to refine the model to include factors that
emerged as the underlying reasons for the use or nonuse of software.

The triangulation process suggests that most mathematicians have a moderate and
somewhat skeptical attitude toward software use in teaching. Small numbers of
mathematicians either strongly oppose or strongly support software use across
undergraduate instruction. Most mathematicians value the benefits of software but are
concerned about its potential harm and prefer traditional instructional methods.

The interviews identified 8 factors and 16 subfactors that contribute to
mathematicians’ attitudes regarding software use. Among these, the triangulation process
suggests that software characteristics, perceived effect on learning, and instructor’s
personality were the three most influential factors. Among the remaining factors,
students’ level, students’ major, instructor’s educational background, and teaching
background were supported. In addition, there were inconsistent results with regard to
institution and research interest as factors, which may warrant future investigation.

Approved: _________________________________

Gregory D. Foley

Robert L. Morton Professor of Mathematics Education
Dedication

This dissertation is dedicated to my mother

Ameera Al-Tayyar

and my father

Dr. Bakr H. Khoshaim;

without your unconditional, ultimate love and support

this work would be just next to impossible
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First, and above all, my ultimate gratitude goes to the Merciful God Almighty for guiding me during this journey. Second, there are several people whom I would like to acknowledge. I would like to thank the dissertation committee members: Dr. Gregory D. Foley, Dr. John H. Hitchcock, Dr. Sergio R. López-Permuth, and Dr. Timothy McKeny for their kind support, thoughtful advice, and helpful input through the whole process. Special thanks goes to Dr. Hitchcock for his valuable assistance during the analysis procedures.

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encouraged me, and celebrated my victory like if it was yours. Thank you, my brothers-in-law, nieces, and nephews.

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Chapter 1: Introduction

The use of software in mathematics instruction is a rapidly developing area of research that interests scholars worldwide. Yet, mathematicians’ points of view with regard to using mathematical software when teaching mathematics are not well known or clearly understood (Ralston, 2004). This study is an in-depth analysis of academic mathematicians’ dispositions toward software use when teaching mathematics in U.S. undergraduate classrooms and the complex of reasons that underlie these dispositions. This research was motivated by a lack of existing knowledge about these dispositions and the related attitudes.

Aiken (2000) defined attitude as “a learned predisposition to respond positively or negatively to a specific object, situation, institution, or person” (p. 248). Defining attitude as a predisposition implies that a person’s attitude comes before and leads to the person’s disposition. An individual’s disposition is relatively fixed and unchanging. Disposition is more than just a feeling or emotion; it is a recurring and stable perspective that a person internalizes. Taylor and Wasicsko (as cited in Almerico, Johnston, Henriott, & Shapiro, 2011) defined disposition as a set of characteristics a person uses that includes both attitude and beliefs. According to this definition, disposition is a broad term that encompasses attitude. This study employs the definitions of Aiken and of Taylor and Wasicsko. The rest of this chapter sets the stage of the study by explaining the need for such an investigation and its educational significance.
Background

For many years, researchers have explored the effect of using mathematical software to facilitate and enhance mathematics teaching and learning (Kaput, Hegedus, & Lesh, 2007; Zbiek, Heid, Blume, & Dick, 2007). According to Heid and Blume (2008), since the 1980s, numerous studies have explored and analyzed the effects of using mathematical software in classrooms. Investigating software use in mathematics instruction still interests researchers not only in the United States but also around the globe. Examples include Artigue (2002); Baek, Jung, and Kim (2008); Barzel (2007); Habre (2011); Man (2007); Ruthven and Hennessy (2002); Sárvári, Lavicza, and Klimcsik (2010); and Shao (2010). Most of these studies have addressed the use of software at elementary or secondary school level (e.g., Adabor, 2008; Fine & Fleener, 1994; Roschelle et al., 2010); few have given attention to the undergraduate level (Quinlan, 2007). Therefore, this study focuses on undergraduate mathematics instruction.

The term mathematical software in this study refers to computer programs that support the exploration of mathematical concepts and that can be used to support the learning of mathematics. Such programs often will be referenced simply as software for the remainder of this document. Examples of such software include, but are not limited to, geometry software, such as Cabri Geometry™ or Geometer’s Sketchpad®, and computer algebra systems (CAS), such as Derive or Mathematica®. These and other digital utilities can serve as tools for mathematical instruction. They can be combined with interactive digital boards and with feedback and networking devices in instructional settings. Such software is now available on various computer platforms: desktop, laptop,
and handheld. In contrast, other types of technology that might be used in classrooms, but not as tools to support mathematics teaching and learning, are outside the scope of this study. For example, using a computer for searching the Internet is not of interest to this research, nor using tutorial packages. Furthermore, using mathematical software for teaching should not be confused with using general software, such as Blackboard or Microsoft Office, for course management, class presentations, or office organization. This investigation, however, does include the use of spreadsheets, such as Microsoft Excel, by instructors or students to investigate mathematical concepts and relationships. In sum, this study focuses on the use of mathematical software utilities as teaching and learning tools to support mathematics instruction.

The impetus for research on the integration of software in undergraduate mathematics instruction is that such integration has the potential to enhance students’ mathematical proficiency. The five strands for mathematical proficiency as presented by the National Research Council (NRC) are as follows:

- conceptual understanding—comprehension of mathematical concepts, operations, and relation;
- procedural fluency—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately;
- strategic competence—ability to formulate, represent, and solve mathematical problems;
- adaptive reasoning—capacity for logical thought, reflection, explanation, and justification;
• productive disposition—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy (NRC, 2001, p. 116).

Most of the studies that have explored the effect of software use in undergraduate mathematics instruction have found positive results with regard to one or more strands of students’ mathematical proficiency. Some studies have discovered that using such technology during instruction deepens students’ conceptual understanding (Heid, 1988; Hollebrands, Conner, & Smith, 2010; Vonder Embse, 1990). Others have indicated that software use enriches students’ problem-solving strategies (Camacho Machín & Depool Rivero, 2003; Evans & Johnson, 1990). Some investigations have reported that software use supports students’ ability to reflect on their thinking (Camacho Machín, Depool Rivero, & Santos-Trigo, 2010; Habre, 2011). Others have suggested that software use could increase students’ motivation to learn (Connor & Grover, 2005; Morrow, 1997), a component of the productive disposition strand of mathematical proficiency. These findings suggest that using software in undergraduate mathematics instruction could enhance components of students’ mathematical proficiency.

**Statement of the Problem**

According to Quinlan (2007) and Ralston (2004), mathematicians’ opinions are not unified when it comes to software use in teaching. Some mathematicians argue that the use of software will hinder students’ thinking, but others believe that it will improve it. Some mathematicians claim that software is a tool that does the mathematics for the students, yet others hold the position that software is a tool that enhances the learning of
mathematics (Quinlan, 2007). Still other collegiate mathematics instructors take a balanced view and argue that technology has both benefits and limitations and that those who teach have to be aware and considerate of both (Grimaldo & Robichaud, 2011; Kortenkamp, 2007). The problem addressed by this study stems from these divided dispositions of academic mathematicians toward software use in their teaching, as well as the reasons underlying this trichotomy of dispositions. The main questions for this study are as follows:

1. What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

2. What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

Although technology has affected many aspects of our lives, these effects are minimal when it comes to mathematics instruction at the collegiate level. Computers have changed how people approach typical activities (Moore & Smith, 2006) and how instructors teach at Grades K–12 (Bransford, Brown, & Cocking, 2000). However, technology has had a limited influence on how mathematics is taught in undergraduate mathematics classrooms (Committee on the Undergraduate Program in Mathematics ([CUPM], 2004). Quinlan (2007) argued, “undergraduates and graduates rarely encounter computer technologies incorporated in the curriculum” (p. 6).

The call for software integration in collegiate mathematics started more than 20 years ago (CUPM, 1990). This includes the call for using powerful calculators with mathematical software; such tools are called graphing calculators, handheld devices,
handheld computers, or simply “handhelds.” NRC (1991) stated, “computers serve mathematics these days as indispensable aids in research and application. Yet only in isolated experimental courses has the impact of computing on the practice of mathematics penetrated the undergraduate curriculum” (p. 17). Although this NRC statement was made two decades ago, it appears that little has changed in this regard. According to the Conference Board of the Mathematical Sciences (CBMS) survey in 2005, only about 50% of calculus courses at universities used graphing calculators (Lutzer, Rodi, Kirkman, & Maxwell, 2007). Up to the time of writing this dissertation, the CBMS 2010 survey results were not published; however, Kirkman (2012) presented a summary of the survey results indicating that only 46% of college algebra classrooms in PhD-granting departments use graphing calculators.

Many scholars have investigated the effect of software use in mathematics instruction at the undergraduate level (e.g., Camacho Machín et al., 2010; Connor & Grover, 2005; Hollebrands et al., 2010). Most of these studies have yielded positive findings with regard to student learning. Moreover, “the use of technology typically underlies mathematics reform movements” (Quinlan, 2007, p. 4). Considering these findings and opinions, one might expect that instructors at the collegiate level would support the implementation of software in teaching. Contrary to this expectation, many mathematicians do not use software in collegiate mathematics instruction. In fact, Usiskin (1999) argued that the issue of the use of graphing calculators in mathematics instruction, for example, is an ongoing debate.
On one side of the argument are mathematicians who believe that using software is harmful to students’ learning (McCallum, 2007) and onerous for instructors. Some argue for thinking over computing: “Teach them to think; they can waste time with a computer later” (Quinlan, 2007, p. 220). Another concern is to develop students’ traditional computational skills, especially because they feel that students are coming to university with limited such skills (Ralston, 1999). In addition, some academic mathematicians claim that the use of technology in mathematics instruction is nothing but an extra burden on them (Jackson & Hundley, 2011). On the other side are advocates who maintain that integrating software when teaching mathematics is beneficial to the extent that it overcomes the potential harm and is actually rewarding (Carroll, 1992); “start integrating technology into the classroom as early as possible” (Quinlan, 2007, p. 220). A third group argue that we can use software but with great caution. Software can benefit students but not without the consideration of certain factors. For example, some mathematicians see that the use of software should occur only at certain levels, only with specific groups, and only to some extent: It “depends on what profession the student chooses” (Quinlan, 2007, p. 220). Despite these findings, the reasons underlying such opinions have remained largely undetermined.

Borwein, Bailey, and Girgensohn (2004) commented that, back in 1985, “there appeared to be a widespread view in the field [of mathematics] that ‘real mathematicians don’t compute’” (p. vii). It is certainly understandable how such a view could have influenced mathematicians’ behaviors in classrooms and have resulted in a reluctance to use software in their instruction in the 1980s. However, since then, numerous studies
have shown positive effects for using software in undergraduate mathematics instruction. Moreover, several software packages, which are designed specifically to enhance mathematics teaching, are now available. Nevertheless, academic mathematicians’ opinions still are divided when it comes to using software when teaching mathematics.

**Significance of the Problem: Connection to K–12 Classrooms**

Learning mathematics is a continuous process. Hence, it is important that students experience a consistent approach between schools and collegiate classrooms. Camacho Machín et al. (2010) took the position that students at the collegiate level are expected to revisit, refine, and build on their prior knowledge from school to learn new mathematical concepts. Mathematics learning is expected to be a continuous coherent endeavor from elementary grades through the collegiate level. Beckmann (2011) noted, “students arrive at college with a long history of learning math” (p. 371). Hence, students’ experiences at school are expected to influence their performance in undergraduate classrooms (Rose & Betts, 2001).

**Using technology in K–12 classrooms.** Given the recommendations of the National Council of Teachers of Mathematics (NCTM) and other national reports to the appropriate use of technology at the school level to enhance the learning and teaching of mathematics (NCTM, 1980, 1989, 1991, 2000; U.S. Department of Education, 2002; National Mathematics Advisory Panel, 2008; Common Core State Standards Initiative [CCSSI], 2010), it is expected that technology affects mathematics teaching in Grades K–12. In fact, Barrett and Goebel (1990) predicted that graphing calculators would influence how mathematics would be taught in secondary grades. Many students graduating from
high school are accustomed to using technological tools, such as graphing calculators, in their mathematics classrooms.

Achieve, Inc., “is an independent, bipartisan, non-profit education reform organization based in Washington, DC that helps states raise academic standards and graduation requirements, improve assessments and strengthen accountability” (Achieve, n.d.). Currently, Achieve is leading the efforts to support the alignment between secondary education and college and career requirements. In an effort to promote college and career readiness, Achieve started the American Diploma Project (ADP). This project has built a network of 35 states so far. The goal is to align high school standards and graduation requirements with college and career needs (ADP Network, n.d.). Achieve, with the National Governors Association and the Council of Chief State School Officers developed the Common Core State Standards Initiative (CCSSI, 2010). One of the standards for mathematical practice presented by the CCSSI is the effective use of appropriate tools, which “might include…a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software” (p. 7). The CCSSI stated that mathematically proficient students “are able to use technological tools to explore and deepen their understanding of concepts” (p. 7). Hence, the use of software in K–12 classrooms is likely to continue given the general encouragement and support to use such tools.

**Lack of alignment.** Although software is being used to a substantial degree in K–12 classrooms, undergraduate mathematics courses rarely use software as a main teaching tool (NRC, 1991; Quinlan, 2007). This lack of alignment is a problem because students,
who are used to software utilities, are prevented from using such tools in their undergraduate classrooms. For instance, Ellis (2001) claimed that in some universities students would be specifically asked not to use graphical calculators.

Reform in teaching mathematics occurs at a much faster pace at Grades K–12 than at the undergraduate level (Davis, 2006; Narayan & Narayan, 2006). In particular, schools implement reforms in teaching mathematics, such as using software, more quickly than institutions of higher education. Narayan and Narayan (2006) stated that one of the major concerns addressed by the mathematical community in their conference meeting, *A Fresh Start for Collegiate Mathematics: Rethinking the Courses Below Calculus*, was that students’ experiences in schools are different from their university experiences. Instead of group work that is emphasized in schools, individual work is the dominant approach in undergraduate classes; instead of student-centered, guided instruction as seen in schools, teacher-centered lecturing are typical in undergraduate classrooms (Jackson, 2011). Most germane to the present investigation, students at schools use software, but they are often forbidden access to such tools in collegiate classes. Hence, students’ experience at K–12 classrooms differ from their experience at the colligate level. Calling for more software integration will not address this lack of alignment, unless the attitudes, and the underlying reasons, of those who teach at collegiate level regarding such integration are well understood.

**Why is attitude important?** Understanding mathematicians’ attitude is important for several reasons. First, as Alcock (2010) argued, a key element of engaging the academic mathematicians’ community in the teaching and learning issues is to
understand their perspectives and concerns with regard to such issues. Second, educators and philosophers theorize that an individual’s attitude toward a behavior is a major influence on whether the individual engages in the behavior (Ajzen & Fishbein, 1970; Ernest, 1991; Fishbein & Ajzen, 1975) and on the success of the implementation of the behavior (Bandura, 1986). In the context of this study, one factor determining an instructor’s pedagogical approach is the instructor’s beliefs about (Sandholtz, Ringstaff, & Dwyer, 2000) and commitments to (Lovitt, Stephens, Clarke, & Romberg, 1990) such an approach. Moreover, it has been shown that an instructor’s beliefs, attitude, and perceptions affect instructor’s practice (Davis, 2006; Fang, 1996). Hence, it is logical to predict that university mathematics professors’ dispositions toward software use in mathematics teaching influence their practice, which might have resulted in the limited integration of software in undergraduate mathematics classrooms.

**Purpose of the Study**

This study is an in-depth analysis of the various perspectives held by academic mathematicians regarding software use in U.S. undergraduate mathematics instruction and the complexity of reasons that underlie these perspectives. The purpose of the study was not to test a given hypothesis or to advocate for or against software integration in undergraduate instruction. However, the contradicting attitudes and behaviors among instructors at the high school level and the collegiate level resulted in a lack of alignment between secondary classrooms and undergraduate classrooms. The disparate behaviors at collegiate classrooms with regard to software integration could be the result of the different dispositions of academic mathematicians. Hence, the purpose of this study is to
develop understanding of the reasons behind academic mathematicians’ dispositions toward software use when teaching mathematics.

**Educational significance of the study.** There is limited research on academic mathematicians’ dispositions toward software use when teaching mathematics (Ralston, 2004) and the reasons that influence these dispositions. This study advanced the existing knowledge base because most prior work that has addressed software integration at undergraduate mathematics has focused on university professors who were already using software in their teaching (e.g., Thompson, 2009), hence potentially ignoring both skeptics and critics. Most prior work focused on specific software, but this study looked at mathematicians’ general perceptions about all software utilities used to support the teaching and learning of mathematics. In addition, although some research studies, such as Quinlan (2007), investigated the factors that influence the implementation of software, this study examined the factors that influence mathematicians’ dispositions even before implementation. Furthermore, because most studies focused on school level with little attention given to undergraduate classrooms, this study expanded the literature at the collegiate level.

Studies that investigated the reasons underlying mathematicians’ dispositions focused on individual reasons and did not necessarily examine the association among them. Such investigation was deemed worthwhile. For example, while Habre (2011) stated that new PhDs at the American University in Lebanon mathematics department did not advocate for the use of software when teaching differential equations to engineering students, Stevens (2007) argued that, in the U.S., new PhDs were eager to use software in
their teaching, especially if they had experienced such tool in their prior education. These contradicting opinions suggested a need for further investigation about the effect of the length of teaching experience on an instructor’s attitude and the associations among cultural background, prior education, and the length of teaching experience. Consequently, academic mathematicians’ dispositions toward software integration in classrooms, the reasons underlying such dispositions, and the intercorrelation among such reasons had been insufficiently explored and are in need of investigation.

**Research questions.** It is worthwhile at this point to restate the main research questions and summarize the essential goals of the study. The main questions that framed the research were as follows:

1. What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?
2. What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

Initial elaborations of these questions were as follows:

1. To what extent do academic mathematicians hold the position that software supports the teaching and learning of undergraduate mathematics?
2. Under what circumstances do academic mathematicians elect to use software during instruction?
3. From academic mathematicians’ point of view, for which kinds of courses is software use beneficial to students?
4. Do cultural backgrounds, educational backgrounds, and teaching backgrounds influence academic mathematicians’ dispositions toward software use when teaching mathematics?

5. What is the significance of the relationships, if any, among the reasons underlying academic mathematicians’ dispositions toward software use when teaching mathematics?

6. What additional factors explain academic mathematicians’ dispositions toward software use in undergraduate classrooms?

**Overall plan for the study.** This study used an exploratory sequential research design (Creswell & Plano Clark, 2011) to build, expand, and test a model to explain mathematicians’ dispositions. Starting with an initial model based on the literature review, in Phase 1, the researcher interviewed informants in the field. The goal was to explore the research problem and to expand the initial model. The expanded model identified a set of possible factors and subfactors. Phase 2 developed a survey instrument based on these factors, and Phase 3 examined them with a large sample of the targeted population: academic mathematicians at PhD-granting institutions in the United States. The results of Phase 1, Phase 3, and the reviewed research then were triangulated, resulting in a final model that suggests a set of factors that influence mathematicians’ attitude with regard to software use.

**Delimitations and Limitations of the Study**

The data in all phases were self-reported. This could be viewed as a limitation of this research. Nevertheless, this approach was appropriate for the goals of the study.
because an individual’s attitudes are best understood through his or her own words (Schensul, Schensul, & LeCompte, 1999). An individual’s behavior is one proxy of attitude, as shall be discussed in Chapter 3, but it is not always an indication of one’s beliefs and perceptions. Hence, this study aimed for an in-depth investigation of mathematicians’ dispositions through their own reflections.

The sample used in Phase 1 was a convenience sample. Generally, when interviewing key informants, it is essential to consider individuals who are likely to be informative, passionate about the research topic, and willing to contribute their time to the study (Glesne & Peshkin, 1992). Given the busy life style of the potential participants, it was crucial to interview only individuals who were known to be enthusiastic about the topic of the present study and ready to volunteer their time for it.

The research design of this study is distinctive and differs from previous research that addressed software use in that it is based on an initial model, which was expanded, tested, and refined based on the information gathered from the participants themselves. The researcher developed a survey instrument based on the expanded model, which identified eight factors as influencing attitude. Thus, the perceptions of individuals in the field were used to develop the instrument instead of the typical “think up items” (Crocker & Algina, 1986, p. 67) procedure, which supported the psychometric validity of the study. Moreover, the items used to measure two of these eight factors were also used as part of the attitude scale. Hence, these two factors are considered subfactors of the attitude variable. The items used to test the remaining six factors were constructed by the researcher. Because the validity and reliability of some scales in the instrument were not
established in prior work, the researcher used a pilot study, peer-debriefing, and a think-aloud method to check and enhance the validity and reliability of these scales.

Gender is a factor that has been examined in many educational studies. However, the reviewed literature and the analysis of the interview data did not indicate that gender would be a factor influencing mathematicians’ attitude regarding software use in collegiate classrooms. In addition, the population of interest consisted of individuals who were at a high level of education and intellectual capacity, in which their attitude regarding a pedagogical approach is unlikely to be influenced by their gender. Hence, gender was not included in the expanded model and was not tested in Phase 3.

Phase 3 focused on PhD-granting departments only. This delimitation restricted the generalizability of the results. However, considering the limited research that addressed this community, this investigation was important especially when taking into account how influential and respected this community within the larger community of all mathematicians in the U.S. and around the world.

The researcher selected the participating departments randomly, but the selection of the potential participants was not random. The selected departments’ websites were used to identify only participants who were considered from the population of interest. With that being said, the cases used in the analyses in Phase 3 were relatively representative, but a nonresponse bias was expected (Umbach, 2004); mathematicians who oppose software use likely have a lower response rate than those who favor software use. In fact, five recipients sent e-mail messages that indicated that they had never used software and hence would not participate. In reply e-mail messages, the researcher
explained to these recipients that the goal of the study was to uncover all points of view and stressed the importance of considering the voices of all mathematicians. However, because of the anonymity of responses in this phase, it is unknown if the reply e-mail messages convinced these recipients to participate in the study.

In addition, Phase 3 collected data through an Internet-based survey, a procedure expected to increase the nonresponse rate (Manfreda, Bosnjak, Berzelak, Haas, & Vehovar, 2008). To compensate, the researcher used an over sampling approach and collected data from 50 PhD-granting institutions throughout the United States. Nevertheless, nonresponse bias remains a threat to the validity and generalizability of the results.

Another limitation was the variance across academic calendars for universities. Although some universities follow the quarter system, others follow the semester system. Because this limitation was expected to influence the response rate, the researcher reviewed the academic calendars of all selected departments and distributed the survey accordingly.

**Definition of Terms**

**Academic mathematicians** in this study are individuals who have a graduate degree in mathematics and are teaching mathematics at postsecondary institutions. Among those, this study focuses only on PhDs who are tenured or tenure-track (TTT) full-time faculty members in PhD-granting mathematics departments in the United States.
**Attitude** has been variously defined in the literature. This study uses Aiken’s (2000) definition of attitude as “a learned predisposition to respond positively or negatively to a specific object, situation, institution, or person” (p. 248).

**Disposition.** This study uses Taylor and Wasicsko’s definition of disposition as cited in Almerico et al. (2011). Almerico et al. stated that Taylor and Wasicsko (2000) defined disposition “as the personal qualities or characteristics that are possessed by individuals, including attitudes, beliefs, interests, appreciations, values, and modes of adjustments” (Almerico et al., 2011, p. 1).

**Emic** is a mode of inquiry in which the points of view of participants in a research study are used to gather information about the topic of interest (Glesne & Peshkin, 1992)

**Knowledge for mathematics teaching** in this study means the knowledge that is needed to teach mathematics successfully. This term does not mean knowledge about mathematical concepts and theories, but rather the pedagogical knowledge that is required to communicate mathematical concepts and theories to others.

**Mathematical software** in this study refers to computer utilities that support the exploration of mathematical concepts, including computer algebra systems, graphing utilities, interactive geometry packages, and spreadsheets. Office utilities, course management systems, and tutorial packages are not included. The term *software* in this dissertation means mathematical software.

**Member-check** is a process “for confirming the veracity of data and interpretations with representatives of the target population” (Nastasi & Schensul, 2005, p. 185)
**Missing at random (MAR)** means that “the probability of missing data in a variable $Y$ is related to some other measured variable (or variables) in the analysis model but not to the values of $Y$ itself” (Enders, 2010, p. 6).

**Missing completely at random (MCAR)** occurs when “the probability of missing data on a variable $Y$ is unrelated to other measured variables and is unrelated to the values of $Y$ itself” (Enders, 2010, p. 7).

**Missing not at random (MNAR)** means “the probability of a missing value depends on the variable that is missing” (Enders, 2010, p. 8).

**Multiple imputation (MI)** is a process that consists of three phases. “The imputation phase creates multiple copies of the data set…each of which contains different estimates of the missing values” (Enders, 2010, p. 187). The analysis phase is used to “analyze the filled-in data set” (p. 187). Finally, the pooling phase aims to “combine everything into a single set of results” (p. 187).

**Reflexivity** is when the “researchers try to understand and self-disclose their assumptions, beliefs, values, and biases” (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005, p. 201).

**Snowball sampling** is the process of “getting new contacts from each person interviewed” (Patton, 2002, p. 194).

**Thematic analysis** is a process followed by qualitative researchers to discover the themes that are reflected by textual data (Howitt & Cramer, 2008).

**Organization of the Chapters**

This dissertation is organized in eight chapters as follows:
• Chapter 1 is the introduction. This chapter represents the background of the study, the statement of the problem, the purpose of this study, and the significance of the study. The chapter concludes with delimitations and limitations, definitions of terms, and organization of the chapters.

• Chapter 2 reviews the related literature to put the current study in context and to highlight its contribution to the related knowledge.

• Chapter 3 develops the theoretical framework of the study. First, the chapter represents Fishbein and Ajzen’s (1975) framework. Then, it explains how this framework was subsumed in building the initial model, which was the starting point of data collection.

• Chapter 4 explains the research design. It describes the targeted population, sampling procedures, data collection, and analyses procedures in all three phases of the study.

• Chapter 5 represents the results of the interview data.

• Chapter 6 explains the process of developing, piloting, and editing a quantitative instrument.

• Chapter 7 represents the results of the statistical tests performed on the survey data.

• Chapter 8 deals with the triangulation of results among interview data, survey results, and the reviewed literature. It concludes with a set of recommendations and suggestions for future research.
Chapter 2: Literature Review

The goal of this chapter is to put the current study in context and frame it within existing knowledge and theory. The literature reviewed in this chapter includes books, journal papers, conference proceedings, and dissertations as well as legislative acts, position statements, and national reports. This chapter consists of four sections:

- A review of studies and empirical data that supports the benefits of using mathematical software in classrooms.

- A report of mathematicians’ perceptions about software use and mathematics educators’ reflections. This section includes three subsections: advocates’ opinions, opponents’ arguments, and mathematics educators’ counterarguments. This section addresses Research Question 1: What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

- Official positions and reports by committees and organizations.

- A summary of the chapter.

Benefits of Software Use in Mathematics Classrooms

For some 30 years, software has been promoted as a means to enhance the teaching of mathematics and support students’ learning (Heid & Blume, 2008). This section provides a review of studies and empirical data concerning software use in collegiate mathematics classrooms to support multiple aspects of mathematics teaching and learning.
Conceptual understanding and cognitive strategies. Software often is used in mathematics teaching to enhance conceptual understanding (Dunham & Dick, 1994). Sárvári et al. (2010) explained that there are “three types of cognitive strategies: (a) activating; (b) elaborating; (c) and embedding” (p. 153). When confronted with new knowledge, students first have to recall related previously learned knowledge—activating. Second, students need to experiment with the new knowledge, which might include developing conjectures and hypotheses and testing them—elaborating. Lastly, students need to bond the new and old knowledge, reorganize the information, and construct new structures—embedding. Sárvári et al., then, discussed specific mathematical problems that might be addressed in an undergraduate mathematics classroom and illustrated how computer algebra systems (CAS) can be used to support each type of cognitive strategies for solving these problems. The authors concluded that CAS is a tool that could enhance students’ comprehension of new knowledge and use of cognitive strategies.

Camacho Machín et al. (2010) investigated the performance of 31 first-year engineering students after they experienced Derive in a problem solving-based calculus course over one academic semester. Using semester-long observations, a questionnaire of all 31 students, and task-based interviews with 6 students, Camacho Machín et al. aimed to explore students’ understanding of definite integral. When solving the questionnaire problems, students had the opportunity to work with and without the software. The 6 students who participated in the interviews were asked to verbalize their thinking while working on the tasks and to explain their approaches to the problems. Camacho Machín
et al. analyzed students’ strategies in the problem solving process aiming to understand the extent to which students have used the software to explore the problems. The results indicated that the Derive software supported students in refining and developing ideas to solve the problems and that, with a cognitively demanding mathematical problem, students may be relieved from the burden of computation and memorizing formulas and focus instead on the problem itself.

Heid (1988) conducted an experimental study to explore the effect of CAS on college students’ learning in an applied calculus course. The experimental group \( (n_1 = 39) \) used “graphical and symbol-manipulation computer programs” (p. 3) to perform typical algorithms, and the control group \( (n_2 = 100) \) used only the traditional approach with no software intervention. “The students reported enrolling in the experimental sections with no particular information about the classes or with only information about the scheduled time and the probable size of the classes” (p. 6). Heid stated that the traditional approach of teaching limits, derivatives, and integrals focuses on developing students’ algorithmic skills with regard to these concepts and noted, “if mathematics instruction were to concentrate on meaning and concepts first, that initial learning would be processed deeply and remembered well. A stable cognitive structure could be formed on which later skill development could build” (p. 4). Hence, Heid sequenced the experimental course to focus on the concepts and use software to practice algorithmic skills during the first 12 weeks of the course. Heid explained that the concepts would be then developed “in greater depth and breadth and through a greater variety of representations than in the traditional class” (p. 7). During the last 3 weeks, the experimental group focused only on
traditional procedures and algorithms rather than problem solving or application tasks. The control group followed the traditional approach and focused on practicing algorithms in all 15 weeks. Heid used field notes, interviews, observations, and test results to compare the two groups and conclude that the experimental group used different language when talking about the problems, which showed deep understanding. “Students from the experimental classes spoke about the concepts of calculus in more detail, with greater clarity, and with more flexibility than did students from the comparison group. They applied calculus concepts more appropriately and freely” (p. 20). Furthermore, the experimental group outperformed the control group with regard to the depth of investigation to the concepts, the complexity of the explored graphs, and the use of multiple representations when exploring the concept.

**Visualization skills and reflection.** Using software gives students the opportunity to engage in high-order thinking such as analysis and reflection (NRC, 2001). When using software, students are involved in discovering knowledge, testing conjectures, and verifying counterexamples, hence, they have a chance to visualize the task and reflect on their thinking (de Villiers, 1997). De Villiers claimed that students should always be given the opportunity to experience this level of thinking and that software supports them to reason and make sense while analyzing patterns and discovering relationships among concepts.

Baki, Kosa, and Guven (2011) investigated the effect of the dynamical geometry software Cabri 3D on 96 first-year, prospective mathematics teachers’ visualizations skills while learning 3D geometry. The sample consisted of three groups:
\[ n_1, n_2, n_3 = 34, 32, 30 \] respectively. The first group used Cabri 3D. The second group used physical manipulatives. The third group was taught in a traditional lecture-format. “Each participant had already been assigned to one of three classes by the university” (p. 295). All students completed the basic geometry class prior to the intervention. The study was a quasi-experimental design and used the Purdue Spatial Visualization Test (PSVT) for the pre and posttests. Baki et al. stressed on the importance of spatial reasoning and visualization in solving geometric problems. They noted the unique features of the software, such as the ability to construct geometric figures, specify relationships and properties, and manipulate the figures to explore them. Baki et al. reported that the first group received a 4-hr training on the software before the beginning of classes. During class time, students worked individually with the teacher’s support and used worksheets to explore the geometric concepts. The second group also worked individually with the help of worksheets and support from the teacher. However, the worksheets explained how to use the manipulatives instead of focusing on the use of software. Baki et al. stated that the third group was taught in a traditional, teacher-centered manner; the teacher lectured and used hand drawings to explain the geometric figures on the blackboard while students solved the problems individually by hand. Baki et al. reported that the ANOVA result of the pretest was not significant, which indicated that students’ visualization skills were the same across groups prior to the intervention. The posttest showed that the first and the second group’s visualization skills had significantly improved, but the third group’s visualizations skills did not change. On the other hand, the first group outperformed both the second and the third group in the Vision section of the test.
Wilburne, Shvartsman, and Walker (2009) looked at the use of the TI-nspire™ hand-held in a calculus course. The sample consisted of two mathematics professors: Professor A with 19 students and Professor B with 21 students. Wilburne et al. noted that both professors had not used the TI-nspire™ before and were known to teach calculus traditionally focusing on procedures to develop the concepts related to limits, derivatives, and integrals. Prior to the intervention, both professors attended a one-day workshop that focused on the technical properties of the software. They discussed with a mathematics educator the various properties of the software, representations of calculus concepts using the TI-nspire™, and activities suitable for its use. Wilburne et al. hypothesized that the software provided a rich environment that allowed for multiple representations of the concepts, which supported deep understating of the mathematical ideas. During class time, the professors used “guided-discovery lessons” (p. 256). All students were provided with worksheets that contained questions “to scaffold students’ explorations and allow the students to work collaboratively” (p. 256). In contrast to the traditional approach, the professors focused on conceptual understanding rather than algorithmic procedures. During lab time, students worked collaboratively in small groups, with the professor assessing them if needed. All students had their own TI-nspire™ hand-held and copy of the activities. Wilburne et al. reported that students felt that working with the software “promoted their learning in a different context than the lecture format” (p. 257). The students expressed their appreciation of the friendly small group activities. They further added that such an environment supported their conceptual understanding of the concepts and allowed them to “verbalize their thinking and help them make sense of the dynamic
representations to visualize the concepts” (p. 257). Wilburne et al. argued that the use of the software supported students in connecting the procedural algorithms to the concepts instead of learning them separately. However, the mean scores of the exam for the classes of both professors were not different from the mean score of students in previous years.

**Multiple representations and connection among concepts.** Another benefit of software integration that has been reported is the use of multiple representations to promote connection among the mathematical concepts. In many classrooms, students know the different mathematical concepts but in isolation from each other and are unable to connect them (Camacho Machín & Depool Rivero, 2003; Camacho Machín et al., 2010). To achieve conceptual understanding, students need to bond newly learned concepts with old ones (Sárvári et al., 2010). Camacho Machín and Depool Rivero (2003), Camacho Machín et al. (2010), and Sárvári et al. (2010) took the position that software provides multiple representations to the concepts and, hence, promote connection among them. Vonder Embse (1990) believed that software makes visual interaction with the mathematics possible. In addition, Foley (1990) stated that using interactive graphing calculators supports students in developing connections among mathematical concepts and solving practical tasks. Foley argued that such tools provide an opportunity “for mathematical experimentation and exploration” (p. 28), and gave three detailed examples of how to take advantage of the graphical capabilities of such tools. Moreover, Alexander (1994) reported on a project—which started in 1993—that encouraged the use of the TI-82 graphing calculators in all college algebra classrooms at the University of Georgia. Calculators were used as a supplemental tool and all students
were required to provide their own device. Alexander stated that using a calculator supported students in understanding various algebraic and graphical representations. “The visualization aspects of the graphing calculator enabled students to fit graphs of functions to pictures and real-world situations” (Alexander, 1994, p. 50).

One advantage of the multiple representations feature provided by software is that students who are challenged by algebraic symbols might benefit from the graphical representation provided by the software (Dunham & Dick, 1994). Camacho Machin and Depool Rivero (2003) reported on the result of a small study \( n = 2 \) that is part of a big project \( N = 11 \). The larger project aimed to look at students’ use of different representations to solve Calculus I problems when they learned the concepts using Derive software. The students attended the normal class time in addition to attending lab classes where they were working with the software. At the end of the course, students were asked to answer eight open-ended calculus problems, which were stated in a variety of representations including algebraic and graphical. A month later, the authors chose two students from the sample of 11 and interviewed them about their responses to the problems. Camacho Machin and Depool Rivero reported that software use supported these two students in interpreting the mathematical problems. They indicated that students’ responses showed that they were capable of solving the tasks in any representation and were able to move easily from one representation to another.

**The mathematical task.** Software can be used to provide more than one method to solving a problem. Several educators argue that one of the most important benefits of software is that it helps students experience nonroutine problems (Mathematical Sciences
Education Board, 1990; Moore & Smith, 2006), work on realistic problems (Foley, 1990; Madison, 2006), and solve the ones that are too complex to solve by paper and pencil (Foley, 1987; LaTorre, 1990). Moore and Smith commented that using software protects students from committing computational errors because they could easily check their solutions using the different approaches provided by the software. “Indeed, modeling provides a strong incentive for students to check their work and correct their mistakes” (Moore & Smith, 2006, p. 231). In addition, the power provided by the software can “free both teacher and students from computational tedium—thus allowing them to focus on conceptual rather than computational matters” (Davis et al., 1986, p. xviii). Moreover, Lipson, Faletti, and Martinez (1990) claimed that the potential advantage of software use in assessment items is to present routine tasks in a richer environment. Furthermore, using software helps students look at a large number of problems and even experience different mathematics. Heid (2002) stated, “with different tools, students are likely to learn different mathematics and to learn it differently” (p. 109). Certain exploration of problems becomes possible with the software. For example, Ruthven (2002) claimed, “the availability of calculating tools facilitates a numeric treatment of derivative in terms of the infinitesimal ratio sense; likewise, graphing tools assist work on the tangent slope and linear approximation senses” (p. 280).

Software can be useful not only with regard to the number of problems, but also with regard to the level of complexity of the problems (Davis et al., 1986). Davis et al. argued that CAS support students in solving problems that are difficult to solve by hand. Moreover, Hollebrands et al. (2010) argued the use of software helps students to explore
tasks that were impossible to work on using paper and pencil only. In this case, the mathematical task is called a technology-active task (Harvey, 1992). Hollebrands et al. examined college geometry students’ thinking and arguments when working on eight geometric activities while they had access to software. One of these activities dealt with the quadrilateral properties in the Poincaré disk, a model of hyperbolic geometry. Among all students enrolled in the geometry class, 11 were interviewed based on their instructors’ comments regarding their ability to reflect on their thinking. However, Hollebrands et al. only analyzed 8 interviews based on students’ articulations during the interviews. Students’ written work, their work on the computer, and their verbal reflections were all recorded, transcribed, and analyzed in order to examine the way students used the software while working with figures in non-Euclidean geometry. One important result is that students used the software to test conjectures. Such exploration of properties of geometric figures in hyperbolic geometry—non-Euclidean geometry—is not possible using paper and pencil only. In fact, Hollebrands et al. indicated that with non-Euclidean geometry, solving tasks with paper and pencil only is considered harmful to students’ learning. In this model, “one can draw more than one line through a point not on a given line parallel to the given line, and the sum of the angles of a triangle is less than 180 degrees” (Hollebrands et al., 2010, p. 329).

**Perceptions About Software Use and Counterarguments**

This section first elaborates on mathematicians’ primary arguments that support and undermine the use of software. It then reports on mathematicians and mathematics educators’ counterarguments. Some of the studies presented in this section use a
reflection from a mathematician’s classroom experience or a representation of a mathematician’s point of view. Moreover, some of the following studies were conducted by mathematics educators or researchers who reported on mathematicians’ visions or beliefs.

In spite of the enormous push to integrate software in undergraduate classrooms to improve mathematics instruction (CUPM, 2004; NRC, 1991), some mathematicians’ dispositions are different from what might be expected. As was discussed in Chapter 1, not all mathematicians agree with software use when teaching mathematics. LaBerge (1997) reported a study that investigated mathematicians’ points of view regarding NCTM (1989) standards. It was revealed that most of the 26 interviewees in this study disagreed with the NCTM that “scientific calculators with graphing capabilities will be available to students at all times” (p. 124). A more recent study, Quinlan (2007) surveyed 422 mathematics faculty members regarding their software use. Quinlan believes that arbitrary use of technology is ineffective and insufficient. Hence, Quinlan aimed to describe software use by university mathematicians. Key results indicated that only 50% of the participating mathematicians agreed that using software was important for teaching and learning of mathematics, although they saw technology as becoming increasingly important in general.

**How do mathematicians see the benefits of software use?** Mathematicians who advocate for the use of software in teaching believe that one important advantage is the expected improvement of students’ motivation to learn mathematics (Carroll, 1992; Connor & Grover, 2005; Demana & Waits, 1990). Students’ level of motivation
increased as a result of doing mathematics, discovering results, and confirming conjectures, instead of being only passive learners. Jackson (2011) stated that the traditional approach does not engage students. Jackson surveyed undergraduate students in her university about their unprofessional behaviors in classrooms, such as using cell phones for texting. She reported some comments: “engage us….make attending class interesting….use technology.” Jackson stated that students are not engaged when they are merely taking notes, but when they are interacting with something tangible, such as software. Jackson added that it is the instructor’s responsibility to engage students in class and that using software can help.

Connor and Grover (2005) agreed with the use of software in a geometry class. In 1997, a PhD-granting mathematics department in the U.S. initiated the Foundations of Geometry I, II sequence, which followed a constructivist, student-centered approach and used software as a primary tool in classrooms. The majority of students were prospective teachers. Connor and Grover stated that students enrolled in this sequence worked in cooperative groups in about 70% of the time, developed their own geometric axioms, and finally used the axioms to learn geometric results. Students would learn about Euclidean and non-Euclidean geometry while using software that they would most likely use in their future classrooms. Based on their experience in teaching this course, Connor and Grover suggested that the approach of doing mathematics and constructing knowledge with the software in student-center classrooms increased students’ motivation level and helped them deeply understand the non-Euclidean concepts. They reported that students
expressed their appreciation of the software because it gave them a context for the new axioms they were developing.

Some mathematicians are convinced that what makes using software in mathematics teaching beneficial is that it promotes discovery learning and exploration. Students have the opportunity to construct the knowledge and build on their prior knowledge. The authority is not solely the teacher’s. Students are not waiting for the teacher’s approval. Instead, students collaborate and cooperate with the teacher and with each other to discover the solution, and hence students take responsibility for their own learning (Goonatilake & Chappa, 2009). Strang believes that using graphical tools can enhance students’ understanding by giving them the ability to discover the concept by themselves.

They [graphical tools] also teach methods of discovery. In using Newton’s method, calculus students can discover rates of convergence and periodic orbits and especially basins of attraction. At the same time they will reinforce their basic understanding of linear and quadratic approximations. By varying the coefficients of a quadratic function of two variables, they will see saddle points and maxima and minima. (Strang, 2001, p. 99)

In addition, some mathematicians are convinced that using software helps students visualize mathematical concepts. In other words, modeling of the abstract concepts and using genuine data would be feasible. Zorn (1988) argued that using CAS supports students in representing the mathematical concepts effectively and efficiently.
The multiple representations provided by the software, such as graphing calculators or dynamic geometry software, support connection among concepts and between the algebraic and the geometric representations, which helps students in reasoning and sense making (D’Ambrosia & Spitznagel, 2011). According to Strang (2001), this will make the dry, abstract concepts visual and tangible to students, which will promote deep understanding. In addition, McCallum (2007) indicated that using mathematical software shifts students’ attention to interpreting and making sense of the problem rather than focusing on the computation part, which makes mathematics meaningful to students.

Several mathematics professors outside the United States are convinced that using software will deepen students’ understanding simply by providing meaning to the concepts that look puzzling the first time (Carroll, 1992). Introducing algebraic expressions to students in a symbolic way at first, for instance, is without a doubt challenging for them. This challenge is magnified when these expressions are not connected to real life situations or, in other words, do not have any meaning to students. Carroll (1992), a mathematics professor at Dublin City University in Ireland, said that students had “little idea what $x \sin(1/x)$ looks like” (p. 20). The software gave them the opportunity to see the graph and maybe change the range and play with it. Moreover, Habre (2011) argued that using mathematical software helped students to connect the visual, numerical, and symbolic representations and to deeply understand differential equations concepts. Habre, as a professor of mathematics at the American University in Lebanon, used dynamical software and writing assignments to support students’ reflection on what they learned. In his presentation, Habre shared with the audience a
sample of students’ writing and explained the difference in the language students used before and after the use of software. Students were able to write, in detail and in a mathematically accepted format, their explanations of the problems and the approaches they used to solve them, which was evidence that their understanding improved.

Some mathematicians recognized the ability to look at a large number of examples in a short time as an advantage of using software in mathematics instruction, especially as a chance to practice (Goonatilake & Chappa, 2009). Donnelly (2011) argued that especially with concepts such as the tangent line, computation could be an obstacle for conceptual understanding. According to Artigue (2002), for some mathematicians, the use of software in teaching mathematics changes not only the pedagogy, but also the content. The software helps students experience different problems and different themes. When using software, students are not restricted to the examples given by the book. Instead, they can alternate the examples to generate others. A wide range of examples that illustrate a certain concept can support students’ understanding of the concept (Carroll, 1992). A mathematician, who participated in Quinlan’s (2007) survey, stated, “it’s a great tool for illustrating various examples in a classroom, especially visualization of graphs” (p. 131). Jackson (2005) quoted Ellen Maycock—the associate executive director of the American Mathematical Society (AMS) in September, 2005—“technology gives students an easy way to generate a lot of examples, and then they can start to recognize patterns” (p. 889). Others argue that even geometric problems, which remained unsolved for many years, are now solvable using software (Bennett, 1997).
How do mathematicians conceptualize the challenges and limitations of software use? Using software in mathematics instruction could benefit students, but not without considerable limitations (Kortenkamp, 2007). According to many mathematicians there is a price to pay, which cannot be tolerated.

Computation skills. Some mathematicians believe that one key reason against the use of software, such as graphing calculators, in undergraduate classrooms is the effect such use has on students’ computational skills. These mathematicians fear that students would depend on the software for the answer without knowing how the software arrived at it (T. W. Tucker, 1999). In Quinlan (2007), some participating professors argued that the calculators should be forbidden; otherwise, students would lose their skills. Mathematicians are concerned that students’ focus would shift from the mathematical concept to the technological tool itself. McCallum (2007) pointed out that some mathematicians are concerned that an integration problem in a calculus course, for instance, could be solved using Mathematica® without any computation done by the students. The assumption here is that software use may promote laziness (Quinlan, 2007). Because some instructors, McCallum argued, fear that the software will do everything, they elect to abandon the software entirely.

In other countries, such as China, mathematicians are generally against the use of calculators. Shao (2010) presented a paper that summarized the findings of three projects conducted by several researchers in China, Singapore, Japan, and the United States. In the first project, observation methods were used in Grade 4 and Grade 8 mathematics classrooms in all four countries to understand the role of technology in these classrooms.
In the second project, U.S. teachers were surveyed to understand the role of technology in their mathematics classrooms. The researchers then compared the results of the survey with the expected pattern of the use of technology in Asian classrooms. In the third project, the researchers observed mathematics classrooms and interviewed five university mathematics professors and three students in China with regard to the effect of using technology, including calculators and computers, on teaching and learning mathematics. Shao presented the results of this third study and indicated that mathematics professors in China see repetition as an important route to understanding mathematics. One Chinese mathematics professor stated, “‘students are encouraged to apply the method of “mental math” and “speedy calculation” and discouraged to use a calculator in mathematics learning’” [double quotation added by the author] (p. 3), which are considered to be unwelcomed devices in classrooms. A university mathematics instructor indicated, “‘they [calculators] are intended to test technology, not the ability of a student’” (p. 3). In sum, Chinese educators generally emphasize independent content teaching and deemphasize the benefit of software use in the teaching and learning mathematics.

**The identity.** In Wilburne et al. (2009), one participating mathematics professor stated in a negative reflection that the TI-nspire™ changed the instructor’s role from a teacher to a technical assistant. Sullivan (2011) commented that if an instructor was taught by lecturing, then it is natural to be comfortable with lecturing and not to be eager to use software in teaching. In his presentation, Sullivan reported on some faculty’s opinion: “‘I lecture in a good way and if students are not learning, this is because they are not working hard enough.’” Sullivan agreed; students are probably not working hard
enough. However, Sullivan acknowledged the importance of an instructor’s identity and how the instructor perceives his role versus students’ role on his action and reaction in classrooms. Sullivan argued that instead of blaming students, the solution is integrating software to motivate students and help them learn better. In addition, A. C. Tucker (1999), as the director of the Long Island Consortium for Interconnected Learning in Quantitative Disciplines (LICIL) project—a cooperation among mathematics faculty and several related quantitative disciplines in 10 colleges and universities on Long Island—indicated that their goal was a universal change in the way instructors teach and the way students learn, not only changing the curricula. A. C. Tucker further indicated that such change includes engaging students in critical thinking, discussing teaching methods and tools with colleagues, giving more time to teaching, and integrating technology when appropriate. Tucker explained that these characteristics confront instructors’ traditional method of teaching. Moreover, Sofronas and DeFranco (2010) used interviews and observations to build a model that categorizes the pedagogical knowledge that college and university mathematics faculty internalize. When asked about educational activities that might be recognized by the university a mathematician is working in, one mathematician clearly stated, “I don’t think of myself as a teacher. I’m a mathematician” (p. 176).

In addition, one of the main reasons why the use of software is not as integrated as we would expect in undergraduate classrooms is that it is opposite to the traditional teacher-centered lecturing approach (Carroll, 1992; Papert, 2000; Ralston, 2004), with which mathematicians are comfortable. Teaching with software is different from teaching
without software. Classrooms activities, classroom discourse, teacher’s and students’ roles, and even assessment processes change when software is used as an essential tool in classrooms (Heid, Sheets, & Matras, 1990). Gordon (2006) argued that the power provided by software in classrooms cannot be denied. Dunham and Dick (1994) noted that teaching with graphing calculators change of the classroom climate and challenge the classroom control, which might be unfavorable to instructors. Integrating technology in undergraduate classrooms change the content(s) and the pedagogical approaches (Committee on the Teaching of Undergraduate Mathematics [CTUM], 1990). Reform in classrooms is challenging in general and is far from straightforward (A. C. Tucker, 1999). Davis (2006) argued that beliefs about teaching and learning mathematics range from traditional to constructivism. In traditional classrooms, students are passive observers and learn by observing and memorizing the information; in constructivist classrooms, students discover and build the knowledge, the teacher only facilitates the process, and learning occurs through exploration and discussion. Zbiek and Hollebrands (2008) noted that instructors who consider software as effective tools in mathematics instruction are also those who appreciate a student-centered approach. Ravitz, Becker, and Wong (2000) indicated that constructivist teaching environments involve students in a variety of assignments such as projects, problem-solving, group work, and thoughtful reflection and writing assignments. Moreover, Ravitz et al. reported that, in general, U.S. teachers are more aligned with the traditional view, rather than the constructivist view. A 1985–1986 survey reported by CTUM (1990) indicated that 99% of the formats of mathematics instruction at the collegiate level were lecture mode, although CUPM (1990) argued that
students in undergraduate classrooms should discover the knowledge rather than observe it.

T. W. Tucker (1999) stated that mathematicians who oppose the reform way of teaching, such as using the constructivist approach, are also the ones who argue against using calculators. Tucker argued, for some mathematicians, “rote learning” (p. 912) or memorization is better than no learning at all. Even in other countries, instructor’s identity and the way they perceive their role in classrooms is important. Many international instructors are challenged when they integrate technology because the teaching environment and the typical procedures change. Shao’s (2010) presentation pointed out that the Chinese system and the U.S. system differ in that the U.S. system focuses on both content and pedagogy while the Chinese system cares about content only. In addition, Shao stated that teaching mathematics in China follows the traditional approach, where practice and continuous repetition are the basic principles for teaching and learning mathematics. The use of calculators and computers in classrooms would conflict with these principles and thus clash with the traditional approach, Shao argued.

**Mathematicians’ and mathematics educators’ counterarguments.** Several writers have argued against the criticisms of software use mentioned in the last section. Some of these writers denied the suggested potential harm about software use, but others acknowledged the limitations of software use and presented solutions to address them.

**Mathematics is not about computation.** Although many academic mathematicians criticized the possible effect of software on students’ computation skills, other scholars argued that mastering computational algorithms is not a measure of
understanding of mathematical concepts (Mathematical Sciences Education Board, 1990; Moore & Smith, 2006; Ralston, 1999). In fact, Ralston (1999) challenged the existence of any noteworthy research that has proven that the use of calculators is dangerous for mathematical learning or that the paper and pencil skill is the best way to learn mathematics. In addition, Dick (2011) and Heid (1997) stated that we should focus initial instruction on conceptual understanding rather than on mastering computation skills. Dick argues that CAS could support the conceptual understanding for calculus concepts, while Heid claims that using CAS and mastering the concepts first would lead to a reduction in the time needed for practicing algorithms. Heid (2002) presented the theoretical framework of knowing and learning to support the effect of CAS on the depth of students’ learning. Based on this framework, she concluded that students’ ability to perform procedures should come after they had comprehended the concepts. On the other hand, Gordon (2006) argued that computational skills should not be a concern. Gordon argued that students, in their future career rarely, if ever, would need such skills. That is, because we live in a rapidly developing era that is greatly influenced by technology, students are not expected to use traditional procedures when applying mathematics in real life situations.

Ellis (2001), while admitting that the use of software may influence students’ computation skills, suggested teaching both with and without the software. Ellis stated that for students in certain disciplines, knowing software skills is more important than mastering computational skills. In addition, T. W. Tucker (1999) took the position that teaching and assessments should incorporate software-rich and software-free procedures.
Moreover, Saddler (2011) stated that some mathematicians argued that students are only “pushing buttons” on calculators. Saddler argued, however, that if students do not understand, which is the case in many traditional classrooms, they would be “pushing pens and pencils” instead. On the other hand, Springer (2011) stated that some mathematics instructors are concerned that the calculators are the ones doing the mathematics. However, nowadays, the answers are not only in the calculators but are everywhere in the Internet. Hence, Springer argued for the use of software that is designed to give step-by-step direction rather than only the right answer, and that this approach enhances learning and address this limitation of software.

_Instructor’s role and identity._ Mathematics educators agreed with the challenge mathematicians face when integrating software with regard to their role in classrooms. It is not questionable that teaching with software is not traditional (Heid, 1997; Olive, 1990). Heid and Olive believed that when students use technological software, the traditional classroom and the mathematics being taught change. Heid claimed that using software in mathematics classrooms is a tool to make teaching student-centered, which is one main feature associated with the constructivist approach. Moreover, Olive took the position that students should learn mathematics in accordance with the constructivist approach. The software gives them the chance to make a conjecture and play with it hoping to confirm it, hence play a mathematician’s role. This helps them make sense of what they are learning, not to mention that it would increase their motivation to learn mathematics (Heid, 1988; Wilburne et al., 2009).
“Because, like life, mathematics was never meant to be a spectator sport” (Arnold, 2008, p. 10), software should be used in mathematics classrooms. Arnold is convinced that students should not be passive observers of information, but rather involved in discovering the knowledge. Arnold stated that the instructor’s role should be switched from providing information to presenting problems and questions; it is the students’ job to find and interpret the information. Students should learn mathematics in a student-centered collaborative environment, where they can be active participants, make sense of the mathematics they are learning, and connect the knowledge they learn to their world. According to Arnold, the instructor’s job is to facilitate and provide scaffolding. Arnold stressed that algebraic symbols and rules are meaningless to students until they see their applications in real life situation and that software is the representation and the scaffolding tool that gives students the opportunity to verbalize and reflect on their thinking.

Mayer (1996) argued that learning occurs in one of three ways: (a) response strengthening, in which the instructional method is through drill and practice; in this approach, the way to support students’ learning is by reward and punishment; (b) information processing, in which teachers distribute information and students process the information; in this approach, the main instructional approach is lecturing; (c) constructivist, in which students construct knowledge using previous knowledge; in this approach, the teacher facilitates discussion only, and encourages the discovery learning method. Prominent learning theorists, such as John Dewey and Jerome Bruner, advised educators to focus on social processes and create learning communities for students
(Dewey, 1963), and support students to discover knowledge and build on their previous knowledge (Bruner, 1977). David Ausubel and Robert Gagné, on the other hand, advised against the discovery learning method and believed in the guided process of education (Shulman, 2004).

**Official Positions and Reports by Committees and Organizations**

CUPM argued in its 2001 publication, *Mathematics and Mathematical Sciences in 2010: What Should Students Know*, that besides the two main dimensions, knowledge and skills, which students are expected to master, a third critical dimension that should be mastered is experience in using a variety of mathematical software (CUPM, 2001). Three years later, in 2004, CUPM gave six major recommendations in its publication, *Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide 2004*. One of these recommendations was for students to experience using software. “At every level of the curriculum, some courses should incorporate activities that will help all students progress in learning to use technology appropriately and effectively as a tool for solving problems [and] as an aid to understanding mathematical ideas” (CUPM, 2004, p. 2).

In 1995, the American Mathematical Association of Two-Year Colleges (AMATYC) presented *Crossroads in Mathematics* as the first set of standards for two-year colleges. Both Standards for Intellectual Development and Standards for Pedagogy stressed the importance of using appropriate technological tools to enhance the teaching of mathematics and for students to experience using such tools (AMATYC, 1995). A decade later, the AMATYC published *Beyond Crossroads* to renew and elaborate more
on the standards. A new set of standards was added in this second publication—Implementation Standards. One of the Implementation Standards is instruction, which emphasized that effective instruction requires the use of appropriate tools including technology to enhance teaching of mathematics (AMATYC, 2006).

Software use is not the same in all colleges or universities. Ellis (2001) stated that students in two-year colleges experience the use of software but not in four-year universities. This claim is consistent with a 1985–1986 survey, which reported that 80% of two-year colleges have mathematical labs (CTUM, 1990) and with the recent CBMS survey result that the percentages of two-year college classrooms that used graphing calculators, or computer assistance in general, were more than the percentages in four-year universities and colleges (Lutzer et al., 2007).

Summary

This chapter reviewed empirical studies that have investigated software use in mathematics instruction. Studies have shown that software can enhance students’ understanding of mathematical concepts, support reflection, and provide multiple representations of the concepts. The chapter also discussed mathematicians and mathematics educators’ experiences, reflections, and opinions regarding software use. The opinions of both proponents and critics were reported along with counterarguments and suggested solutions. Finally, the chapter presented reports and statements from several committees and organizations. The next chapter describes the theoretical framework used for this study.
Chapter 3: Initial Theoretical Model

This chapter reviews studies that have addressed factors that influence mathematicians’ dispositions toward software use in mathematics instruction. These studies were used to build an initial model (the formative model). The aim of presenting this review is to elaborate on Research Question 2: What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms? This chapter concludes by presenting the initial model that captures these reasons, which was expanded, tested, and refined using the data collected in this study.

This study, first, adopted the Fishbein and Ajzen’s (1975) framework (Figure 1), which represents the multiple dimensions of attitude. Fishbein and Ajzen indicated that an individual’s beliefs about an object influence the individual’s attitude, which result in a set of intentions with respect to this object that influence an individual’s behaviors. These relationships are illustrated with straight arrows among beliefs, attitude, intentions, and behaviors. Fishbein and Ajzen also argued that the resulted behaviors might cause new beliefs with regard to this object, which is demonstrated with a straight arrow from behaviors to beliefs. Finally, attitude might cause a change of beliefs, and hence the arrow between attitude and beliefs represents a bidirectional relationship. This framework was used because it connects beliefs to attitude, intentions, and behaviors and, hence, reflects on Taylor and Wasicsko’s definition of disposition (as cited in Almerico et al., 2011). Taylor and Wasicsko argued that an individual’s beliefs and attitude act as a proxy for disposition and defined disposition “as the personal qualities or characteristics that are
possessed by individuals, including attitudes, beliefs, interests, appreciations, values, and modes of adjustments” (Almerico et al., 2011, p. 1).

![Diagram of Fishbein and Ajzen’s attitude framework.](image)

*Figure 1: Fishbein and Ajzen’s (1975, p. 15) attitude framework.*

**A Broader Context: Teaching Grades K–12**

Since 1980, educational organizations called for reforms in mathematical curricula and pedagogy at the school level. The NCTM (1989, 2000) took the position that students should learn different mathematical topics, not only arithmetic, and develop various problem-solving skills, going beyond computations. For this to be achieved, the NCTM (1991, 2007) stated that teachers’ pedagogical procedures should be improved. Students should be treated as active learners, should be given the opportunity to reflect on their thinking, should be involved in an intellectual community of learners, and should have access to various technological tools as appropriate. In addition, the NCTM suggested that teachers model the use of various technological tools to enhance teaching and support students’ learning. In the Common Core State Standards for mathematics (CCSSI, 2010), the “use of appropriate tools strategically” (p. 7) is one of the standards
for mathematical practice. This standard states that mathematically proficient students “are able to use technological tools to explore and deepen their understanding of concepts” (p. 7).

**Teaching in Undergraduate Classrooms**

Most of the calls to improve mathematics teaching focused on Grades K–12 (LaBerge, 1997) with little attention to undergraduate mathematics (Speer, Gutmann, & Murphy, 2005). Nevertheless, addressing teaching issues in collegiate mathematics was not totally omitted. For example, the CBMS series, *Issues in Mathematics Education*, devoted several volumes to research papers that address mathematics education at the collegiate level—*Research in Collegiate Mathematics Education* (RCME). The RCME, which started in 1994, is for mathematicians interested in educational issues. The series supports cooperation between mathematicians and mathematics educators and encourages mathematicians to attend to teaching (Hitt, Holton, & Thompson, 2010). The CUPM, which is a committee of the Mathematical Association of America (MAA), publishes curriculum guidelines once every decade. However, these guidelines are not as influential as the NCTM standards for curriculum, pedagogy, and assessment, which have been regarded as the nationwide, comprehensive set of standards for mathematical teaching for Grades K–12 (Cuoco, 2003). On the other hand, the Committee on the Mathematical Education of Teachers (COMET) and the Committee on the Teaching of Undergraduate Mathematics (CTUM), other MAA committees, focus on improving instruction at the collegiate level. COMET specifically considers the NCTM recommendations for teachers and addresses the mathematical courses that are specifically designed for prospective
teachers. For example, Leitzel (1991) acknowledged that the NCTM (1989) standards gave a guideline for school mathematics and encouraged changing the mathematics for future teachers accordingly. In addition, the MAA established Project NExT, *New Experiences in Teaching* (MAA, 2005) to support new mathematicians to learn about matters related to teaching.

At the institutional level, many universities developed on-campus centers to support faculty with regard to teaching strategies and learning outcomes. The first such center was the Center for Research on Learning and Teaching at the University of Michigan, which was founded in 1962 (University of Michigan, n.d.). Nowadays, most higher education institutions in the U.S. have their own center that shares the same goal of supporting excellence and innovations in teaching (Cook & Sorcinelli, 2002). For example, the University Center for the Advancement of Teaching (UCAT) aims “to assist all those who teach at The Ohio State University to excel in teaching, support student learning, and experience the satisfaction that results from teaching well” (Ohio State University, n.d.). Besides being a consulting and resource center, UCAT supports projects to advance the quality of teaching. Another example is the Center for Teaching and Learning (CTL) at Ohio University, which organizes periodical programs for teaching assistants and professors, in addition to providing resources to support them to focus on students’ outcomes (Ohio University, n.d.).

The support given to teaching varies across institutions. The NRC recognizes that mathematics faculty in liberal art colleges devote their time and energy to teaching and advising students. Actually, they are expected and required to do so in order to get
promoted or tenured (NRC, 1991). More recently, Beisiegel (2009) stated that, based on her experience, a small undergraduate department focuses on teaching skills as a major requirement to hire faculty; whereas, a large research university does not require high-quality teaching skills to be accepted as a faculty member.

**Mathematicians’ awareness of, involvement with, and beliefs about teaching strategies.** Individual mathematicians, however, are not all on the same page when it comes to awareness and involvement in educational issues. In many countries, including the U.S., PhDs in mathematics do not necessarily attend formal courses in mathematics teaching methods (Bass, 1997; Speer et al., 2005), and are not necessarily aware of the reform in mathematics teaching (LaBerge, 1997). Courses that deal with educational issues and teaching practices usually are designed for prospective teachers not for future mathematicians. Even research studies that address education in undergraduate classrooms focus on prospective teachers (Beisiegel, 2009). LaBerge (1997) interviewed 26 mathematicians teaching at seven Midwestern colleges and universities and reported that collegiate mathematics instructors were not aware of reforms in teaching.

Interestingly enough, LaBerge indicated that the level of awareness of NCTM’s (1991) *Professional Standards for Teaching Mathematics* was less than the level of awareness of NCTM’s (1989) *Curriculum and Evaluation Standards*. In fact, Bass (1997) and Cuoco (2003) stated that mathematicians and mathematics educators not only have different professions and practices, but also have different cultures and speak two different languages about mathematics. Mathematicians are busy proving theorems and solving problems while mathematics educators are busy analyzing what is in students’ minds and
how they think and learn (Dubinsky, 1996). Beisiegel (2009) stated that considering the extent of mathematicians’ preoccupation with mathematical research, it is probably not entirely surprising that they do not have the time to think deeply about teaching. Even mathematicians who are involved in educational research might tend to work individually in their own community, separate from the mathematics education community (Heaton & Lewis, 2011).

On the other hand, the importance of having quality pedagogical skills is not given much attention by some mathematicians. As early as 1990, the CTUM argued that mathematicians’ attitudes regarding the time and attention given to instruction “require a substantial discussion, and perhaps a change in values” (CTUM, 1990, p. 8). Some mathematicians do not see the importance and the value of being involved in teaching (Bass, 1997; Kehoe, 2009; A. C. Tucker, 1999). Bass (1997) argued that mathematicians’ professional culture “implicitly devalues the importance and substance of pedagogy” (p. 20). Some mathematicians think their time should not be wasted on teaching (A. C. Tucker, 1999). Kehoe (2009) talked about the appointment of Steven G. Krantz as the editor of the Notices. Kehoe quoted Krantz and his experience in a conference meeting with relation to how some mathematicians think about teaching.

He [Krantz] remembers an experience while he was a visiting faculty member at Princeton in 1980 and attending an orientation session. “The person conducting the session, a very senior and famous mathematician, got up in front of the room and said, ‘these days you can prove the Riemann hypothesis or you can learn how to teach.’ And
that was the extent of his advice to us on the craft of teaching. I started
to wonder whether we could do better.” (p. 1445)

In contrast, Bass (1997) and Cuoco (2003) believe that knowing mathematics is
not enough to teach it. They agreed with Shulman that teaching is not only “knowing
some subject matter” (Shulman, 1987, p. 6). Skemp (1971) stated, “to know mathematics
is one thing, and to be able to teach it—to communicate it to those at a lower conceptual
level—is quite another” (p. 36). Fendel (2011) argued that it is challenging to help
students see the complex concepts as meaningful and comprehensible ones. Rodi (1986)
admitted that

Sitting around in the afternoon with a group of 4 or 5 colleagues
discussing subtle points of algebraic topology feels better, is more
personally rewarding, and maybe even easier, than worrying and
struggling about exposing 18 year olds for the first time to some of
history’s great ideas like limits and derivative” (p. 118).

Furthermore, Bransford et al. (2000) not only claimed that expertise in a field
does not guarantee successful teaching of this field to others, but also argued that an
expert might find it more challenging than a novice to communicate to students’ level of
comprehension. In fact, Bass (1997) encouraged a professional pedagogical training for
all mathematics graduate students. In addition, Cuoco (2003) claimed that the separation
between education and mathematics is a key element of the lack of alignment between
high school classrooms and the undergraduate classrooms. A. C. Tucker (1999) claimed
that best teaching comes from good researchers and challenged mathematicians to prove
this claim by showing their talent in classrooms. Moreover, Beckmann (2011) acknowledged the importance of learning about teaching skills, the source of students’ misconceptions, and students thinking. Beckmann stated that a good textbook, a clearly structured course, and a set of well-written homework tasks are not enough for excellent teaching. In Dubinsky and Moses (2011), Dubinsky admitted that for many years, although he “was a good lecturer, [and] enthusiastic about teaching”, what he “produced, more often than not, was ineffective teaching” (p. 401). Dubinsky stated that what he needed was to learn about how students think and learn mathematics, and he subsequently devoted his career to mathematics education.

**Prior experience, knowledge, and beliefs influence attitude.** “Teaching is a cultural activity” (Stigler & Hiebert, 1999, p. 11). Instructors teach the way they were taught (Sandholtz et al., 2000; Shulman, 2004). Hence, prior education is a major influence on a mathematician’s behavior in classrooms. Small (1990) argued that even mathematicians who are actually aware of the reform in mathematics teaching face a dilemma of choosing the teaching methods that they had always known and experienced or obeying the new calls for using reform methods, such as software, in their instruction. Beisiegel (2010) reported that one key result from interviewing graduate students in mathematics is that the belief regarding the importance of research over teaching is transferred from mathematicians to their students—who are future mathematicians. Graduate students in mathematics are convinced that their major future duty is as researchers. Working on mathematical research projects is at the top of their priority list, with teaching placed at the bottom of the list. Beisiegel asked these future college
classrooms teachers about the Calculus Reform movement. In a negative, despondent, pessimistic voice, they replied that there was only one way to teach calculus, which is the traditional way they experienced in their previous classes. For them, no one is expected to do it differently and no one will accept it to be done differently including the students themselves. Beisiegel claimed that one important finding of the study was that future mathematicians’ beliefs and attitude about teaching mathematics had been influenced by their prior education.

**Prior experience, knowledge, beliefs, and attitude influence intention.**

Beisiegel (2009) argues that the knowledge and experience the future mathematicians have acquired influence not only their beliefs and attitude about the importance of teaching and the effective approach of teaching, but also their intentions in the future. According to Beisiegel, the responses of the interviewees demonstrated that experiencing the traditional approach of teaching as students in undergraduate classrooms has resulted in a belief that this is the only effective approach to teaching, and so alternative approaches are not even considered. Their intention about their future classrooms then is simply “a replication” (p. 249) of other professors they have experienced during their education.

Speer (2001) looked at mathematics graduate students’ experiences in a calculus course. The graduate students were encouraged to use reform-teaching approaches, such as encouraging students’ reflections and discussions. These approaches are different from what the participants have experienced in their prior education. Speer concluded that graduate students’ beliefs about mathematics, about how students learn, and about what
constitutes evidence of learning influenced the learning opportunities they intended to provide to students and their decisions about types of questions to rise in classrooms. Shulman (2004) argued that how a person learns affects that person’s pedagogy in classrooms in the future. Shulman stated that when we teach mathematics, not only content, but also pedagogy will become part of a consistent cycle that is transferred from one generation to another; that is, when we teach, “both about the content and regarding the pedagogy, they will carry to generations of young people whom they will subsequently teach” (p. 406). In short, if students were to teach one day, they would copy their teachers’ approaches of teaching.

**Prior experience, beliefs, attitude, and intention influence behavior.** Many scholars have argued that teachers’ beliefs and attitude influence their behaviors in classrooms (Davis, 2006; Ernest, 1991; Fang, 1996). Regarding mathematics teaching at the undergraduate level specifically, Speer et al. (2005) looked at mathematics teaching assistants’ (TAs) preparation programs and stated that TAs’ prior experience and beliefs about teaching influence their approaches in classrooms. Speer et al. argued that such programs are in urgent need for examination especially that teaching assistants are future mathematics professors. Speer et al. further indicated that TAs’ experience in classrooms “will develop teaching practices they likely will carry with them into their careers as faculty members” (p. 76).

The proceeding paragraphs highlight the literature that addresses the following: mathematicians’ awareness, knowledge, and attitude about mathematics teaching and reform in teaching; the effect of prior education, knowledge, and beliefs on
mathematicians’ attitude with regard to teaching; and finally, the effect of prior experience, beliefs, and attitude on mathematicians’ intentional behavior and behavior in classrooms. These relationships are illustrated in Figure 2.

Fishbein and Ajzen’s framework (Figure 1) appears to the right portion of Figure 2, and has been adapted to reflect beliefs, attitude, intentions, and behavior regarding teaching. To the left of the figure appears knowledge for teaching and past educational and teaching experiences. The literature reviewed in the last section indicated that there is an influence from

- knowledge for teaching on attitude
- past educational and teaching experiences on attitude
- past educational and teaching experiences on knowledge for teaching
- and finally past educational and teaching experiences on behavior while teaching.

These relationships are represented with straight arrows in Figure 2.

*Figure 2: Model of factors that influence attitude about teaching in general.*
Review of Reasons Underlying Instructor’s Attitude Toward Software Use

Using software in mathematics classrooms to enhance the teaching and learning of mathematics is an instructional behavior. In the following paragraphs, the constructs in Figure 2 will be considered when looking at software use in mathematics classrooms specifically instead of teaching in general. The researcher used the following literature to reflect on Figure 2 and build on it by connecting certain factors, such as prior experience and knowledge about software, the course being taught, and cultural background, to the constructs in the figure.

Knowledge about software and prior experience influence attitude and behavior. One important factor that contributes to an instructor’s attitude regarding software use in classrooms is the instructor’s knowledge about using such tool (Jackson, 2011, Jackson & Hundley, 2011; Wilburne et al., 2009). Indeed, Moore and Smith (2006) took an extreme position with regard to the importance of learning about software and stated, “learning how to learn in this environment [the environment that includes software] is as important as learning about the mathematics itself” (p. 230). Page (2007) indicated that given the diversity in goals and technological skills, it is not totally surprising to see various interests among mathematicians regarding software use in instruction. Jackson (2011) argued that with the rapid development of software, it is expected that many mathematics faculty are not aware of how to effectively use such tools. A. C. Tucker (1999) and Jackson indicated that instead of just asking for more technology integration in mathematics classrooms, faculty should be supported in learning how to effectively use such utilities. On the other hand, Jackson and Hundley
(2011) claimed that some faculty might consider knowing how to effectively use software in classrooms as an extra burden on them.

In addition, prior experience with software might influence attitude toward using it. In a recent qualitative study, Hollebrands et al. (2010) interviewed eight mathematics and mathematics education students and analyzed the themes of their arguments in a college geometry class. Hollebrands et al. concluded that the respondents did not use software when explaining their arguments because they learned mathematics traditionally, which does not include technology as a way of justifying formal proofs. In addition, one of the factors that have been investigated with relation to prior experience is the length of the instructor’s teaching experience. Stevens (2007) commented that because new PhDs realize that their limited teaching experience needs to be enriched, they are usually interested in using software in teaching, not to mention that technology is part of their generation’s experience. In contrast, Habre (2011) stated, in a surprised depressed voice, that his newly graduated colleagues at the American University in Lebanon do not believe in the use of software when teaching differential equations, although they are much younger than him, Habre added.

Fleener (1995) and Sandholtz et al. (2000) took the position that it is crucial to address instructors’ beliefs about technology if we want to change practice in classrooms. In many cases, teachers’ beliefs explain the reluctance to integrate technology in classrooms. Teachers’ perceptions about technology and mathematical software (Zbiek & Hollebrands, 2008), and about students’ abilities (Tall, Smith, & Piez, 2008) influence their integration of such instructional tools into classrooms. Tall et al., in their
recommendations and suggestions for a successful calculus reform with technological software integration, indicated that teacher’s attitudes and beliefs cannot be ignored.

**The course being taught influences attitude.** It can be inferred from the literature that using software in undergraduate classrooms depends on the course being taught, which includes course content and the audience. Most mathematics departments serve three types of students: (a) students who intend to be future mathematicians, (b) students who intend to be mathematics teachers, and (c) students who are taking mathematics courses as part of the general requirement for their programs. In this last category, there are students in liberal arts, who will take a limited number of basic calculus courses, but there are also engineering and science majors, who encounter a wide range of mathematics courses. Within the first category, there are students who are mainly interested in pure mathematics, such as abstract algebra and real analyses, or students who are mainly interested in applied mathematics, such as differential equations.

Whether the course is taught to freshmen, sophomores, juniors, or seniors may influence instructor’s disposition regarding the effectiveness of software use. One comment from opponents of software use is that students should master paper and pencil procedure first (Ellis, 2001; Quinlan, 2007). On the other hand, some mathematicians believe that the appropriateness of software use in instruction “depends on what profession the student chooses” (Quinlan, 2007, p. 220). A mathematician’s decision to use software when teaching mathematics might be influenced by the discipline of students, whether the students are future mathematician, future mathematics teachers, or in a different discipline, or the level of the students being taught (Ellis, 2001).
Quinlan (2007) concluded that the use of software depends on the course itself. Courses such as calculus, linear algebra, and differential equations are expected probably to take advantage of the existing software. Quinlan reported that 22% of mathematicians, who participated in the study, said that software use in teaching mathematics is not important to their particular field. Zbiek et al. (2007) stated that different software is appropriate for different mathematical activities. So the nature of the task students are working on will inform the appropriateness of software use and the type of software that is most helpful. For example, some mathematicians believe that applied mathematics courses should incorporate mathematical software to be taught effectively. Lopez (2005) stated clearly the CAS should be the main working tool for teaching and learning mathematics in classical applied mathematics courses and that CAS gives students the opportunity to learn mathematics more efficiently. Lopez started an initiative in his institution in 1988 to introduce CAS to all courses taught beyond calculus. By 1995, students in applied mathematics courses were expected to use software in classes, for homework, and during exams.

On the other hand, other mathematicians argued that programming software could be used to teach concepts in abstract algebra or discrete mathematics (Dubinsky & Leron, 1994; Fenton & Dubinsky, 1996). The authors presented textbooks that could be used to teach concepts in the said areas using programming software as a teaching tool. In addition, Borwein et al. (2004) presented several mathematical problems and the best ways to solve them using different technological software. Borwein et al. claimed that using software makes proofs more understandable and easy to be remembered later.
Borwein et al. discussed the difference between solving such problems with and without the technology. In what they called computer-aided proofs, an abstract topic such as complex analysis comes “to life” (p. 274). In addition, Maycock, who is well known for her advocacy to use technology in teaching abstract concepts, created a course to teach abstract algebra using a software package called Exploring Small Groups. Maycock also used software in teaching analysis (Jackson, 2005).

Since the 1980s, there has been an ongoing debate about the way calculus should be taught in undergraduate classrooms. The result was the Calculus Reform movement (Tall et al., 2008). Technology was identified as one characteristic that distinguished the recommended reform in curriculum and instruction from the traditional curriculum and instruction in calculus classes (T. W. Tucker, 1999). It could be argued that the call for reform in calculus classrooms supported the development and use of sophisticated software; however, Tucker stated that the availability of such software shaped calculus reform. The point is, the area in mathematics most influenced by the existing software was calculus (Tall et al., 2008). Many studies, such as: Girard (2002), Heid (1988), McCallum (2007), and Speer (2001), which addressed the effect of software on the teaching and learning of mathematics, focused on calculus classes.

In January 1985, the AMS and MAA joint meeting was held to discuss calculus curriculum and teaching in undergraduate classrooms (Douglas, 1986). Douglas stated that one key result from the meeting was that changing the way calculus is taught in undergraduate classrooms is not only desirable, but also unavoidable. Douglas claimed that despite the diversity of the participants in the conference, an agreement has been
reached that technology is the main reason behind such necessary change. Davis et al. (1986) argued that because of the role of calculus in all discipline, software should be incorporated so students will experience the tools that they will eventually need in their future. As a result of the Calculus Reform movement, the National Science Foundation supported the development of a number of calculus curricula. One of these grants was used to develop the Calculus Consortium Based at Harvard University (Gleason & Hughes-Hallett, 1992). One vital principle of this project is “The Role of Three…graphical, numerical, and analytical” (p. 1). Gleason and Hughes-Hallett stated that to satisfy such a principle, a computer or a graphics calculator should be used so students have the opportunity to work on all presentations.

**Cultural background influences attitude.** Instructors’ use of software when teaching mathematics is a popular research topic that has been investigated around the world (Artigue, 2002; Barzel, 2007; Camacho Machín & Depool Rivero, 2003; Habre, 2011; Sárvári et al., 2010; Shao, 2010). Interestingly, while some international academic mathematicians encourage the use of software in mathematics classrooms (e.g., Habre, 2011; Sárvári et al., 2010), others do not share the same opinions (e.g., Shao, 2010). Habre criticized the limited use of software when teaching differential equations at Lebanon, whereas, Shao stated that most academic mathematicians in Singapore and China criticize software use in mathematics classrooms. Habre argued that although he is convinced that using software when teaching differential equations is beneficial to students, the traditional approach, with no software integration, is the primary teaching
method in most Lebanese undergraduate classroom and that most of his colleagues are totally against the use of mathematical software.

The United States of America is a multicultural country. Not all tenured or tenure-track professors in PhD-granting mathematics departments are U.S. citizens, and those that are may be foreign born. According to Philips, Maxwell, and Rose (2008), among all U.S. universities, only 43% of the mathematics PhD’s awarded in 2007 were U.S. citizens. Schoenfeld (1989) claimed that each mathematical community has its own culture that consists of sets of norms and beliefs, which are transferable from teachers in classrooms to their students. Beyer (1997) took the position that culture influences individual’s motivation and practice in higher education. Hence, it is logical to expect that cultural background is one factor that might influence professors’ dispositions to integrate software in their teaching. Jackson (2011) stated that, in her college, more than 50% of the mathematics faculty is above the age of 50. This means that these individuals will be retired soon and replaced by other faculty members. If these new mathematicians are coming from other countries, then, they might be interested in research more than teaching. Hence, she argued, they might not be interested in the effective use of software to enhance mathematics instruction.

**International perspectives from K–12 classrooms.** The following studies address the use of software in international classrooms. Because of the lack of similar studies at the undergraduate level, the following studies are being referenced here just to give a broader perspective about teaching mathematics and the use of software outside the U.S.

While the cultural background matters, Alzahrani (2004) noted that educational background also has an influence on instructors’ attitude toward the use of software.
Alzahrani surveyed 149 Saudi high school mathematics teachers and applied a two-way multivariate analysis (MANOVA) and an independent t test to examine their attitude regarding the use of graphing calculators in their instruction. One key result is that teachers who graduated from science colleges held a significantly higher attitude than teachers who graduated from education colleges. This result might suggest that even when the cultural background is the same, the educational background may influence instructors’ attitude. Moreover, the length of teaching experience has been reported in other countries to be a factor that influences technology integration. Wu, An, and Wang (2005) conducted a comparison study between Chinese teachers and U.S. teachers with regard to the use of calculators and the level of confidence and knowledge about this technology. Wu et al. surveyed 48 American and 77 Chinese elementary school teachers. One of the main results was that in both groups the confidence level of using calculators was negatively related to the length of teaching experience. Meaning, experienced teachers tend to not be confident with the use of calculators.

Baek et al. (2008) discussed the factors that influence Korean teachers’ decision to use technology in their classrooms and examined the degree of this influence. The study consists of two sessions. In the first session, 64 elementary and middle school teachers generated a list of 88 reasons that influence a teacher’s decision to use technology in classroom. In the second session, 202 middle and elementary school teachers evaluated the developed 88 items on a Likert scale. Beak et al. categorized the responses in six main factors that influence teachers’ attitude: “adapting to external requests and others’ expectations, deriving attention, using the basic functions of technology, relieving physical fatigue, class preparation and management, and using the
enhanced functions of technology” (p. 228). The participants were divided into three groups according to their teaching experiences (0–4, 5–16, and more than 17) and a one-way ANOVA was used to examine them. The results indicated that expert teachers employed technology only if they had to conform to external obligations, whereas less experienced teachers were willing to use technology because they believed in its benefits.

The initial model. Figure 3 below summarized the findings of the above literature. This figure was the initial model, which served as the starting point of data collection. The right portion of Figure 3 is almost identical to the right portion of Figure 2 except when considering attitude and intentions toward software use rather than teaching. Straight arrows suggest an influence from a certain factor and double arrows indicate bidirectional relationships. The model indicates that three main factors might contribute to professors’ attitude toward software use:

- educational and teaching experiences;
- the course being taught;
- and cultural background.

It also suggests that the association among these factors should not be ignored. Educational and teaching experiences influence attitude and behavior, but an individual’s experience is influenced by attitude and behavior. Moreover, educational and teaching backgrounds are part of an individual’s culture, but culture shapes an individual’s experience. Finally, there is a bidirectional relationship between knowledge about software and an individual’s experience. This model was refined and expanded recursively using the interview data. The interview data focused on factors that influence
attitude only and hence, the bidirectional arrow between educational and teaching experience and behavior disappeared in the expanded model. The expanded model was, then, tested using a survey instrument, as explained in the next chapter.

**Summary**

This chapter first adopted Fishbein and Ajzen’s (1975) framework. Then, the literature reviewed was used to build on it and address elements that influence attitude with regard to teaching in general. Lastly, the model was considered when looking at software use in classrooms. Figure 3 is a visual representation of the results of the reviewed research that addressed factors that influence attitude regarding software use in teaching.

*Figure 3: Model of factors that influence attitude about teaching with software.*
Chapter 4: Research Design

This study investigated academic mathematicians’ dispositions regarding software use in mathematics instruction and the reasons that underlie these dispositions. The investigation used an exploratory mixed-methods design similar to Creswell and Plano Clark’s (2011) conceptualization of an exploratory-sequential approach. This study consisted of three phases:

1. Phase 1 was the interview phase;
2. Phase 2 was the survey instrument development and piloting phase;
3. Phase 3 was the survey implementation phase.

As explained in Chapter 3, the author used past studies and related theories to build the initial model (Figure 3). This model was reflectively and continuously polished and modified throughout the phases of the study. In Phase 1, the researcher used interview data to expand the initial model to include a set of factors and subfactors that influence attitude regarding software use, and, then, expanded the supplementary research questions mentioned in Chapter 1 (pp. 28–29). In Phase 2, the central goal was to build a survey instrument based on the expanded model. Upon developing the initial instrument, the researcher piloted it with a small sample and revised it based on the results of the pilot study. The revised survey instrument was used in Phase 3 to test the factors and subfactors in the expanded model and answer the expanded supplementary research questions. The researcher triangulated the interview results and the survey results with the initial model, and hence, created a quantitative picture concerning mathematicians’ dispositions regarding software use and the reasons supporting their
patterns of usage. In other words, all phases were iterative and interactive; the results of each phase informed and updated the others. The research questions were

1. What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

2. What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

This chapter explains the population, sampling, data collection, and analyses procedures in all phases. The data in all phases were collected after the Ohio University Institutional Review Board (IRB) approved the proposed study.

**Phase 1: Ethnographic Interviews**

The literature review presented in Chapter 2 indicated that mathematicians’ dispositions toward software use in teaching are not unified. The model presented in Figure 3 suggested that certain variables tend to influence mathematicians’ dispositions. These include, but are not limited to, culture, prior experience, and the course being taught. Hence, in Phase 1, the researcher used an ethnographic approach to collect interview data from key informants in the field aiming to explore these variables and search for possible new reasons that might contribute to and influence mathematicians’ dispositions toward software use in mathematics classrooms.

**Why an ethnographic approach?** Ethnographic research is an approach of investigation in which the focus is on a group within a culture or community (Creswell, 2009), and the main aim is to understand people’s behaviors and the reasons behind such behaviors in this community (LeCompte & Schensul, 1999a). Ethnography is defined as
“holistic depiction of uncontrived group interaction over a period of time, faithfully representing participant views and meanings” (Goetz & LeCompte, 1984, p. 51). Goetz and LeCompte stated that ethnography focuses on “discovering shared beliefs, practices, artifacts, folk knowledge, and behaviors” (p. 51) among a group. Eisenhart (1988) suggested that if a study aims to investigate “why is mathematics teaching and learning occurring in this way in this setting” (p. 100), then the most appropriate method of investigation is ethnography.

Academic mathematicians share specific beliefs and values within the community of mathematicians that are different from beliefs and values within other academic cultures, including the culture of mathematics educators (Bass, 1997; Cuoco, 2003). The main goal of the ethnographic interviews in this phase was to uncover shared beliefs and attitudes toward software use in collegiate mathematics instruction within the academic mathematicians’ culture (Eisenhart, 1988). Listening to the participants when they reflected on their opinions revealed their dispositions and the reasons that may have influenced these dispositions and those of other members of the community of academic mathematicians. The use of the ethnographic approach in the interview phase was distinctive because mathematicians’ voices were used to expand the initial model and build the survey instrument. This phase allowed the researcher to transform the interview data into a set of factors, and hence, expand the initial model. These factors were then transformed “into the necessary items and scales” (Glesne & Peshkin, 1992, p. 64), which were used in the subsequent phases.
**Participants’ selection.** The researcher first contacted each anticipated interviewee and explained the study stressing the following points:

1. The overall purpose of the study
2. The expected significance of the results to the community of mathematics and mathematics education
3. The importance of understanding mathematicians’ points of view with regard to educational issues
4. Confidentiality and privacy insurance
5. Recognition and appreciation of the time given for meeting and interviewing.

The participants were assured that their comments would be appreciated and considered seriously. When the contacted person agreed, a time was scheduled according to the participant’s availability.

The researcher used the snowball sampling procedure (Patton, 2002) and the pre-interview meetings to select only individuals who were interested in and knowledgeable about the research topic. All interviewees were faculty members who had experienced the use of software themselves, or who had been involved in a discussion or a research project that investigated this issue. Three of the interviewees were not originally U.S. citizens. The age of the interviewees ranged approximately from 30 to 65 years, with teaching experience ranging from 9 to 30 years inside and outside the U.S. The sample included proponents, skeptics, and critics.

Schensul et al. (1999) indicated that in an ethnographic research, and specifically when interviewing key informants, data might be collected from a broader population. In
this phase, not all interviewees were from the population of interest, in that not all of them were teaching at PhD-granting departments and not all were PhD holders. The participants were teaching at four mathematics departments in a large Midwestern state in the U.S. Two of the four departments were PhD-granting mathematics departments, and the other two were bachelor-granting departments. In addition, the sample included three assistant professors, four associate professors, and two full professors. The remaining two participants held master’s degrees in mathematics and were working as mathematics lecturers. These two participants had lengthy teaching experience, had amicable relationships with other professors of mathematics, and have expressed their interest in the research topic. Schensul et al. stated that, although key informants might not be representative of the targeted population, they know enough about this specific culture of interest to be chosen for the interview.

**Data collection.** The researcher conducted 11 interviews from June 17, 2011 through September 20, 2011. The interviews were conducted face-to-face with a convenience sample of relative experts (Onwuegbuzie & Leech, 2007). Prior to each interview, all participants signed the Ohio University consent form (Appendix A), and received a copy of it. All interviews were conducted at the participant’s office, a classroom, or a meeting room. The interviews lasted for at least 60 min. The researcher audio taped all interviews using a primary voice recorder and a secondary backup recorder.

In this phase, the author used unstructured and semistructured interview questions to collect data. Preplanned semistructured interview protocol (Appendix B) was used in
the interview, in addition to prompt and follow-up questions as appropriate. The interviews contained in-depth and open-ended questions to allow for deep understanding of participants’ perspectives. The participants had the opportunity to express their opinions and to elaborate on their experience, if any, of using software in teaching. The interviews focused on the following issues:

- Instructor’s typical teaching style
- Instructor’s beliefs about the effectiveness of software use in mathematics classrooms
- Instructor’s point of view regarding traditional teaching versus teaching using innovative tools and strategies
- Instructor’s point of view about the factors that may influence software integration
- Instructor’s point of view about other mathematicians’ dispositions regarding software use in mathematics instruction
- Instructor’s point of view regarding the effect of specific factors, such as cultural and educational background, the nature and level of the courses being taught, instructor’s previous education and experience, instructor’s beliefs about mathematics teaching and learning
- Instructor’s opinion concerning other factors that may influence mathematicians’ dispositions.

As recommended in the literature, the interviewer maintained a neutral attitude during the interviews to avoid influencing the participants’ responses (LeCompte &
Schensul, 1999a). Specifically, the interviewer refrained from expressing any support or criticism regarding the use of software in instruction. Instead, during the interviews, comments and opinions, and in some cases quotes, from other mathematicians with varying perspectives were shared to give the participants the feeling that all points of view would be respected, welcomed, and valuable. Sharing other people’s opinions showed that mathematicians’ dispositions regarding software use vary and indicated that behind every attitude is a set of beliefs and points of view that support such an attitude. The interviewer informed the participants that the aim of the interview was exploratory, rather than criticizing or supporting a certain teaching method. Other listening and communication skills recommended in the literature (Glesne & Peshkin, 1992) were followed. For example, Glesne and Peshkin indicated that, although it is essential for the interviewer to be a good listener throughout the whole interview, it is important to realize that feedback from participants could be nonverbal. In addition to listening to participants’ responses, the interviewer should be able to translate body language and observe signs of discomfort or annoyance.

**Subjectivity and bias.** The procedures described above addressed the subjectivity issue that is a concern in qualitative research (Glesne & Peshkin, 1992; Kilbourn, 2006). Kilbourn argued that researchers in qualitative studies interpret the data with the lens that has been influenced by one’s experiences, beliefs, etc. Hence, Kilbourn recommended that the researchers’ subjectivity should be addressed. One approach to dealing with this issue is to acknowledge the characteristics in oneself that might be a source of bias.
Kilbourn argues that addressing subjectivity is “a way of providing individual insight to a situation” (p. 547).

I was raised in a culture in which the use of software was not welcomed or encouraged, neither at Grades K–12, nor at the collegiate level. I did not use any kind of software in my mathematics classrooms through the master’s degree or in my teaching after earning it. Upon arrival in United States and beginning the PhD program in 2008, I held a conservative attitude regarding software use in teaching mathematics. However, soon after exploring the literature that has addressed this issue, I started to realize that many benefits of software use were possible. Nevertheless, I understand the challenges mathematicians could face in integrating software in undergraduate instruction. I appreciate the points of view of mathematicians who criticize software use. I agree with instructors who are concerned about the overemphasis or misuse of software in mathematics instruction. I am neither a total advocate nor a total critic, and I still value the traditional approach of teaching. Up to the time of writing this dissertation, I have never used software in teaching, but have experienced its use as a PhD student.

In the last three years, I read research articles that encouraged software use and was involved in research projects that reflected software integration in K–12 classrooms. What I found to be surprising, and rather unexpected, is the limited integration of software in undergraduate classrooms (CUPM, 2004, Kirkman, 2012). My experience and observation of the way mathematics is taught in undergraduate classrooms raised many questions. Some answers came to reveal that many mathematicians do not assent with mathematics educators with regard to teaching mathematics with software. What
motivates me more is the limited knowledge in the literature about mathematicians’ points of view, especially those who oppose software integration. The literature that I explored suggested that, not only do many mathematicians disagree with software use in teaching, but many of them maintain that it is not important for them to be involved in educational issues. Hence, I became interested in uncovering mathematicians’ dispositions and the reasons that have influenced them.

**Data analysis.** As recommended by Miles and Huberman (1984), data analysis started by the end of the first interview. The analysis procedure was purposefully redundant. This means that the analysis started with the first interview, and continued until all themes were well supported and no new information was discovered. After each interview, the researcher transcribed the data. To ensure confidentiality, only letters, A, B, etc., identified the interviewees. The corresponding name of each letter and the transcribed data were stored in a private computer, accessible by a password only. The researcher analyzed the transcripts for themes and for key quotes and ideas. The researcher used thematic analysis (Howitt & Cramer, 2008) to reveal the hidden patterns and themes that were reflected by the textual data. The researcher created a table for each interviewee, which contained the key ideas, supporting quotes, and the researcher’s interpretation of the quotes. The author, then, used the transcript and the created table of each interviewee to edit the interview questions and to guide the main themes and interests for the subsequent interview.

After interpreting the transcripts and identifying the main themes, the researcher sent an e-mail message to each participant, which included the transcription of the data
related to the participant’s interview and a brief interpretation of it. The researcher requested feedback from the participants on this interpretation. This member-check procedure supported the credibility and the trustworthiness of the analysis (Brantlinger et al., 2005; Glesne & Peshkin, 1992; Nastasi & Schensul; 2005). Most of the participants replied to the e-mail message with a detailed feedback that reflected their perceptions. Some of them elaborated more on certain key ideas and gave specific examples to support their opinions.

Upon completion of the interviews, the author sorted the data by patterns and themes. As suggested by LeCompte and Schensul (1999b) and Schensul et al. (1999), the researcher used a comprehensive organizing chart to support the analysis process. The central goal of this chart was to convert the themes into a list of possible factors that influence the use of software in undergraduate mathematics classrooms. Appendix C (Table C1) represents a selected portion of this chart. The chart included four columns:

- Column 1 contained key ideas and themes;
- Column 2 contained quotes that were used to identify the key idea;
- Column 3 contained the researcher’s interpretation of the quotes;
- Column 4 included the supporting literature to each specific theme.

The researcher used the redundancy of informants’ responses (data saturation) to identify the factors. Some of the identified factors coincide with the initial model presented in Figure 3 (p. 81); however, additional factors were also uncovered, as explained in Chapter 5. The chart was, then, shared with two other PhD candidates in mathematics education, one of whom had had extensive course work in qualitative
methods. This peer-debriefing approach supported the credibility of the results and addressed the subjectivity issue.

The identified factors and subfactors were used to transform the initial model (Figure 3, p. 81) to the expanded model (Figure 4, p. 126). Each identified factor and subfactor from the interview data was added to Figure 3. The researcher used straight arrows and dotted lines to express the different relationships among the factors and subfactors and to indicate what relationships would be explored in Phase 3. Lastly, the researcher used Figure 4 to expand the supplementary questions that were presented in Chapter 1 (pp. 28–29) so that each of the identified factors would be investigated.

**Phase 2: Developing the Survey Instrument**

In Phase 2, the author developed, piloted, and, then, edited the survey instrument to be used in Phase 3. The identified factors and subfactors in Figure 4 were used to write the survey items.

**Developing the instrument.** A mathematician’s attitude was the response variable. The researcher used an attitude scale—Attitude Instrument for Mathematics and Applied Technology (AIM-AT)—to measure a mathematician’s attitude. AIM-AT was used initially by Huang (1993) to address students’ attitude toward using calculators. Fleener (1995) adapted Huang’s instrument and used it to address teachers’ attitude toward using calculators. This study adapted Fleener’s (1995) instrument. Fleener’s instrument consists of 23 items, each on a 4-point scale, divided in three categories: cognitive, experiential, and affective, with reported internal consistency .77, .71, and .76 respectively (Appendix D). Adabor (2008) used Fleener’s (1995) instrument and reported
internal consistency of .73, .64, and .44 of each category respectively and .757 for the whole instrument. The AIM-AT instrument in its entirety, and without considering Fleener’s categorizations, was adjusted to measure attitude toward software use, not only calculators (Appendix E). Permission to use the instrument was given by M. Jayne Fleener (Appendix F).

While the researcher adapted the attitude scale from an existing instrument, she constructed other items to measure the factors that might influence attitude. The instrument was developed using the Qualtrics online survey software. The researcher followed the guidelines suggested by Converse and Presser (1986) and Schonlau, Fricker, and Elliott (2002) for developing a user-friendly instrument. For example, the force-response option was not used except when it was essential to ensure that the respondent was from the targeted population (e.g., in the item that investigated the respondent’s research interest). This is because mathematics educators and statisticians are not from the targeted population for this research and need to be excluded from the analysis. In addition, because the survey consisted of several scales and was expected to take some time to be completed, an indication of measure of completion was available and the participants had the freedom to quit and re-enter the survey based on their convenience. The authors’ recommendations for item display and presentation were also considered. These strategies were suggested to support the validity of the instrument and increase the response rate. Survey items were close-ended and sought specific information. The aim was to explore the identified factors, rather than to discover new factors (Schensul et al., 1999).
Upon developing the instrument, the researcher sent it to the participants in Phase 1. The goal of this step was two-fold. First, it was a cross-method procedure to support the reliability of the collected interview data (Brantlinger et al., 2005). In other words, the researcher compared the data that was collected by the survey and by the interview with the same individual to check consistency. Second, it reflected the interview participants’ opinions about the clarity and appropriateness of the survey items.

**Piloting the instrument.** There were two main goals of the pilot study. The first was to increase the clarity, simplicity, and flow of the items. The second was to establish the reliability of the instrument. The pilot study used varied computer platforms such as Mac and PC and used different browsers to identify any unexpected problems. As recommended by Schonlau et al. (2002), troubleshooting of any obstacles or technical difficulties with regard to the invitations through e-mail and the database browsers was conducted.

Upon constructing the instrument, the researcher piloted it electronically with the think-aloud approach with two colleagues, one of them was a PhD candidate in mathematics education and the other was a PhD candidate in mechanical engineering. Their comments and suggestions were discussed with two of the dissertation committee members. Then, the researcher piloted the survey electronically with faculty members at the Department of Mathematics at Ohio University and its regional campuses. The survey universal resource locator (URL) hyperlink, along with an invitational e-mail message (Appendix G), was sent to 21 faculty members at the Ohio University mathematics department, excluding the interview participants. It was also sent to 13 faculty members
at the regional campuses and 44 graduate students. A force-response item in the survey asked about the degree sought by the graduate students, and all master’s level respondents were excluded. The survey was available on October 21, 2011 Eastern time. Following the link in the invitational letter was regarded as an acceptance of participation and no signed consent was required. Johanson and Brooks (2010) suggested a sample size of 24–36 in pilot studies to detect acceptable reliability. To increase the response rate and reach the recommended interval, the researcher made every effort to meet or verbally contact each faculty to ask for participation.

**Phase 3: Survey Implementation**

In Phase 3, the researcher used the survey instrument to obtain data on mathematicians’ dispositions regarding software use in mathematics classrooms. The author measured the participating professors’ attitudes and the suggested factors underlying such attitude. These factors were, then, tested as predictors of professors’ attitude toward software use in teaching. One goal of this phase was to extract a list of possible factors that underlie mathematicians’ dispositions. The reason for using the survey instrument was that it was not possible to interview a large number of academic mathematicians. These are individuals who are occupied with many responsibilities. This study aimed to explore a large number of mathematicians’ opinions to support the validity of the inferred results, lend generalizability of the results, and support the main goal of the study, which is understanding mathematicians’ dispositions regarding software use and reasons underlying such dispositions.
**Population and sampling.** The target population was individuals who had earned doctorate degree in mathematics, who were tenured or tenure-track (TTT) full-time faculty members in doctoral-granting mathematics departments in the United States. This phase did not consider individuals who did not fulfill these criteria. For example, part-time faculty, post doc faculty, or graduate teaching assistants (GTAs) were not considered in this phase. According to the third report of the 2009 CBMS survey, the approximate number of PhDs, tenured or tenure-track, full-time faculty at PhD-granting departments was 7217 (Cleary, Maxwell, & Rose, 2010). In addition, Kirkman (2012) reported that the number of TTT faculty decreased and the number of non-TTT faculty, including post doc, increased. Kirkman indicated that the approximate number of TTT faculty at PhD-granting mathematics departments as reported by the 2010 CBMS survey was 5615.

The American Mathematical Society divides all mathematics departments into groups based on the highest degree offered by the department. According to AMS (n.d.), there are 185 doctoral-granting departments in the U.S. These “doctoral-granting departments of mathematics are further subdivided according to their ranking of ‘scholarly quality of program faculty’” (Cleary et al., 2010, 1317), as shown in Appendix H. Ignoring these subdivisions and excluding Ohio University, the researcher selected 50 departments using a random number generator. First, a number between 1 and 184 was randomly assigned to each PhD-granting department, excluding Ohio University mathematics department. Then, the researcher used an online random number generator (http://random.org) to generate a set that included 50 unique random integers between 1
and 184. The corresponding departments were selected for this phase. However, by exploring the websites of these universities, the author realized that one department offers a PhD degree in computational sciences and statistics, not mathematics; another department offers a PhD degree in applied science, and two other departments offer PhD degrees in mathematics education only. These four departments were disregarded and four randomly chosen departments from the remaining departments replaced them. Then, the researcher used the websites of the 50 selected departments to create a list of faculty members who satisfy the criteria mentioned in the last paragraph.

To determine the number of participants for this phase, the researcher performed power analyses for all planned statistical tests, including linear regression, ANOVA, and \( t \) tests. For the regression test, one approach to determining the minimum number of participants is based on a statistical significance of .05, a desired power of .80, and the expected effect size of the study. However, an effect size for a similar study was not identified in the literature. The next recommendation in the literature, then, is to use Cohen’s suggestions (.20, .50, .80) for small, medium, and large effect size and to use the number of predictors that will be used in the regression model (Warner, 2008). According to Warner, adequate statistical power (.80) to detect medium effect size (.50) with \( K \) predictors will require \( N \) cases. The relation between \( N \) and \( K \) is the following: \( N > 50 + 8K \) for the test of the overall regression significance and \( N > 104 + K \) for the test of each predictor’s significance. The larger of these two numbers should be used as the minimum number of participants needed for the study. Hence, with the number of predictors ranging from 5–10, the needed number of participants is 109–130. Another
approach is using the *G*\textit{Power} 3.1 software to investigate the number of cases required to achieve .80 power, with a medium effect size and 10 predictors when employing a linear multiple regression model with null hypothesis that $R^2$ is zero. The result indicated that a sample size of 118 is sufficient. The *G*\textit{Power} 3.1 software was also used to investigate the number of cases required when performing $t$ tests and ANOVA tests. In all cases, around 130 cases are sufficient.

**Data collection.** The researcher distributed the instrument electronically. The literature has identified several advantages and disadvantages of this approach. For instance, using web survey is convenient with regard to cost and the number of possible participants. In addition, this approach does not encounter the response bias that is expected in other approaches such as face-to-face survey. However, a high nonresponse rate was expected (Manfreda et al., 2008; Schonlau et al., 2002). Considering the nature of the study and the participants, an even higher nonresponse rate was expected. However, using the web survey was the most appropriate approach for this study, especially because it aimed for responses from all over the country. To increase the response rate, the researcher implemented the following procedure. On November 4, 2011, the researcher mailed 50 invitational letters to the 50 selected department chairs (Appendix I). The letter was an invitation to participate and it included information about the following:
• The goal of the study
• An emphasis on the fact that the main goal of the study is not to critique a certain
teaching method, but rather to understand the reasons behind mathematicians’
dispositions regarding software use in teaching
• The importance of hearing and reporting the voices of all range of views, and the
intention to submit the results of this study to the Notices of the AMS
• Compensation
• Optionality, confidentiality, and privacy assurance
• Participating process and the time expected to complete the survey
• Contact information of the researcher
• Appreciation and recognition comments

The letter informed each department chair that an invitational e-mail would be sent on
November 10 to all faculty in the department that fulfill the criteria for participation,
including the chair. The letter requested the chairs to encourage all TTT faculty members
in their departments to participate.

On November 10, 2011, the author sent the survey universal resource locator
(URL) hyperlink along with a brief description of the study and the participation process
to 1,766 professors of mathematics in the selected 50 departments (Appendix I).
Following the link in the invitational letter was regarded as an acceptance of participation
and no signed consent was required. Responses were limited only to professors who
satisfy the profile mentioned in page 96. Following Umbach’s (2004) recommendation,
one week later, the researcher sent a follow-up e-mail message as a kind reminder.
From the above analysis and results of the *G*\*\textit{power} Software, sending the survey to 1,766 faculty members was an oversampling approach. However, the researcher expected a high nonresponse rate because of the nature of lifestyle of the population. In fact, Quinlan (2007), who surveyed Group I departments, reported a response rate of only 14.8%. According to this percentage, the expected number of responses was 261 mathematics professors. Hence, even, with the expected low response rate, using the oversampling approach is expected to provide the minimum number of cases required.

\textbf{Data analysis.} This study used the Statistical Package for the Social Sciences (SPSS), version 19.0, software for the analyses. First, the researcher recoded the positively worded items and computed new variables, as reported later in Chapter 7. For data screening, and to assess any violation of assumptions and outliers, the researcher graphed a histogram of the response variable. The author also obtained scatter plots and box plots to test the linear relationship assumption and to explore any bivariate outliers. Frequencies and descriptive statistics were obtained on each item and on the computed variables. Then, internal reliability coefficients to measure the consistency of the scales, such as coefficient alpha, were obtained. Alpha is an internal consistency estimate, “which takes into account variance attributable to subjects and variance attributable to the interaction between subjects and items” (Cortina, 1993, p. 98). Alpha is an appropriate estimate of internal consistency if there is only one factor (Cortina, 1993). Hence, coefficient alphas were calculated for each scale in the instrument. Alpha calculates the intercorrelation of the items but not without considering the number of items in the scale.
So, the number of items has to be taken into account when using coefficient alpha for measuring internal consistency.

The author reported consensuses of responses that were higher than 60%.

Moreover, missing data analysis was performed and the Multiple Imputation strategy was followed to handle missing data, as reported in Chapter 7. Then, the researcher used linear regression tests to measure the relationship between the continuous explanatory variables and the response variable. Next, the researcher used an overall multiple regression model, which contained all $K$ variables, to determine the significance of the $K$ predictor variables on a mathematician’s attitude. The statistics test that was used is an $F$ test with $(K, N-K-1)$ degrees of freedom, and $N$ participants in the survey. To examine the significance of each individual explanatory variable as a predictor of the response variable, the partial slope coefficient was assessed to see if it was significantly different from 0 using a $t$ test and $N-K-1$ degree of freedom. High correlations among variables, or multicollinearity, might suggest that some predictors should be dropped from the overall test (Warner, 2008). Hence, the researcher obtained the correlation coefficients matrix among all continuous variables and then used the value of the VIF and tolerance to assess the amount of the shared variance among the variables. The Durbin-Welch test was used to examine the independence assumption. To assess the extent to which the model fit the data and to assess any violation of assumptions, diagnostic tests were performed. Then, the author performed ANOVA tests and $t$ tests to explore the relationships between the non-continuous variables and the response variable. The significant variables were later used as dummy variables in a regression model. The
essential characteristic of the analyses was the interview-survey-model triangulation. When the results of the survey data were analyzed, the researcher cross-validated the findings by triangulating and comparing the results of the interview data, the survey data, and the initial model (Figure 3). The aim of this step was to see how each analysis validates and supports the other. The triangulation results are presented in Chapter 8.

**Reliability and validity.** What distinguished this research was that the survey was unique and was built to address only this specific purpose for this specific culture. The author built the survey based not only on the initial model (p. 81), but also on the perspectives of the participants in Phase 1. The fact that the survey was developed locally and based on emic perspectives supported the psychometric validity of the instrument (Crocker & Algina, 1986), but only for this context. Importantly, the definitions of constructs vary according to cultures (Hitchcock et al., 2005). Mathematical software for teaching is probably defined differently among varying contexts. For example, the phrase “the use of software” could be interpreted as the use of technological tools for administration and communication purposes, such as Blackboard and Livetext. Another example is the phrase “for teaching,” which does not include the use of mathematical software for research purposes, for instance. Students may use technology or computers in the classrooms, but for other reasons, not to support their learning of mathematics. To address this concern, the instruction of the survey gave a clear definition of what software means in this study.

This study used coefficient alpha to measure reliability as discussed in the last section. Although reliability is a prerequisite for validity, it is not a sufficient condition to
ensure the validity of the instrument. Mueller (1986) indicated that although coefficient 
alpha is used to measure the internal reliability of the instrument, content validity and 
internal consistency could be combined to support construct validity. Mueller stated that 
although these are not sufficient reasons to prove that the instrument is measuring what it 
is designed to measure, they are reasons to support such claim.

**Summary**

This study used a mixed-methods approach to investigate mathematicians’ 
dispositions regarding software use in teaching. The investigation consisted of three 
phases, each contributing to the study and informing the next phase. This chapter 
summarized the research design used in all three phases. This includes sampling and 
population, data collection, and data analyses in all phases.

The initial model presented in Chapter 3 (p. 81) is the starting point for data 
collection. In Phase 1, the researcher used interview data to expand the initial model and 
the supplementary research questions. The central goal of Phase 2 was to construct a 
survey instrument based on the expanded model. The instrument was used in Phase 3 to 
create a quantitative picture concerning mathematicians’ dispositions with regard to 
software use and the reasons supporting the pattern of usages among them. The interview 
results and the survey results were triangulated with the initial model. Appendix J (Table 
J1) presents the Timeline of this research.
Chapter 5: Interview Results and Expanded Model

Data Analysis Process

In Phase 1, 11 key informants participated in individual face-to-face interviews. To promote confidentiality, letters (i.e., A, B) identified the 11 participants. The interview protocol contained in-depth, open-ended, unstructured, and semistructured questions. After each interview, the researcher transcribed the data and analyzed them for themes and key quotes. The goal was to uncover the participants’ beliefs, attitudes, and behaviors; the participants’ opinions about their peers’ attitudes; and the factors that might influence attitude with regard to software use in teaching. The researcher created a table for each participant, which contained the key ideas, supportive quotes, and the researcher’s interpretation of the quotes. As a sample, Table 1 shows a subset of the table created for Participant H that includes sections related to six of the key ideas that emerged from the interview. The analyses process was purposefully redundant. The analysis of the interview data of each participant informed and guided the interview questions and the main interest for each subsequent interview. The researcher combined the transcripts of all interviews in one data document, and then, analyzed it searching for recurrent patterns among the participants regarding the identified factors in the initial model (Figure 3, p. 81) and other themes that were not directly identified in the figure. As a result, a compound picture that contained a set of factors that could influence attitude with regard to software use in teaching started to surface. The researcher combined the main factors in a comprehensive chart, as explained in Chapter 4.
### Table 1

*Subset of the Table Created for Participant H*

<table>
<thead>
<tr>
<th>Key Idea</th>
<th>Supporting Quote</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How important is software?</strong></td>
<td>I think it [software] is effective and useful, but it is something that you can’t really do more than 15 minutes a week….For some concepts, you know, showing the integrals it is useful, for many others, it is not any better than a good chalkboard drawing.</td>
<td>The participant believes that there are some concepts that could be illustrated and explained using software. However, learning with such tools is not essential especially for the basic concepts.</td>
</tr>
<tr>
<td><strong>Can software be harmful to students’ learning?</strong></td>
<td>There are certainly some students who will use the calculators instead of thinking….The calculator can do derivative and integrals, so if I let them [students] use the calculators, then I cannot test the chain rule [for example].</td>
<td>The participant believes that software could hinder students’ thinking and prevent learning certain concepts if used inappropriately.</td>
</tr>
<tr>
<td><strong>Culture and past experience effect</strong></td>
<td>Probably if they [mathematicians] are coming from a place that does not use the software, they are not familiar with it….they could be coming from the culture where they encouraging conformity, in which case, just trying something different maybe discouraged in that culture.</td>
<td>The participant indicated that the culture effect could be a factor that influence attitude but what is really related to culture is the past experience and whether a person is familiar with it or not.</td>
</tr>
<tr>
<td><strong>Colleagues’ effect</strong></td>
<td>If they are here [in the U.S.] and they can see their colleagues using it, which gives them an example they wouldn’t get back home.</td>
<td>The participant stated that colleagues’ effect might overcome the culture and the past experience effect.</td>
</tr>
<tr>
<td><strong>Institution effect</strong></td>
<td>In a teaching oriented place, you probably are allowed and expected to spend more time doing innovative teaching….So, I think they are more likely [to use software] from that standpoint.</td>
<td>The participant believes that the institutional support influences attitudes and behaviors toward software use, especially if faculty members are encouraged to try nontraditional methods.</td>
</tr>
<tr>
<td><strong>Knowledge about mathematics teaching</strong></td>
<td>I learned not so many years ago about learning styles, and that some people are visual and some people are not, and that certainly influences my attitudes about using software in visualizing.</td>
<td>The participant believes that the knowledge about teaching and learning influences attitude about software use.</td>
</tr>
</tbody>
</table>
Results of the Interview Data

Participants’ backgrounds, attitudes, and behaviors in classrooms. The first few questions in the interview inquired about each participant’s research interest, teaching experiences, and educational background in addition to the participant’s attitude and typical teaching style with regard to software use. The participants’ backgrounds, pedagogical strategies, and opinions were highly varied. Three participants (B, E, G) had a high positive attitude. Participant B (age 35–45), a coding-theory specialist, who was educated outside the U.S. and has a degree in mathematics education, advocated software use. Participant G, a topologist with an age less than 55, who had taught outside the U.S., argued that software should be used to enhance teaching at the undergraduate level. In addition, Participant E (age 35–45), with an interest in multivariate calculus and an educational and teaching backgrounds in the U.S. only, was an advocate of software use.

On the other hand, Participants A, F, and H were strongly critical of software use. Participant A (age 35–45), an algebraist from Eastern Europe, was educated outside the U.S. and a supporter of the traditional approach of teaching. Participant F was the youngest interviewee with an interest in logic and a negative attitude regarding software use. Moreover, Participant H (age 35–45), a numerical analyst who has graduated from one of the most prestigious research universities in the United States, argued that software could be used only in limited situations.

The other five participants had a moderate position. Participants C and J (age 45–55), who are interested in analysis and differential equations respectively, have a long teaching experiences in the U.S. and indicated that there are a lot of reasons why one
would use and why one would not use software when teaching mathematics. Participants C and J did not believe that software enhances students’ understanding of mathematical concepts as claimed in the literature, “I wouldn’t say that it necessarily enhances the learning of the traditional materials that much” (Participant J). They suggested that it might help in different aspects. For example, “students seem to enjoy the course more, it does seem to spark discussion more than the traditional approach” (Participant C).

Although Participants J and L suggested that software could be helpful, they were not using it in their own teaching. Participant J believed that technical difficulties could easily suspend an effective integration of software, and hence, is not using software when lecturing. Participant L, who is interested in analysis, had over 30 years of teaching experience at U.S. classrooms and had used software before. However, Participant L argued that the use of software requires a great deal of efforts from the professor, and hence, is not using it nowadays.

The opinion of Participant K (age 35–45) depended on the software itself; the participant stated that graphing tools were effective when teaching geometry, but calculators might hinder students’ learning. In addition, Participant D (age 35–45) was an Eastern European with interest in multivariate calculus and applied mathematics, who believed that software could be used only in limited cases when the traditional approach is insufficient. Table 2 and Table 3 include quotes that summarize participants’ attitudes and behaviors in classrooms with regard to software use.
Table 2

*Interviewees’ Attitudes Regarding Software Use: Representative Quotes*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>You do not give a cane to a man who can walk. There are different ways to teach the theory, but to say it can be facilitated by visual aids or by software, actually it is…humiliating for mathematics.</td>
</tr>
<tr>
<td>B</td>
<td>Technology is a tool and as all tools, there are proper uses and improper uses and that is true for technology as well. When used appropriately, it [software] can be very effective and very useful.</td>
</tr>
<tr>
<td>C</td>
<td>In some places, I think it is appropriate; in other places, not so much.</td>
</tr>
<tr>
<td>D</td>
<td>If you know what you are doing, they are effective and they are good….[but] software and technology should not replace completely the ordinary teaching.</td>
</tr>
<tr>
<td>E</td>
<td>I never quite understood the idea of how we are divorcing ourselves from the reality of how to use these things…if it is up to me, we would apply more of that [software].</td>
</tr>
<tr>
<td>F</td>
<td>I am very skeptical…if you are using it appropriately where…it is…being used in addition to the students doing work…I think…go for it, but I personally have not seen a lot of applications that are used in that way.</td>
</tr>
<tr>
<td>G</td>
<td>I will always experiment to see if I can find something worthwhile…I am always willing to try new things to make things better. [Can we teach without software?], I can draw a picture, I just do not think it is as effective.</td>
</tr>
<tr>
<td>H</td>
<td>The end-goal is [that] you want people to learn difficult material, organize it, think critically about what is happening and express their ideas…there really isn’t technological steps in there.</td>
</tr>
<tr>
<td>J</td>
<td>I think it can be effective in some circumstances and for certain people.</td>
</tr>
<tr>
<td>K</td>
<td>Theoretically, you can teach all of this stuff [traditional calculus concepts], without the use of calculators [or software]…I really do not have a problem with calculators except when they distract attention away from other things.</td>
</tr>
<tr>
<td>L</td>
<td>I thought using the TI calculators…was a really good way to give students a better picture…the unfortunate thing is that…it takes a lot of work…. If I were 10 years earlier in my career, I would make that effort.</td>
</tr>
</tbody>
</table>
Table 3

*Interviewees’ Behaviors Regarding Software Use: Representative Quotes*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>For many years, I did not use any kind of software....I do not even use graphing calculators.</td>
</tr>
<tr>
<td>B</td>
<td>I have been using mathematical software, you know, and applying different kinds of teaching methods as well.</td>
</tr>
<tr>
<td>C</td>
<td>I taught a couple of calculus sections and used graphing calculators in a very intense way.</td>
</tr>
<tr>
<td>D</td>
<td>I, sometimes, use MATLAB...I, sometimes, use Mathematica and Maple.</td>
</tr>
<tr>
<td>E</td>
<td>I do like to use a piece of software called Geogebra quite a bit in my lectures.</td>
</tr>
<tr>
<td>F</td>
<td>I am very traditional; I do not use calculators in my classes.</td>
</tr>
<tr>
<td>G</td>
<td>I have my graphing program that is available freely on-line that I use when I want to generate graphs for exams or for display purposes. I have taught with Maple [before].</td>
</tr>
<tr>
<td>H</td>
<td>[In] one course,…Math [MMM(^1)], that is taught in a computer lab…basically, I taught for 10 minutes and then they [students] were working on problems on the computer. [For] calculus…I do not use any technology.</td>
</tr>
<tr>
<td>J</td>
<td>I typically lecture and do group work in class and I give mathematical software assignments to students in most classes. Like five or six assignments per quarter…I do not ever use it [software] in the classroom.</td>
</tr>
<tr>
<td>K</td>
<td>These days I use Geogebra a lot. I have used some other computer drawing tools… I used non-Euclid, another drawing program…In my calculus courses, I use a variety of websites that provide calculation and graphing tools.</td>
</tr>
<tr>
<td>L</td>
<td>I currently do not use any software in the classroom. For many years, I have used TI calculators…[but now] what I basically do is just use the very old technology of a chalkboard. I do not use any software.</td>
</tr>
</tbody>
</table>

**Participants’ perspectives about other mathematicians’ attitude.** When the participants reflected on their peers’ opinions with regard to software use in teaching, \(^1\) Course number and name have been deleted for confidentiality.
their opinions varied. Some participants (D, E, H) immediately connected a
mathematician’s attitude to factors related to the mathematician’s himself, such as
personality or age, or to external factors, such as the software. Others, described the
mathematics community as a whole. Participant B believed, “there is not one opinion of
the mathematical community, but I can say that the use of software is getting more
accepted.” Participant C, on the other hand, believed that some mathematicians were
complete advocates, or entirely against software use, but a large percentage of them
would have a moderate position, “I think you will find many people, kind of, in the
middle; you do not use software for every possible thing,” whereas Participant J argued,
“out of a 100, I would say that…it would probably be about evenly split between for and
against, but neither one will have good justification for it.” Participant A, on the other
hand, indicated that not using software when teaching is a characteristic of research
mathematicians.

If you ask mathematicians in the U.S. or around the world, most of the
ones who continue learning mathematics, who continue research, will say
that they appreciate technology but as far as…, if you put the question
from the point of view of teaching, they will object. (Participant A)

Participants’ perspectives about factors that influence attitude. Because the
goal of Phase 1 was to collect data that supports the development of the instrument, the
focus of the interviews was on the factors that should be investigated as reasons that
might influence other professors’ attitude regarding software use. The analysis of the
transcripts indicated that there were eight factors that were identified as influential on a
professor’s attitude regarding software use. In the following paragraphs, each factor and the associated subfactors are explained and supported by selected quotes.

1. The course being taught. The “course being taught” factor was identified in the literature as an influence on attitude regarding software, as presented in the initial model (p. 81). Hence, one of the interview questions inquired about the effect of the course being taught. The participants reflected on the influence of three subfactors: (a) course content, (b) students’ major, and (c) students’ level. Almost all participants believed that content matters. For example, Participant D indicted that course content influences attitude regarding software use, “depending on the course, I prefer to use technology from time to time…in numerical analysis, they do a lot of things with software and computers; in pure analysis, they are just doing proofs, they do not need computers.” Participant H stated, “[in] one course, Math MMM, that is taught in a computer lab…basically, I taught for 10 minutes and then they [students] were working on problems on the computer”…[for] calculus…I do not use any technology.” In addition, Participant L argued, “there are two classes in which software could be quite useful. One of them is the applied complex variable class and the other is vector analysis.” In fact, Participant L indicated that the content and the level of the course combined might be a factor that influences the extent of benefits of software use, “in real graduate mathematics courses, which are entirely theorem-proving courses, I would say that the vast majority of the materials cannot benefit from the use of software.”

Some participants reflected on the influence of students’ future career, or major, and suggested that a professor might use software just because the students being taught
need to learn such tools. Participant C argued that one important factor to be considered when we think about software was “perception of what students would need later in life.”

On the other hand, Participant G indicated that students’ major also influences students’ approach and comfort-level with the software, “if you are teaching engineering students, then you are going to expect them to be comfortable with MATLAB and things like that.”

Participant C believed that it depends on students’ professional needs, but it also depends on students’ level.

In my graduate mathematics courses or advanced level courses, I may very little use technology or software; I tend to use sort of a lecture discussion format….If it is a very low level course, like college algebra or basic courses, I will probably shy away from using the technology too much because they should really build up their basic skills. When they get to calculus level and so forth, then they should know enough of that stuff that I do not need to test them on. (Participant C)

Interestingly enough, Participants B and E, who have a more positive disposition toward software use, believed that students’ level should not be used as a deciding factor, and that it was always possible to find effective ways to use software at any level and for all majors, “it is not that you can only start using technology after students reach this level. Maybe there is a proper use of technology for students at a lower level” (Participant B); “I would still advocate using software and calculators in lower level classes as well” (Participant E). Participants A, F, and H, who have a rather conservative disposition, indicated that software should be used only when students reach a level of mathematical
maturity or when it was absolutely necessary for their future career. “Once a solid math background is established, then you may use [software], once the student becomes more oriented as of pursuing a certain topic in math or applied application” (Participant A); “if you know that you are specifically preparing your students for a specific career where you know [that] using software is going to be a big part of that career, then I think yes” (Participant F).

In my calculus classes, I do not let them use calculators. At the higher-level class, Math MMM, these are people who are going to use the software in their work. And then you want them to be able to use it.

( Participant H)

2. **Software characteristics.** One factor identified by the participants is the software being used. Some participants reflected on the influence of the (a) knowledge about software, while others indicated that the (b) ease and simplicity of software is an important attribute. Yet, others mentioned the (c) availability of software as an influence on software use. The participants believed that not knowing how to use software could be an obstacle that affects attitude and behavior. “If you are not being trained to use the software, it is maybe very difficult for you to start using it….You have to invest some time and energy to learn it” (Participant B); “I do not have the confidence in myself technologically to get it right in the classroom, so I prefer not to do it” (Participant J).

In addition, some participants believed that one major factor that influences a mathematician’s attitude and behavior regarding software use was the ease and simplicity of the interface of the software, “if it is complicated software, then you have to spend
class time talking about the software, and if you are talking about the software, you are not necessarily talking about what is perceived as the course content” (Participant C). Finally, Participant G stated in a negative voice, “we do not usually have things like that [Mathematica or Maple] available for teaching in class….MATLAB is the one software we have available on the computers,” and Participant L indicated that the use of software will increase “as computation becomes inexpensive enough that people all over the world can buy and use it easily,” which implied that the availability of software could influence the use of software in classrooms.

3. Perceived effect on students’ learning. Many participants discussed their beliefs about the shortcomings of using software in teaching and the effect of these on students’ learning. “I once witnessed a student calculating the square root of 1 in their calculator. So there are certainly some students who will use the calculators instead of thinking” (Participant H); “I once had a student in office hours who came by dividing 100 by 2 and he put it in his calculator, just unbelievable” (Participant J).

The point of learning math is to train the mind to think well and correctly. Technology-use proponents act like its aim is to teach people the results, theorems of mathematics, and with this mindset, which obviously contradicts the aim mentioned above, they claim that technology use facilitates it. My point is, whatever technology is helpful with to students, it is exactly what it deprives them of. (Participant A)

What I am really concerned about is the bad calculators’ habits that I see students getting….They can’t do symbolic manipulations….They can’t do
simple calculations involving fractions…Last year I had a student who did not know the value of $\frac{1}{2} - 1$…She had no idea how she would do that calculation. (Participant K)

My experience with students is that they think they cannot do anything without the calculator….I feel that you need to be able to do the procedures. If something else is doing the procedures for you then…you cannot really get a firm grasp of what is happening. (Participant F)

On the other hand, many participants reflected on the advantage of software on students’ learning of mathematics. For example, software could be a tool to “facilitate understanding and exploration of mathematical ideas” (Participant B), and “facilitate learning for some difficult concepts, in which visualization helps” (Participant D). Participants E, G, and L argued that software supports understanding of mathematics. “It [software] is just do a better job….I am very much a visual learner…So I do a lot teach with that in mind because I think a lot of our students are the same” (Participant E); “students cannot visualize the abstract ideas just based on what you say on the chalkboard or the pictures you draw. Sometimes you need to be able to animate things” (Participant G); “using the TI calculators in class was a really good way to give students a better picture of what actually was going on” (Participant L).

The points mentioned above from the opponent participants (A, F, H) and the advocate participants (B, E, G) indicated that the “perceived effect” of software on students’ learning influences attitude regarding software use. In fact, some participants acknowledged the perceived effect factor and the influence of it on attitude. “If the
person perceives that it will pay off, then they will continue to spend the extra energy to explore the new pedagogical style” (Participant C); “most of our classes have enough materials in them…unless you can do it quickly…it is probably not worth it to me to bring in some technology” (Participant J).

One question is cost effectiveness. How much time do you have to invest in doing the Mathematica, and assuming you are consuming time, what are you going to cut off in order to do that, especially if the students do not know the software and you have to teach them the software, it may not be cost effective. (Participant H)

Participant G indicated that the belief in software effectiveness affects not only attitude regarding using it, but also the benefits of it when it is used, “it is one of these situations where it is only going to be effective if you believe it will be effective.”

4. Instructor’s personality. One of the factors suggested by the interviewees as an influence on attitude regarding software use was “instructor’s personality.” However, the interviewees’ opinions varied on how personality influences attitude. The interview analysis revealed that four subfactors might contribute to attitude: (a) knowledge about mathematics teaching, (b) interest in teaching, (c) resistance to change, and (d) the identity. Some participants indicated that learning to teach mathematics was not among the requirements for mathematicians, “from my experience, not many faculty members really think about the mathematics knowledge for teaching…It is certainly not part of the typical training of a mathematician” (Participant C). This fact might lead to a lack of teaching skills or the lack of knowledge about teaching tools, “many professors, at the
university level, are brilliant, brilliant mathematicians but they…do not know the first thing about teaching” (Participant F). This lack of skills could be accompanied by the lack of interest in teaching. The participants indicated that some mathematicians do not see the value of teaching, “there is emphasis placed on rigorous proofs…So, it is not part of the aesthetic in mathematics to think about how well something is explained…it is not really considered to be more valuable just because it has been explained well” (Participant K).

I think most professors, in their mind, think that they are great teachers….There are going to be people who will draw a line, a hard line, and say ‘on this side is mathematics, on this side things that are worthless’; and you have some that will say, ‘well, I am a mathematician, that means I am automatically a math educator.’ (Participant G)

Some participants argued that the lack of interest in teaching affects the willingness to spend the required time investigating software use in mathematics instruction, “some people say: ‘oh, I am a good enough teacher, all I need is a blackboard and chalk, I will spill forth wisdom on everyone.’ They will look at things like research in software as waste of time” (Participant G).

If you have more interest in teaching, then you are willing to take the time to investigate whether or not you might want to use technology for this or that….These two things [knowledge for mathematics teaching and interest in teaching] wouldn’t be independent, and they probably
would influence whether or not you would take the time to investigate technology. (Participant J)

On the other hand, a major influence on attitude was how a professor perceives his identity as a researcher or a teacher. Participant D indicated that for some mathematicians “teaching and researching are considered…in the two opposite sides of mathematics”; researchers in mathematics do not consider teaching a priority. Participant E agreed that researchers are usually not passionate about teaching. “we need researchers…but we, just as much or even more, need people who are passionate about teaching pre-calculus or Calculus I, and it is hard to get researchers that are passionate about that.” Participant H stated, “there are people who are very good researchers, not very good educators. They are really brilliant as researchers and teaching a graduate level class…you put that same person in a college algebra freshmen class and it is a disaster.” However, Participant H continued to add, “I do not think there is any contradiction between the two [research and teaching],” and Participant J certainly agreed, “as far as your time goes, there is some give and take because teaching well and doing research well both require time…but you can have a much more balanced approach.” Yet, Participant A and Participant K clearly indicated that mathematics researchers would not use software in teaching.

If you ask mathematicians in the U.S. or around the world, most of the ones who continue learning mathematics, who continue research, will say that they appreciate technology but as far as…, if you put the
question from the point of view of teaching, they will object.
(Participant A)

In the research mathematics community, I think you will find more of
the types of mathematicians who will say you should not use
calculators at all...It is partly a research faculty member versus a
faculty member whose job is about teaching. (Participant K)

Participant G did not agree that the interest in teaching implies the interest in software, “I
know some traditional people that are very interested in their teaching....I know enough
people that are quite interested in their teaching who would never touch software.”

Participant E, Participant G, and Participant L believed that there was another important
point with regard to personality, which was the resistance to change. “People do not want
to change a lot of times, and that is what I am fighting against, people do not want to do
things differently” (Participant E); “the most important thing is how open the professor is
to doing such things” (Participant L).

I am willing to bet that you can predict someone’s response [about the
effect of software] by how conservative or liberal they are in general. I
mean, there are some people that are extra conservatives in everything,
and for them chalk is the only thing....It is all about how willing you
are to experiment with things. (Participant G)

5. The institution. The analysis of the data revealed that “the institution” was a
factor that influences using or not using software in classrooms. The interviewees
elaborated on three subfactors: (a) support, (b) expectation, and (c) colleagues’
experience. Participant A stated that, as a Teaching Assistant, the only choice was to obey the university regulations and use software in a calculus section, even if the instructor was not convinced that it was useful. In addition, Participant G indicated that professors’ behaviors at a research department were entirely influenced by their obligations and commitments, “if you are under pressure to get...three papers a year, then you know, maybe figuring out how to use MATLAB is not such an attractive proposition.” On the other hand, the institution not only influences behavior with regard to software use but also attitude. Participant H indicated that in certain institutions, there is emphasis on teaching, including using software, “in a teaching-oriented place, you probably are allowed and expected to spend more time doing innovative teaching; and basically at the beginning of using technology, it takes a lot more time and efforts.” However, other participants feel that the reason behind the different behaviors between faculty in a research department and a teaching-oriented department with regard to software use was the time factor.

There are research departments in which the primary requirement of a professor in order to advance their career is to do research. And then, there are teaching departments…and so they are…focus on teaching at the undergraduate level. I would suspect that those people, just because they have more time to think about teaching, might be more open to new ideas about how to do it [teaching], including software. (Participant L)

Other participants indicated that the colleagues’ effect cannot be ignored; “you might be more likely to use it because everyone else is using it” (Participant J); “if you see other
people doing this [using software], and see them have successful experience, that is very compelling” (Participant G).

6. *Research interest.* From the participants’ responses, it was inferred that a mathematician’s “area of research” could influence attitude regarding software use in teaching. “If I know his [a mathematician] area of research, I can say something about what he might think about teaching using software” (Participant D); “someone who, for example, does work in set theoretic topology, this is such an incredibly abstract area that it is really does not seem likely to be open to using software” (Participant L). The interview participants believed that, depending on the area and the branch of mathematics, software could become essential or not. “For some research areas, it [software] will be more useful, and even necessary, and for some other research areas, it [software] may not be necessary or maybe totally not necessary” (Participant B); “there are certainly some branches of mathematics…you must have computers to do” (Participant H); “my research is very very pure mathematics, so software is in no help at all as far as research is concerned” (Participant G); “if they are applied mathematicians they are going to use tools to help them solve these things” (Participant E).

7. *Age.* Most interviewees indicated that “age” might be a reason behind the reluctance to use software. However, looking at the quotes critically revealed that the real reason was past education. People who did not grow up with it were not familiar and conformable with it. Selected quotes are presented in Table 4.
Table 4

Selected Quotes About the Age Effect

<table>
<thead>
<tr>
<th>Participant</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>The vast majority of older mathematicians would not be inclined to use technology. Many of the younger mathematicians…grew up with technology and are more familiar with it, and would be more inclined to take advantage of it classrooms.</td>
</tr>
<tr>
<td>D</td>
<td>There is an old generation in the department…they are more inclined to use the traditional methods that, you know, they are more familiar with. I know some of them are pretty mad…that technology is abused in the classrooms.</td>
</tr>
<tr>
<td>E</td>
<td>Generally, a younger group of professors have been more exposed to software, and they are open minded; they have been working with it and are more comfortable with it…Older generation professors are less comfortable with it.</td>
</tr>
<tr>
<td>F</td>
<td>The older professors, the generations, you know, that did not grow up with the computers, would tend to be more traditional.</td>
</tr>
</tbody>
</table>

8. Instructor’s background. Almost all participants agreed that “background” likely influences attitude regarding software use in teaching. Some related the effect of background to (a) culture only, while others related it to (b) past educational experience, or (c) teaching experience, including the length of teaching experience. Participant A believed that, “learning and teaching with a calculator has become more of a culture than a conviction….Mathematicians who come from…who were not born here …they will not think it’s a necessity and they will be against looking at it as necessity.” However, other participants indicated that culture was not a dominant factor, and that the effect of culture is related to the educational and teaching experiences. On the other hand, the length of teaching experience was also mentioned as related to the culture factor. Table 5 summarizes these responses. Participant L, however, believes that
As computation becomes inexpensive enough that people all over the world can buy and use it easily, and as cultures begin to realize that this is something that they need to incorporate…as other countries are able to get on board, I think this [cultural] will be less of a factor.

**Interpretation of Results and the Resulting Expanded Model**

The analysis of the interview data suggested that there were eight factors that influence a mathematicians’ attitude regarding software use in undergraduate classrooms.

- The course being taught
- Software characteristics
- Perceived effect on students’ learning
- Instructor’s personality
- Institution
- Research interest
- Age
- Instructor’s background
Table 5

Selected Quotes Regarding the Background Factor

<table>
<thead>
<tr>
<th>Participant</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>If you have taught in a traditional way and if you did not use it [software] for a long time…then of course it will be difficult to start using it.</td>
</tr>
<tr>
<td>C</td>
<td>If the person came through with a very traditional lecture/exam approach to learning mathematics, they will do the lecture/exam thing.</td>
</tr>
<tr>
<td>D</td>
<td>Of course, you are affected by the environment you grew up in, and the way you were educated is very important for decision making, but it may not be a dominant factor.</td>
</tr>
<tr>
<td>F</td>
<td>If you are coming from a country where you are not used to using it [software], then you might be more inclined to not use it, and really not be interested.</td>
</tr>
<tr>
<td>G</td>
<td>It also depends on where someone was educated. I mean, students who have come up the American system, have seen a lot of these stuff and are more comfortable….if you have got 20 years teaching in a certain system and you come here, then you view anything that is outside that as a threat.</td>
</tr>
<tr>
<td>H</td>
<td>They could be coming from the culture where they’re encouraging conformity, in which case, just trying something different maybe discouraged in that culture….I would guess that it [culture] is an influence, but…I do not know how significant.</td>
</tr>
<tr>
<td>J</td>
<td>If you were not exposed to any software, you would be less likely to think about it hard and have any idea of why it would be useful or not, you would simply have a shallow understanding of it.</td>
</tr>
<tr>
<td>K</td>
<td>For most of us who are teaching math, these tools were not available when we were students…I think it [educational background] is a smaller factor.</td>
</tr>
</tbody>
</table>

The participants reflected on the subfactors of five of the eight factors, as summarized in Table 6. Figure 4 below is a visual representation of the suggested factors and subfactors. Most of these were directly or indirectly included in the initial model (Figure 3, p. 81), which was the starting point of the expanded model presented in Figure 4. However, others unforeseen emerged, such as, the perceived effect and research interest. The adopted framework (Figure 1) appears in the right portion of Figure 4.
Column 2 of the figure shows the eight factors that were identified by the interview data as likely influencing attitude and Column 1 contained the associated subfactors. One-way arrows show the expected influential relationship. For example, perceived effect is connected to attitude with a straight arrow because the interview data revealed that the perceived effect on students’ learning influence attitude. Dotted lines represent the relationships among factors and the associated subfactors.

Table 6

Summary of Factors and Subfactors

<table>
<thead>
<tr>
<th>Factors</th>
<th>Subfactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course being taught</td>
<td>(a) Course content</td>
</tr>
<tr>
<td></td>
<td>(b) Students’ level</td>
</tr>
<tr>
<td></td>
<td>(c) Students’ major</td>
</tr>
<tr>
<td>Software characteristics</td>
<td>(a) Software knowledge</td>
</tr>
<tr>
<td></td>
<td>(b) Software availability</td>
</tr>
<tr>
<td></td>
<td>(c) Ease of use</td>
</tr>
<tr>
<td>Perceived effect</td>
<td>No subfactors</td>
</tr>
<tr>
<td>Instructors’ personality</td>
<td>(a) Interest in teaching</td>
</tr>
<tr>
<td></td>
<td>(b) Knowledge for mathematics teaching</td>
</tr>
<tr>
<td></td>
<td>(c) Resistance to change</td>
</tr>
<tr>
<td></td>
<td>(d) Identity</td>
</tr>
<tr>
<td>Institution</td>
<td>(a) Support</td>
</tr>
<tr>
<td></td>
<td>(b) Expectation</td>
</tr>
<tr>
<td></td>
<td>(c) Colleagues’ experiences</td>
</tr>
<tr>
<td>Research interest</td>
<td>No subfactors</td>
</tr>
<tr>
<td>Age</td>
<td>No subfactors</td>
</tr>
<tr>
<td>Instructors’ background</td>
<td>(a) Education background</td>
</tr>
<tr>
<td></td>
<td>(b) Teaching background</td>
</tr>
<tr>
<td></td>
<td>(c) Cultural</td>
</tr>
</tbody>
</table>
Figure 4: Expanded model of factors that influence attitude about software use.
**Expanded Research Questions**

The two main research questions stated in Chapter 1 (p. 28) were not changed.

These are as follows:

1. What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

2. What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?

The supplementary questions, however, were expanded based on the results of Phase 1. These questions addressed the factors that likely influence a mathematician’s attitude regarding software use and that should be investigated quantitatively in Phase 3. These are as follows:

S1. From academic mathematicians’ point of view, to what extent do students’ major and students’ level influence the decision to use software in classrooms?

S2. From academic mathematicians’ point of view, is the course content a factor that influences the use of software in undergraduate classrooms?

S3. From academic mathematicians’ points of view, and if answering “yes” to S2, for which kind of courses is software use beneficial to students?

S4. Are academic mathematicians’ points of view regarding the effect of the course being taught independent of their attitudes regarding software use?

S5. Do software characteristics correlate and predict a professors’ attitude to use software when teaching?
S6. To what extent does a professor’s perceived effect of software correlate with and predict attitude regarding software use?

S7. To what extent does an academic mathematician’s personality correlate with and predict attitude regarding the use of software when teaching?

S8. To what extent do the environment and support of an institution correlate with and predict attitude regarding the use of software when teaching?

S9. Do areas of research interest explain academic mathematicians’ attitudes toward software use in undergraduate classrooms?

S10. Does instructor’s age explain attitude regarding software use?

S11. Do cultural background, educational background, and teaching background influence academic mathematicians’ attitudes toward software use when teaching mathematics?

**Bias and Trustworthiness**

Collecting and interpreting qualitative research introduces the threat of bias. As explained in Chapter 4, the researcher pursued every effort to avoid showing any bias during the interviews. To address the credibility of the data collected, the researcher implemented several procedures. First, the researcher checked all quotations at least twice for accuracy using the original tape recording. The researcher did an additional check of the quotes used in the final comprehensive chart. Nastasi and Schensul (2005) indicated that member-check is one technique to address trustworthiness in qualitative research. When the data from each participant was compiled and interpreted, the researcher sent an e-mail message to each participant, which included the transcription of
the data related to the participant’s interview and a brief interpretation of it. Each participant was asked to provide feedback on the main themes identified from the transcript, the quotes used to support them, and the interpretation of the quotes. This member-check procedure supported the credibility of the data (Glesne & Peshkin, 1992). In addition, the researcher shared the comprehensive chart with two mathematics education colleagues. This peer-debriefing approach aimed to support the credibility of the interpretation of the results and to address the subjectivity issue. Moreover, at the end of Phase 3, the researcher triangulated the reviewed literature, the interview data, and the survey data. The triangulation process will be discussed in Chapter 8.

**Summary**

This chapter presented the results of Phase 1. The researcher reported on the process of data analysis followed by the results of the interview data. Specifically, this chapter reported on the 8 factors and the 16 subfactors that were suggested as influential on attitude. These factors and subfactors were, then, used to transform the initial model (Figure 3, p. 81) to the expanded model (Figure 4, p. 126). The following chapter summarizes the results of Phase 2, which includes developing, piloting, and revising a survey instrument.
Chapter 6: Survey Development and Pilot Study

This study collected data through three phases. In particular, Phase 2 was the survey instrument development and the piloting phase. The results of the interview data transformed the initial model (Figure 3, p. 81) into the expanded model (Figure 4, p. 126), as explained in Chapter 5. Figure 4 served as a practical tool for the instrument development; the instrument constitutes variables and scales to measure attitude and each of the 8 factors and 16 subfactors presented in the figure.

Developing the Instrument

The response variable. The researcher adapted the Attitude Instrument for Mathematics and Applied Technology (AIM-AT) to measure attitude regarding software use in classrooms (the response variable). The AIM-AT consists of 23 Likert scale items:

1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree

Chapter 4 presented a brief history of the AIM-AT instrument, which has established its reliability. Fleener (1995) adapted the instrument that was used by Huang (1993) and used it to measure attitude regarding the use of calculators in mathematics classrooms. This study adjusted Fleener’s instrument to measure attitude toward software use, not only calculators. A copy of the original AIM-AT and the modified draft are provided in Appendices D and E respectively. The mean of a participant’s responses to the 23 items was regarded as the score that represented a participant’s attitude. The maximum available score is 4 and the minimum score is 1. A score greater than 2.5 was regarded as a positive attitude, and a score less than the nteral score of 2.5 was regarded as a negative attitude.
**Explanatory variables.** The results of the interview data suggested that there are 8 factors and 16 subfactors that might influence a professor’s attitude regarding software use (see Table 6). These factors were called explanatory variables. Using the subfactors, the researcher constructed the items that constitute each factor.

1. **The course being taught.** The survey instrument constitutes six items that reflected the effect of the course being taught factor and its three subfactors: (a) course content, (b) students’ major, and (c) students’ level. Two items reflected what the respondents believe about the effect of the course content; two items represented the effect of students’ major, and two items represented the effect of students’ level. Four of these items were inclusive response items, in which a participant could select more than one choice. Selecting a choice represented “yes” to the item and was given the value of “1” and not selecting the choice represented “no” and was given the value of “0.” The remaining two items were Likert scale items:

   1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree

2. **Software characteristics.** Five different items from the AIM-AT instrument were part of a scale that measures the software characteristics factor. Based on the subfactors in Figure 4, two more items were added, resulting in a total of seven items in the software scale. These seven items represent three subfactors: (a) software knowledge, (b) simplicity and ease of use, and (c) software availability. The average of these items was used to reflect the score of the software factor. Participants responded on a Likert scale:

   1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree
3. **Perceived effect on students’ learning.** The researcher used eight items from the AIM-AT instrument to represent a scale that measured the perceived effect factor. These items are statements that indicate the negative and positive effect of software on students’ learning. The average of these items was used as the score of the scale that represents the perceived effect factor. Participants responded on a Likert scale:

   1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree

4. **Instructor’s personality.** The interviewees indicated that subfactors of a professor’s personality influence attitude regarding software use, such as (a) knowledge about mathematics teaching, (b) interest in teaching, (c) resistance to change, and (d) the way a professor identifies himself as a researcher in mathematics versus a teacher of mathematics (identity). Therefore, the instrument contained five items to reflect an instructor’s personality with regard to knowledge, interest in teaching, and resistance to change. Participants responded on a Likert scale:

   1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree

The researcher added one item to gather information about a participant’s identity. The average of these items was used as a score that represents the personality factor.

5. **The institution.** The results of the interview data indicated that several subfactors of the institution, such as (a) support, (b) expectation, and (c) colleagues’ experiences, influence a mathematician’s attitude with regard to software use. Hence, the researcher created six items to reflect the scale that represents these subfactors. All items, but one, were rated on a Likert scale:

   1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.
In the last item, participants had to choose the best percentage that represents the use of software among their colleagues. The researcher used the average of these items as a score to represent this factor.

6. Research interest. One inclusive response item in the survey represented different areas of research interest. The respondents were allowed to choose one or more areas of research that were among their interests. Choosing an area represented “yes” and was given the value of “1”, while not choosing an area represented “no” and was given the value of “0.”

7. Age. The author added one item that asked the participants to choose the best interval that represents their age.

8. Instructor’s background. Five items reflected the background factor with regard to (a) culture, (b) past education, and (c) teaching experience. One item inquired about the length of a respondent’s educational experience in the U.S. to collect data about participants’ “educational background with regard to culture.” A second item collected data about participants’ “educational background with regard to software use.” This item was structured as a Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The author added a third item to inquire about the length of a participant’s teaching experience in the U.S. to collect data about participants’ “teaching background with regard to culture.” The fourth item assessed participants’ culture (race) by asking them to select one of eight choices of different cultures. The fifth item asked the participants to indicate their length of teaching experience by choosing among five different intervals. Finally, one item already existing in the AIM-AT scale was used to
reflect the teaching experience with regard to software use, and was called “teaching experience with regard to software use.” It was structured as a Likert scale:

1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree

Hence, there were six items that represented this factor. The instructor’s educational and cultural background factor will be called the background factor for the remainder of this document.

**Piloting the Instrument**

Upon writing the items, the researcher first piloted it electronically using the think-aloud approach with 2 colleagues; 1 was a PhD candidate in mathematics education, and 1 was a PhD candidate in mechanical engineering. The survey universal resource locator (URL) was sent to the 2 colleagues through e-mail messages. With the researcher’s presence, they were asked to reply to the survey and to loudly verbalize their thinking when responding to the items. The researcher took notes of their reflections and comments. Their comments and suggestions were discussed with two of the dissertation committee members. An example of such comments was not to use agreement-level choices with some items in the personality scale (e.g., I read about topics in mathematics education), but rather use frequency-level choices (i.e., 4 = often, 3 = sometimes, 2 = rarely, 1 = never). In addition, the researcher shared the items that constituted the course being taught factor and the item about the research interest factor with a committee member, who is an expert in mathematics courses at the undergraduate level, given his long teaching experience at undergraduate mathematics departments.
The total number of items in the instrument was 50 (Appendix K, Table K1). The researcher added four items to ensure that the data in the pilot stage were collected from mathematics faculty or PhD students only, as shown in Appendix K (Table K2).

**Analysis and Results of the Pilot Study**

There were two main goals of the pilot study: first, to increase clarity, simplicity, and flow of the items; second, to establish the reliability of the instrument. The researcher distributed the instrument to a total of 78 faculty members and graduate students at the Department of Mathematics at Ohio University and its regional campuses, as explained in Chapter 4. By November 1, 2011, a total of 37 responses were received: 20 tenured or tenure-track (TTT) professors, 6 non-TTT, 1 mathematics educator, and 10 PhD students. The respondents were not all from the target population. However, these responses were used to satisfy the first goal of the pilot study. Non-TTT professors, mathematics educators, and PhD students were suitable for the pilot stage because they know enough about the topic to provide their feedback about the appropriateness of the items. The respondents gave valuable comments that supported the first goal of the pilot study. One of the comments was to add the choice “I do not know” to all items in the institution scale. All comments and suggestions were taken into consideration.

The author, then, used the 20 responses from TTT faculty members to test the reliability of the five different scales in the instrument. The results were downloaded to an SPSS file. The 4-point attitude items were coded automatically as follows:

1 = strongly agree, 2 = agree, 3 = disagree, and 4 = strongly disagree
The researcher recoded the positively worded items so that 4 = strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree. Using SPSS, the internal reliability values (α) for the continuous variables were calculated:

- Attitude: α = .903 (23 items);
- Perceived effect: α = .869 (8 items);
- Institution: α = .594 (6 items)
- Software characteristics: α = .662 (7 items);
- Personality: α = .542 (6 items).

**Revising the Instrument**

According to Litwin (1995), only internal reliability of at least .7 is acceptable. The researcher first consulted two of the dissertation committee members, and based on their recommendations and the above results, the instrument was edited as follows:

**Perceived effect scale.** The perceived effect scale consists of eight items with internal reliability .869. The item-total statistics table showed that all items have reasonably strong corrected item-total correlation. Hence, the full study included these eight items. The mean score of all eight items was used as the score that represented the perceived effect factor.

**Institution scale.** The institution scale consisted of six items with internal reliability .594 (Appendix L, Table L1). The corrected item-total statistics table showed that the item “the technical support service at my institution is poor” was correlated negatively with the other items. When this item was removed, the internal reliability achieved was .855 (Appendix L, Table L2). So, the researcher decided to delete this item
from the institution scale and only use the remaining five items. This item was considered as part of the attitude scale and more analysis was done before deleting it completely, as explained below.

**Software scale.** This scale had seven items with internal reliability .662 (Appendix L, Table L3). The corrected item-total correlation showed that two items, “mathematical software is generally easy to use” and “mathematical software that is available at my institution is not user friendly,” had low negative correlations with the other items in the scale (Appendix L, Table L4). When the first item was removed, the reliability was .729, and when both items were removed, the achieved reliability was up to .802 (Appendix L, Table L5). Before deciding to remove the items, the researcher calculated the reliability of the attitude scale including these two items and the item “the technical support service at my institution is poor” that was negatively correlated in the institution scale. The reliability of the 26-item attitude scale was .869. Although, this result was less than the reliability of the original 23-item scale, it was acceptable. However, all three additional items had low, negative item-total correlation. Accordingly, the researcher decided to delete all three items permanently.

**Instructor’s personality scale.** This scale had six items with internal reliability .542 (Appendix L, Table L6). The corrected item-total correlation table indicated that the items “I try to improve my teaching” and “I read about topics in mathematics education” had low item-total correlations with the other items. When the first item was removed, the reliability increased, but only up to .581 (Appendix L, Table L7). The researcher examined these two items in depth to find that all 36 respondents either agreed or
strongly agreed with them. Hence, the decision was to reword some of the items and to add two more items to this scale. Tables 7 and 8 below summarize this process.

Table 7

*Items Reworded in the Personality Scale*

<table>
<thead>
<tr>
<th>Original Item</th>
<th>Reworded Edited Item</th>
<th>Comment(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I read topics in mathematics education</td>
<td>I read expository articles in mathematics education</td>
<td>The stem was reworded and the choices were quantified.</td>
</tr>
<tr>
<td>(A) Often</td>
<td>(A) at least once a week.</td>
<td></td>
</tr>
<tr>
<td>(B) Sometimes</td>
<td>(B) at least once a month.</td>
<td></td>
</tr>
<tr>
<td>(C) Rarely</td>
<td>(C) several times a year</td>
<td></td>
</tr>
<tr>
<td>(D) Never</td>
<td>(D) once a year.</td>
<td></td>
</tr>
<tr>
<td>(E) less than once a year.</td>
<td>(E) Never</td>
<td></td>
</tr>
<tr>
<td>My teaching style is traditional.</td>
<td>My teaching style does not lend itself to using mathematical software.</td>
<td>The stem was reworded.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>The statement that best describes me is:</td>
<td>The statement that best describes me is:</td>
<td>The stem was not changed, but the choices were modified.</td>
</tr>
<tr>
<td>(A) I am a mathematics teacher.</td>
<td>(A) I am primarily a mathematics researcher.</td>
<td></td>
</tr>
<tr>
<td>(B) I am a mathematics researcher.</td>
<td>(B) I am a primarily a teacher of mathematics.</td>
<td></td>
</tr>
<tr>
<td>(C) I am both a mathematics teacher and a mathematics researcher.</td>
<td>(C) Neither of the above.</td>
<td></td>
</tr>
<tr>
<td>(D) Neither of the above.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I try to improve my teaching.</td>
<td>I discuss my teaching strategies with my colleagues</td>
<td>The stem was reworded, and the choices were quantified.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) at least once a week.</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) at least once a month.</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) several times a year.</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) once a year.</td>
<td></td>
</tr>
<tr>
<td>(E) less than once a year.</td>
<td>(E) Never</td>
<td></td>
</tr>
</tbody>
</table>
Table 8

*Items Added or Unchanged in the Personality Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>Comment(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I read research articles in mathematics education</td>
<td>This item was added.</td>
</tr>
<tr>
<td>(A) at least once a week.</td>
<td></td>
</tr>
<tr>
<td>(B) several times a year.</td>
<td></td>
</tr>
<tr>
<td>(C) less than once a year.</td>
<td></td>
</tr>
<tr>
<td>(D) at least once a month.</td>
<td></td>
</tr>
<tr>
<td>(E) once a year.</td>
<td></td>
</tr>
<tr>
<td>(F) Never</td>
<td></td>
</tr>
<tr>
<td>I attend conference presentations that discuss mathematics education</td>
<td>This item was added.</td>
</tr>
<tr>
<td>education topics</td>
<td></td>
</tr>
<tr>
<td>(A) more than once a year.</td>
<td></td>
</tr>
<tr>
<td>(B) once a year.</td>
<td></td>
</tr>
<tr>
<td>(C) once every several years.</td>
<td></td>
</tr>
<tr>
<td>(D) Rarely</td>
<td></td>
</tr>
<tr>
<td>(E) Never</td>
<td></td>
</tr>
<tr>
<td>We teach the way we were taught.</td>
<td>This item was not changed.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>In my personal life, I tend to be among the first people to use</td>
<td>This item was not changed.</td>
</tr>
<tr>
<td>new technologies.</td>
<td></td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
</tbody>
</table>

**Recommendations and suggestions.** In addition to the above changes to the personality scale items, and based on the comments and recommendations given by the pilot study participants, the researcher made a few changes to some of the other items. Only the items that have been changed are summarized in Table 9 and 10.
Table 9

*Items Changed in the Institution Scale*

<table>
<thead>
<tr>
<th>The Original Item</th>
<th>The Edited Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>My department’s chair advocates the use of mathematical software when teaching.</td>
<td>My department’s chair advocates the use of mathematical software when teaching.</td>
<td>The choice “I do not know” was added.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>(E) I do not know</td>
<td>(E) I do not know</td>
<td></td>
</tr>
<tr>
<td>The technical support service at my institution is poor.</td>
<td>The technical support service at my institution is poor.</td>
<td>The choice “I do not know” was added.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>(E) I do not know</td>
<td>(E) I do not know</td>
<td></td>
</tr>
<tr>
<td>The general trend in the department is NOT to use mathematical software when teaching.</td>
<td>The general trend in the department is NOT to use mathematical software when teaching.</td>
<td>The choice “I do not know” was added.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>(E) I do not know</td>
<td>(E) I do not know</td>
<td></td>
</tr>
<tr>
<td>Most of my colleagues DO NOT use mathematical software in classrooms.</td>
<td>Most of my colleagues DO NOT use mathematical software in classrooms.</td>
<td>The choice “I do not know” was added.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>(E) I do not know</td>
<td>(E) I do not know</td>
<td></td>
</tr>
<tr>
<td>My department expects faculty to use mathematical software when teaching.</td>
<td>My department expects faculty to use mathematical software when teaching.</td>
<td>The choice “I do not know” was added.</td>
</tr>
<tr>
<td>(A) Strongly Agree</td>
<td>(A) Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>(B) Agree</td>
<td>(B) Agree</td>
<td></td>
</tr>
<tr>
<td>(C) Disagree</td>
<td>(C) Disagree</td>
<td></td>
</tr>
<tr>
<td>(D) Strongly Disagree</td>
<td>(D) Strongly Disagree</td>
<td></td>
</tr>
<tr>
<td>(E) I do not know</td>
<td>(E) I do not know</td>
<td></td>
</tr>
</tbody>
</table>
Table 10

*Items Changed in the Instrument Excluding the Institution and Personality Scales*

<table>
<thead>
<tr>
<th>The Original Item</th>
<th>The Edited Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>My research interest is</td>
<td>Which of the following best describes your primary area of research?</td>
<td>Choices (D), (E), (F), and (H) were added.</td>
</tr>
<tr>
<td>(A) Algebra</td>
<td>(A) Algebra</td>
<td></td>
</tr>
<tr>
<td>(B) Analysis</td>
<td>(B) Analysis</td>
<td></td>
</tr>
<tr>
<td>(C) Applied Mathematics</td>
<td>(C) Applied mathematics</td>
<td></td>
</tr>
<tr>
<td>(D) Differential Equations</td>
<td>(D) Combinatorics</td>
<td></td>
</tr>
<tr>
<td>(E) Dynamical Systems</td>
<td>(E) Differential equations</td>
<td></td>
</tr>
<tr>
<td>(F) Geometry</td>
<td>(F) Discrete Mathematics</td>
<td></td>
</tr>
<tr>
<td>(G) Mathematics Education</td>
<td>(G) Geometry</td>
<td></td>
</tr>
<tr>
<td>(H) Statistics</td>
<td>(H) Logic</td>
<td></td>
</tr>
<tr>
<td>(I) Topology</td>
<td>(I) Mathematics Education</td>
<td></td>
</tr>
<tr>
<td>(J) Other</td>
<td>(J) Statistics</td>
<td></td>
</tr>
<tr>
<td>(K) Topology</td>
<td>(K) Topology</td>
<td></td>
</tr>
<tr>
<td>(L) Other</td>
<td>(L) Other</td>
<td></td>
</tr>
</tbody>
</table>

Which of the following best describes your cultural background?
(A) African American, Black
(B) American Indian, Alaska Native
(C) Asian, Asian American
(D) Hispanic, Latino
(E) Middle Eastern
(F) Native Hawaiian, Pacific Islander
(G) White, Caucasian
(H) Other

**Summary of the edited survey.** The survey that was used in the full study consisted of 49 items. These 49 items represented the response variable (the attitude score), four continuous variables (perceived effect, software characteristics, personality, and institution), and four non-continuous variables (background, the course being taught, research interest, and age). However, the researcher added five more items: one item required the respondent’s department name for compensation purposes, and four items
 ensured that the respondents were from the population of interest, as shown in Appendix M (Tables M1 and M2). Table 11 gives the number of items for each factor.

**Table 11**

*Number of Items for Each Factor in the Instrument Used in the Full Study*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Number of Items in Each Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude scale (AIM-AT)</td>
<td>23 items</td>
</tr>
<tr>
<td>Course being taught</td>
<td>6 items</td>
</tr>
<tr>
<td>Software characteristics</td>
<td>5-item scale</td>
</tr>
<tr>
<td>Perceived effect</td>
<td>8-item scale</td>
</tr>
<tr>
<td>Instructor’s personality</td>
<td>8-item scale</td>
</tr>
<tr>
<td>The institution</td>
<td>5-item scale</td>
</tr>
<tr>
<td>Research interest</td>
<td>1 item</td>
</tr>
<tr>
<td>Age</td>
<td>1 item</td>
</tr>
<tr>
<td>Instructor’s background</td>
<td>6 items</td>
</tr>
</tbody>
</table>

**Summary**

This chapter presented the process of developing the instrument, results and analysis of the pilot study, and the procedure used to edit the instrument. The modified instrument was used in the full study. This chapter, first, reported on how the researcher used Figure 4 to develop the initial survey instrument, which was, then, used in the pilot study. The results and the analysis of the pilot study were reported next. Finally, the chapter reported on the process that followed the analysis of the pilot study results to edit the survey items before using them in the full study.
Chapter 7: Survey Results

This dissertation investigated academic mathematicians’ dispositions with regard to software use in undergraduate instruction and the factors that influence these dispositions. This study collected data through open-ended interviews in Phase 1, Internet-based questionnaire for the pilot study in Phase 2, and Internet-based questionnaire for the full study in Phase 3. As explained in Chapter 4, Phase 3 aimed to measure mathematicians’ attitudes regarding software use in teaching and to examine possible predictors that underlie their attitudes. This chapter reports on the results and analyses of Phase 3. The statistical tests reported in this chapter addressed the main research questions (p. 28), and the expanded supplementary questions (S1–S11, pp. 127–128). Due to the exploratory nature of this study and to the number of tests in this phase, results likely are complicated by elevated Type I error (Warner, 2008). Hence, statistical significance should not be over-interpreted to suggest a confirmatory approach.

The targeted population for this phase consisted of persons who had earned doctoral degrees in mathematics and who are tenured or tenure-track (TTT) full-time faculty members in PhD-granting mathematics departments in the United States. The researcher sent the survey URL, along with the e-mail invitational message, to 1,766 professors of mathematics at the randomly selected 50 PhD-granting departments, as explained in Chapter 4. Out of the 50 departments, responses were received from 49 departments ranging from a minimum of one response to a maximum of seven responses per department. Out of the 1,766 e-mail messages, eight were returned as undeliverable, and two automatic replies indicated that the receivers were out of reach. So, the e-mail
message was delivered successfully to 1,756 professors. Out of the 1,756 messages, thirteen respondents replied indicating that they were not interested. Two emeritus professors, one mechanical engineering professor, and five non-TTT mathematics professors replied indicating their apology for not participating because they did not fulfill the criteria of participation. In addition, three e-mail messages were received from participants who indicated that they have completed the survey but they wanted to state their open-ended opinions. These e-mail messages contained the participants’ detailed attitudes about software use in classrooms. They also commented on the survey items. The author replied to these open-ended opinions with e-mail messages of acknowledgement and appreciation.

In all, 220 recipients started the survey, and 200 of those completed and submitted it, which accounted for a response rate of 11.39%. Among these 200 cases, 11 cases were deleted because the participants were not TTT professors, 2 cases were deleted because the participants were professors of statistics who were teaching statistics courses only, and 4 cases were deleted because the participants were mathematics educators. Data analyses were performed on the remaining 183 cases.

**Coding and Computing Details**

The instrument used in the full study consisted of 54 items. One item gathered information about the departments for compensation purposes and four items were used to ensure that the respondents were from the population of interest. The remaining 49 items represented the response variable and the eight explanatory variables, as shown in Table 11 and Appendix M. The researcher recoded the data as necessary to handle
positively worded items and computed five new variables to represent the attitude score, the perceived effect factor, the software factor, the personality factor, and the institution factor. The new variables were the mean of the scores of the items that constitute the scale that represents the intended construct of interest, as explained in Chapter 6.

**Preliminary Data Screening**

The first step of the analysis was to perform preliminary data screening to test the normality assumption of the response variable (the attitude score). Table 12 gives the descriptive statistics of the response variable. Using the skewness and kurtosis values in Table 12, Field’s (2009) recommendation of using 2.58 as the cut off score for standardized skewness and kurtosis scores, and the histogram in Figure 5 yielded no concerns for the normality assumption. The box plot in Figure 6 indicated that there were few outliers. These outliers were taken into consideration and will be discussed later in the chapter.

Table 12

*Descriptive Statistics of the Response Variable*

<table>
<thead>
<tr>
<th>Mean Statistic</th>
<th>Standard Deviation</th>
<th>Skewness Statistic</th>
<th>Skewness Std. Error</th>
<th>Kurtosis Statistic</th>
<th>Kurtosis Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.66</td>
<td>.382</td>
<td>.432</td>
<td>.180</td>
<td>.776</td>
<td>.357</td>
</tr>
</tbody>
</table>

Then, the scatter plots of each explanatory continuous variable with the response variable demonstrated any bivariate outliers of any concern and displayed the linearity of the relationship between the response variable and each continuous explanatory variable. Figures 7–10 represent the scatter plot between the attitude variable and the personality
variable, the institution variable, the software variable, and the perceived effect variable respectively. These figures showed the relationships between the response variable and the explanatory variables. There were no extreme outliers of any concern, but the linear relationship between the attitude variable and the institution variable (Figure 8) appeared to be relatively weak. The box plots of the four explanatory continuous variables reported on any univariate outliers of concern. Figures 11–14 represent the box plots of the personality variable, the institution variable, the software variable, and the perceived effect variable respectively. The figures indicated a few outliers in the perceived effect variable only (Figure 14). These outliers were taken into consideration and will be discussed later in the chapter.

There were 50 departments involved in this phase. For the most part, there were only one or two responses from each department. Only in limited cases, there were up to seven responses from a single department. This is potentially important because some respondents hailed from the same university, suggesting their scores may not be independent. However, TTT faculty are expected to make independent curricular decisions under the premise of academic freedom and the expectation that they are experts who know best how to teach their material to their students. For this reason, it is arguable that having a common employer should not violate the independent assumption. Although it is possible that mathematics professors are influenced by what their colleagues’ think about software use, they have their own perceptions and beliefs. Furthermore, respondents were expected to have individual access to e-mail and a PC. Because the survey was distributed electronically and to each participant independently
from others, it is likely they responded to the survey on an independent basis. In addition, the researcher requested the Durbin-Watson test to examine the independence assumption. According to Field (2009), the value of the test should be between 1 and 3. The result for the original data set in the model summary table was 1.955. This result and the logical nature of the study suggested that violation to the independence assumption is of limited concern.

Figure 5: Histogram of attitude.

Figure 6: Box plot of attitude.
**Figure 7:** Scatter plot of attitude and personality.

**Figure 8:** Scatter plot of attitude and institution.
Figure 9: Scatter plot of attitude and software characteristics.

Figure 10: Scatter plot of the attitude and perceived effect.
Figure 11: Box plot of the personality factor.

Figure 12: Box plot of the institution factor.
Figure 13: Box plot of the software characteristics factor.

Figure 14: Box plot of the perceived effect factor.

Internal Reliability

The second step in the analyses process was to test the internal reliability of the five continuous variables. Table 13 below summarizes and compares the results of
Cronbach’s alpha in the pilot study and in the full study. There has been a general improvement in the internal reliability of all scales, except the perceived effect scale. However, the reliability of the perceived effect scale is still greater than .7.²

Table 13

*Comparison of Cronbach’s Alpha in the Pilot Study and the Full Study*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Pilot study</th>
<th>Full study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cronbach’s Alpha</td>
<td>Number of items</td>
</tr>
<tr>
<td>Attitude</td>
<td>.903</td>
<td>23</td>
</tr>
<tr>
<td>Software characteristics</td>
<td>.662</td>
<td>7</td>
</tr>
<tr>
<td>Perceived effect</td>
<td>.869</td>
<td>8</td>
</tr>
<tr>
<td>Personality</td>
<td>.542</td>
<td>6</td>
</tr>
<tr>
<td>Institution</td>
<td>.594</td>
<td>6</td>
</tr>
</tbody>
</table>

*Descriptive Statistics of the Attitude Scale*

To address Research Question 1 (what are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?), the researcher examined the descriptive statistics of the attitude variable in Table 12 and the histogram in Figure 5. The mean score was 2.66 out of a maximum possible score of 4. The attitude scale consists of 23 items; each can be given the value of 4, 3, 2, and 1 (for strongly

² Chapter 6 reported on the editing process to the initial instrument.
agree, agree, disagree, strongly disagree). Scores greater than 2.5 represented positive attitude and those less than the neutral score of 2.5 were considered negative. Hence, the mean score of the sample represented a slightly positive attitude. In addition, the frequency of responses indicated that 63.9% of the respondents had a mean score greater than 2.5, and only 12.0% had a high positive score greater than 3.0.

Then, frequencies and descriptive statistics of all items in the attitude scale provided a critical examination of the respondents’ perceptions and beliefs. The consensuses of agreement or disagreement for some items were up to 80%. For example, 83.1% disagreed or strongly disagreed with the item “mathematical software is a tool only for solving the problems more quickly” and 90.2% disagreed or strongly disagreed with the item “mathematical software should be used only to check work once the problem has been worked out on paper.” This consensus suggested that the participant saw some value in the use of software. In addition, 81.9% agreed or strongly agreed with the item “more interesting problems can be done when students have access to mathematical software,” which indicates that the participants believed that mathematics teaching could be improved when software is used. On the other hand, up to 49.7% agreed or strongly agreed with the item “in general, the use of mathematical software will cause students to lose basic computational skills,” and up to 65.7% agreed or strongly agreed with the item “students understand mathematics better if they solve problems using paper and pencil.” This means that about half of the participants were concerned about the possible harm caused by software use on student learning and preferred the traditional approach. Moreover, 86.9% agreed or strongly agreed with the item “most of
my students have access to mathematical software,” and 73.8% indicated that they know ways to use software effectively in teaching; yet, only 56.3% agreed or strongly agreed with the item “all students should learn to use mathematical software,” and 53.1% reported not using software in their past teaching. This suggests that although participants had access to software and knew how to use it, they elected not to use it.

Exploring the Course Being Taught Factor Using Descriptive Statistics

To answer S1 (from academic mathematicians’ point of view, to what extent do students’ major and students’ level influence decision to use software in classrooms?), the researcher explored the frequencies of the items that investigated the effect of students’ major and level, as summarized in Table 14. Table 14 indicated that most participants believed that students’ major is not a factor that influences them, with 80% and 71.6% of the responses disagreeing or strongly disagreeing with the item “my decision to use software depends on students’ majors” and the item “mathematical software could be used when teaching all majors,” respectively. In addition, there was consensus with regard to the items that indicated that software use should be avoided at a certain level (e.g., Freshmen) or that the use of software was associated with introductory level, advanced level, or calculus-level courses, with up to 98.9% disagreeing with these statements. Moreover, 84.7% agreed that software might be taught to all levels. Such consensus suggests that the respondents did not regard students level as a factor.
Table 14

Consensus of Items Represented the Effect of Students’ Major or Level

<table>
<thead>
<tr>
<th>The Item</th>
<th>Attitude</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>My decision to use software depends on students’ majors.</td>
<td>Disagree</td>
<td>80.0</td>
</tr>
<tr>
<td>Mathematical software could be used when teaching all majors</td>
<td>Agree</td>
<td>71.6</td>
</tr>
<tr>
<td>Software should not be taught to Freshmen.</td>
<td>Disagree</td>
<td>89.1</td>
</tr>
<tr>
<td>Software should not be taught to Sophomore.</td>
<td>Disagree</td>
<td>93.4</td>
</tr>
<tr>
<td>Software should not be taught to Juniors.</td>
<td>Disagree</td>
<td>98.4</td>
</tr>
<tr>
<td>Software should not be taught to Seniors.</td>
<td>Disagree</td>
<td>98.9</td>
</tr>
<tr>
<td>Software should not be used when teaching introductory level courses.</td>
<td>Disagree</td>
<td>85.5</td>
</tr>
<tr>
<td>Software should not be used when teaching calculus level courses.</td>
<td>Disagree</td>
<td>90.2</td>
</tr>
<tr>
<td>Software should not be used when teaching advanced level courses.</td>
<td>Disagree</td>
<td>97.8</td>
</tr>
<tr>
<td>Software might be taught to all level.</td>
<td>Agree</td>
<td>84.7</td>
</tr>
</tbody>
</table>

To answer S2 (from academic mathematicians’ point of view, is the course content a factor that influences the use of software in undergraduate classrooms?), the researcher examined the frequencies of items that explored the content effect, as summarized in Table 15. Table 15 shows an almost 90% agreement with regard to the item “the content of the course I am teaching influences my decision to use or not use software” and 60.1% disagreement with the item “mathematical software could be used when teaching any course.” These percentages indicate that the participating mathematicians consider course content when they think about software use in their classrooms.
Table 15

*Consensuses of Items Represented Course Content Effect*

<table>
<thead>
<tr>
<th>Item</th>
<th>Attitude</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>The content of the course I am teaching influences my decision to use or not use software.</td>
<td>Agree</td>
<td>89.6</td>
</tr>
<tr>
<td>Mathematical software could be used when teaching any course.</td>
<td>Disagree</td>
<td>60.1</td>
</tr>
</tbody>
</table>

To answer S3 (from academic mathematicians’ point of view, and if answering “yes” to S2, for which kind of courses is software use beneficial to students?), the data were first split with regard to the item “mathematical software could be used when teaching any course.” The following statistics was performed only on the 60.1% (N = 110) who disagreed with this item. Among them, large percentages indicated that software could not be used when teaching certain courses. For example, 89.1% indicated that software could not be used when teaching logic. Table 16 summarizes these results. On the other hand, 87.3% indicated that software could be used when teaching applied mathematics, 85.5% indicated that it could be used when teaching numerical analysis, and 55.2% indicated that software could be used when teaching calculus.

**Missing Data**

In recent years, researchers started to reconsider missing data and reevaluate the approaches used to handle it (Enders, 2010). Enders recommended using the multiple imputation (MI) approach, unless the percentage of missing data is less than 5.0%. Only in that case, traditional methods, such as listwise deletion, could be used. Missing data analyses on the data indicated that missing data percentages ranged from 0.5% to 9.3%,
with only three items with missing data percentages greater than 5.0%. Tables 17–23 summarize the items with missing data.

Table 16

*Consensus of Items Investigated Software Use in Certain Courses*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Percentage of disagreement that software could be used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real analysis</td>
<td>85.5</td>
</tr>
<tr>
<td>Logic</td>
<td>89.1</td>
</tr>
<tr>
<td>Theorem-proving course</td>
<td>89.1</td>
</tr>
<tr>
<td>Abstract algebra</td>
<td>68.2</td>
</tr>
<tr>
<td>College algebra</td>
<td>62.7</td>
</tr>
</tbody>
</table>

The percentage of missing data on any particular item rarely exceeded 5% but when using the listwise deletion method, the pattern of missing responses reduced the effective sample size to 149. Hence, the researcher used the MI option offered in SPSS Statistical Premium GradPack to deal with missing data.

3 Tables 17–23 include only items that have missing data.
Table 17

*Items With Missing Data in the Institution Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>Valid</th>
<th>Missing</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>In my department, the percentages of faculty members who advocate software use is</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>My department chair advocates the use of software when teaching.</td>
<td>180</td>
<td>3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 18

*Items With Missing Data in the Personality Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>Valid</th>
<th>Missing</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>My teaching style does not lend itself to using mathematical software.</td>
<td>180</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Mathematics researcher or a teacher of mathematics.</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>In my personal life, I tend to be among the first people to use new technologies.</td>
<td>182</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>In general, we teach the way we were taught.</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
</tbody>
</table>

First, all items were examined to explore the pattern of missing data. Using Little’s Missing Completely At Random (MCAR) test for each variable suggested that the null hypothesis could not be rejected. Therefore, data might have been MCAR, \( p = .079 \). With that being said, Little’s test has low power, and hence there is a higher potential of a Type II error. Even when Little’s test supports the rejection of the null
hypothesis that the data is MCAR, it does not identify the variable that violates MCAR (Enders, 2010). Hence, even with this result of the test, it is probably safer to assume Missing At Random (MAR).

Table 19

*Items With Missing Data in the Background Factor*

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the following best describes your cultural background?</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>I have been teaching at US institutions for</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>As a teacher of mathematics, I used mathematical software.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>As a student, I used mathematical software.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 20

*Items With Missing Data in the Software Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical software is available for my class(es) to use.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>I know ways I can use mathematical software effectively in teaching.</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>Most of my students have access to mathematical software.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>I have lots of ideas about how to teach using mathematical software.</td>
<td>180</td>
<td>3</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Table 21

*Items With Missing Data in the Course Being Taught Factor*

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>Missing</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>My decision to use or not to use mathematical software depends on students’ majors.</td>
<td>180</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>The content of the course I am teaching influences my decision to use or not to use mathematical software.</td>
<td>182</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 22

*Items With Missing Data in the Perceived Effect Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>Missing</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical software is a tool only for solving problems more quickly.</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>In general, mathematical software use will cause students to loss basic computational skills.</td>
<td>177</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>Students understand mathematics better if they solve problems using paper and pencil.</td>
<td>175</td>
<td>8</td>
<td>4.4</td>
</tr>
<tr>
<td>In general, mathematical software use causes a decline in computational skills.</td>
<td>177</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>In general, the use of mathematical software causes a decrease in students’ estimation skills.</td>
<td>174</td>
<td>9</td>
<td>4.9</td>
</tr>
<tr>
<td>In general, using mathematical software makes students better problem solvers.</td>
<td>176</td>
<td>7</td>
<td>3.8</td>
</tr>
<tr>
<td>More interesting mathematical problems can be done when students have access to mathematical software.</td>
<td>181</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>Mathematics is easier for students if mathematical software is used to solve problems.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Table 23

Remaining Items With Missing Data in the AIM-AT

<table>
<thead>
<tr>
<th>Item</th>
<th>$N$</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Valid</td>
<td>Missing</td>
<td>Percentages</td>
</tr>
<tr>
<td>Mathematical software should be used only to check work</td>
<td>176</td>
<td>7</td>
<td>3.8</td>
</tr>
<tr>
<td>once the problem has been worked out on paper.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students should not be allowed to use any kind of software</td>
<td>180</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>while taking math tests.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematical software makes mathematics fun.</td>
<td>174</td>
<td>9</td>
<td>4.9</td>
</tr>
<tr>
<td>Mathematical software motivates students to learn</td>
<td>173</td>
<td>10</td>
<td>5.5</td>
</tr>
<tr>
<td>mathematics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All students should learn to use mathematical software.</td>
<td>179</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>Using mathematical software will make students try harder.</td>
<td>170</td>
<td>13</td>
<td>7.1</td>
</tr>
<tr>
<td>When students work with software, they do no need to</td>
<td>177</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>explain their work.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematical software should be used on mathematics</td>
<td>167</td>
<td>17</td>
<td>9.3</td>
</tr>
<tr>
<td>homework.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students should not be allowed to use any kind of software</td>
<td>177</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>until they have mastered the concept of procedure.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Enders (2010) argued that “finding evidence for or against MCAR does not change the recommendation to use maximum likelihood or multiple imputation” (p. 17) as they are with no doubt the state of art methods to handle missing data. Indeed, Enders stated that “blindly applying maximum likelihood estimation or multiple imputation will likely lead to a more accurate set of estimates than using one of the traditional missing data handling techniques” (p. 344). This dissertation did not do a blind application of MI but rather followed what is recommended in the literature and examined the patterns of
missing data to conclude that MI is the best approach. Hence, the remaining sections of this chapter reports results based on the MI technique.

This dissertation used MI to generate five complete copies of the original data by using 44 questions from the survey in the imputation model. Using SPSS, a sequential regression procedure was completed in the imputation phase; for each statistical test, SPSS presented the results for each of the five complete data set and for the original data set, but it also provided the pooled value, which is meant to represent the result, had the original data been complete (Enders, 2010). Hence, unless stating otherwise, the following results represent the pooled analyses given by the MI procedure. It is important to mention here that there were no significant differences between the results achieved by the listwise deletion and the pooled results for all performed tests.

**Beliefs About the Effect of the Course Being Taught and Attitude**

To answer S4 (are academic mathematicians’ points of view regarding the effect of the course being taught independent of their attitudes regarding software use?), a t test compared the mean attitude score between the group who agreed or strongly agreed \((n_1 = 36)\) with the item “my decision to use software depends on students’ majors” with the mean attitude score of the group who disagreed or strongly disagreed \((n_2 = 114)\).

From the original data set only, the homogeneity of variance assumption was not violated as indexed by the Levene’s test, \(F = 1.311, p = .25\). The mean of the first group \((M_1 = 2.53, SD = .034)\) was significantly lower than the mean \((M_2 = 2.69, SD = 0.38)\) of the second group, \(t(181) = -2.172, p = .03\), with a small effect size, \(\eta^2 = .025\). In other words, mathematicians who found software use to depend on students’ majors (i.e.,
software should not be used unless students need it in their future careers) also tended to have a conservative attitude, whereas those who thought software use should not depend on students’ major, had an overall positive attitude toward software use. The descriptive statistics about the attitude score supports this result; most of the participants had a slightly positive attitude and most of them did not regard students’ major as a factor to be considered when integrating software in classrooms.

Then, a $t$ test compared the mean attitude score of the group of participants ($n_1 = 164, M_1 = 2.67, SD = 0.28$) who agreed with the item “the content of the course influences my decision to use software” with the mean attitude score of the group of participants ($n_2 = 18, M_2 = 2.66, SD = 0.39$) who did not agree. The original data set indicated that equal variance could be assumed, $F = 1.480$, $p = .225$. The result of the $t$ test is not significant, $t(181) = .086$, $p = .93$. Regardless of their attitude, mathematicians believe that course content is important when deciding whether to use or not to use software in undergraduate classrooms. On the other hand, the mean attitude score ($n_1 = 29, M_1 = 2.41, SD = 0.37$) of respondents who disagreed with the item “software could be used at any level” was compared with the mean attitude score ($n_2 = 154, M_2 = 2.71, SD = 0.37$) of respondents who agreed with this item. The homogeneity of variance assumption was not violated as indexed by the Levene’s test, $F = .154$, $p = .696$. The $t$ statistics indicated that the null hypothesis that the two means are equal can be rejected, $t(181) = -3.989$, $p < .001$. The calculated effect size is .08. This suggests that individuals who found software use to depend on students’ level (i.e., software should not be used for less mature students) also tended to have a conservative attitude,
whereas those who thought software use should not depend on student level, had an overall positive attitude toward software use. The descriptive statistics about the attitude score supports this result; most of the participants had a relatively positive attitude and most of them did not regard students’ level as a factor to be considered when integrating software in classrooms.

In sum, the $t$ statistics indicated that mathematicians who consider students’ level and students’ major when deciding on software use have lower attitude than those who believe that software might be used with any level and any major. In addition, mathematicians believe that course content is one major factor that influences them when deciding to use software; this belief, however, is not related to their attitude.

**Software Characteristics, Perceive Effect, Instructor’s Personality, and Institution**

The researcher used linear regressions to address, S5, S6, S7, and S8. Four linear bivariate regressions evaluated if the attitude score was correlated and predicted from software characteristics, perceived effect, personality, and the institution. To answer S5 (do software characteristics correlate and predict a professors’ attitude to use software when teaching?), a correlation test examined the relation between the attitude score and the software score for $N = 183$ cases. The zero-order Pearson $r$ was statistically significant, $r(181) = .719$, $p < .001$ with $r^2 = .517$. This means that more than 50% of the attitude score is explained by software characteristics. In other words, it appears that mathematicians with high attitude tend to have high score with regard to software knowledge and availability. The coefficients table showed that the software factor was
significantly predictive of the attitude score, $t = 13.918$, $p < .001$, which supports the rejection of the null hypothesis that the raw slope coefficient $b = .507$ is equal to 0.

To answer S6 (to what extent does a professor’s perceived effect of software correlate with and predict attitude regarding software use?), the relation between the attitude score and the perceived effect score was assessed for $N = 183$ cases. The zero-order Pearson $r$ was statistically significant, $r(181) = .845$, $p < .001$. In addition, $r^2 = .714$, which means that more than 70% of the variance in the attitude score is explained by the perceived effect factor. In other words, it appears that mathematicians with high attitude tend to have high score with regard to their perceived effect of software. The $t$ statistics supported the rejection of the null hypothesis that the raw slope coefficient $b = 0.777$ is equal to 0 and suggested that the perceived effect factor is significantly predictive of the attitude score, $t = 6.817$, $p < .001$.

To answer S7 (to what extent does an academic mathematician’s personality correlate with and predict attitude regarding the use of software when teaching?), the relation between the attitude score and the personality score was examined for $N = 183$ cases. The zero-order Pearson $r$ gave a statistically significant result, $r(181) = .449$, $p < .001$, with $r^2 = .201$. In other words, it appears that mathematicians with high attitude tend to have high score with regard to their knowledge and interest in teaching, and are more flexible with changing their traditional methods in teaching. In addition, the personality factor was significantly predictive of the attitude score, $t = 6.755$, $p < .001$ which supported the rejection of the null hypothesis that the raw slope coefficient $b = 0.257$ is equal to 0.
To answer S8 (to what extent do the environment and support of an institution correlate with and predict attitude regarding the use of software when teaching?), the relation between the attitude score and the institution score was assessed for $N = 183$ cases. The zero-order Pearson $r$ was statistically significant, $r(181) = .130$, $p = .040$, $r^2 = .017$. In other words, it appears that mathematicians with high attitude tend to have supportive institutional environment with regard to software use. However, $r^2$ is small, which suggests that the relationship is weak. In addition, the institution factor was not significantly predictive of the attitude score, $t = 1.763$, $p = .078$ which indicates that the raw slope coefficient $b = 0.068$ is probably not different from 0.

Next, the researcher performed a standard linear regression with the three factors that were significantly predictors of attitude. The dependent variable for the model was attitude. All variables were entered at the same time. The model summary table provided the results for each data set but did not give a pooled result. Based on the original data set, the overall regression model was statistically significant, $R = .941$, $R^2 = .886$, $adjusted \ R^2 = .884$, $F(3, 179) = 464.296$, $p < .001$. The attitude scores were predictable from perceived effect, software characteristics, and personality with almost 90% of the variance accounted for by the regression model. The coefficient table provided the pooled result for the $t$ statistics that test if the slope coefficient $b$ for each predictor is different from 0. For the perceived effect factor, $t(181) = 23.067$, $p < .001$; for the software factor, $t(181) = 14.470$, $p < .001$; and for the personality factor, $t(181) = 2.855$, $p = .004$. Table 24 summarizes the slope coefficients and the part and partial correlations for each
predictor. The zero-order correlation gives the correlation between the response variable and each explanatory variable when no other variable in the model is controlled. Part (i.e., semipartial) and partial correlations give the correlation between the response variable and each explanatory variable when the other variables are partially or completely controlled in the model.

Table 24

*Slope Coefficients and Part and Partial Correlations for the Regression Model*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unstandardized Coefficients</th>
<th>95.0% Confidence Interval for B</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( B )</td>
<td>Std. Error</td>
<td>Lower Bound</td>
</tr>
<tr>
<td>(Constant)</td>
<td>0.154</td>
<td>.068</td>
<td>0.020</td>
</tr>
<tr>
<td>Software characteristics</td>
<td>0.297</td>
<td>.021</td>
<td>0.257</td>
</tr>
<tr>
<td>Perceived effect</td>
<td>0.595</td>
<td>.026</td>
<td>0.545</td>
</tr>
<tr>
<td>Personality</td>
<td>0.049</td>
<td>.017</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Next, the researcher evaluated the regression assumptions by first examining the correlation matrix among all variables. There were significant correlations among the predictors; however, all correlation coefficients were less than .50. According to Field (2009), this should minimize concern about multicollinearity, which is “the degree of intercorrelation among predictor variables” (Warner, 2008, p. 1023). In addition, the coefficient table for the original data set reported VIF values of 1.33, 1.23, and 1.22 and tolerance values of 0.74, 0.81, and 0.80 for all predictors respectively. These values are close to 1, and hence, there is little reason to be concerned about multicollinearity.
Moreover, the collinearity diagnostic of the original data was examined. The variance proportions of the predictors were distributed across different eigenvalues. This result supports the position that there was no multicollinearity.

Then, diagnostic statistics examined the extent to which the model fits the data. Field (2009) stated that if there were no outliers, there should be no cases with standardized residual greater than 3.29 in absolute value, no more than 1% of the data with standardized residual more than 2.58 in absolute value, and no more than 5% of the data with standardized residual more than 1.96 in absolute value. It appeared that there were two cases in the original data set that violated these assumptions. The two cases were examined and the regression model was performed when deleting these two cases. This sensitivity analysis yielded in essence the same results as the original data, with only slight difference. For example, in the regression model that used the perceived effect factor, the software factor, and the personality factor as predictors, $R^2$ with the original data was .886 and the adjusted $R^2$ was .884 when no cases were deleted (i.e., $N = 183$). However, a slight increase occurred ($R^2 = .898$, and adjusted $R^2 = .897$) when deleting the extreme cases (i.e., $N = 181$). Finally, the Cook’s distance and the Mahalanobis distance in the residual statistics table were examined. According to Field’s (2009) recommendation, because there are no values above 1 for the Cook’s distance and above 15 for the Mahalanobis distance, there are no influential cases.

**Research Interest**

To measure the effect of the research interest factor on attitude, in particular to answer S9 (do areas of research interest explain academic mathematicians’ attitudes
toward software use in undergraduate classrooms?), the researcher performed $t$ tests with each area of research in the items (algebra, analysis, applied mathematics, combinatorics, geometry, differential equations, topology, logic, discrete mathematics, mathematics education, statistics, and others including probability and biomathematics). The research area was the group factor and the attitude score was the response variable. For example, an independent $t$ test measured whether the mean attitude score differs significantly for the group of participants who chose algebra as an area of research interest ($n_1 = 29$) from the group of participants who did not choose algebra ($n_2 = 154$). For all research interest areas mentioned above, the homogeneity of variance assumption was not violated as indexed by Levene’s test. In addition, for all groups except mathematics education, analysis, and applied mathematics, the results indicated that the null hypothesis that the mean of the two groups is the same could not be rejected. Table 25 summarizes the mean and sample size of each group and provides the probabilities and effect sizes ($\eta^2$) associated with the $t$ tests that were conducted with each group.

For the mathematics education group, the mean ($M_1 = 3.06, SD = 0.43$) of the group who chose mathematics education was significantly higher than the mean ($M_2 = 2.64, SD = .036$) of the group of participants who did not choose mathematics education, $t(181)=3.52, p < .001$. The effect size, as indexed by $\eta^2$, was .06, which is considered a medium effect size. For the applied mathematics group, the mean ($M_1 = 2.67, SD = 0.43$) of the group who chose applied mathematics was significantly higher than the mean ($M_2 = 2.63, SD = 0.35$) of the group of participants who did not choose applied mathematics, $t(181)=2.05, p = .040$. The effect size, as indexed by $\eta^2$,
was .02, which is considered a small effect size. For the analysis group, the mean 
\((M_1 = 2.49, \ SD = 0.44)\), of the group of participants who chose analysis was significantly 
lower than the mean \((M_2 = 2.69, \ SD = 0.35)\) of the group who did not choose analysis, 
\(t(181) = -2.77, \ p = .006.\) The effect size, as indexed by \(\eta^2\), was relatively small \(.04)\.\(^4\)

Table 25

*Descriptive Statistics for Research Interests*

<table>
<thead>
<tr>
<th></th>
<th>Mean of attitude</th>
<th>Sample size in each group</th>
<th>(p)</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algebra</td>
<td>2.58</td>
<td>29</td>
<td>.217</td>
<td>.008</td>
</tr>
<tr>
<td>Analysis</td>
<td>2.49</td>
<td>32</td>
<td>.006</td>
<td>.040</td>
</tr>
<tr>
<td>Applied Mathematics</td>
<td>2.77</td>
<td>42</td>
<td>.040</td>
<td>.040</td>
</tr>
<tr>
<td>Combinatorics</td>
<td>2.79</td>
<td>12</td>
<td>.252</td>
<td>.022</td>
</tr>
<tr>
<td>Differential equations</td>
<td>2.68</td>
<td>21</td>
<td>.858</td>
<td>.007</td>
</tr>
<tr>
<td>Discrete mathematics</td>
<td>2.89</td>
<td>7</td>
<td>.104</td>
<td>.014</td>
</tr>
<tr>
<td>Geometry</td>
<td>2.56</td>
<td>21</td>
<td>.177</td>
<td>.010</td>
</tr>
<tr>
<td>Logic</td>
<td>3.13</td>
<td>2</td>
<td>.080</td>
<td>.016</td>
</tr>
<tr>
<td>Mathematics education</td>
<td>3.06</td>
<td>10</td>
<td>&lt;.001</td>
<td>.060</td>
</tr>
<tr>
<td>Topology</td>
<td>2.55</td>
<td>27</td>
<td>.081</td>
<td>.020</td>
</tr>
<tr>
<td>Other</td>
<td>2.68</td>
<td>24</td>
<td>.819</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Because topology and algebra are areas of pure mathematics, individuals who 
chose topology or algebra are expected to have lower attitude score than the rest of the 
participants. So, participants who chose topology as an area of interest were combined

\(^4\) \(\eta^2 > .05\) is a medium effect size and \(\eta^2 > .15\) is a large effect size (Cohen, 1988).
with individuals who chose algebra aiming to increase the sample size and hence increase
the power to detect any difference. The mean \( (M_1 = 2.54) \) of the group \( (n_1 = 53, \)
\( SD = 0.29) \) who chose topology or algebra was significantly lower than the mean
\( (M_2 = 2.71) \) of the group of participants \( (n_2 = 130, SD = 0.40) \) who did not choose one of
these research areas, \( t(181) = -2.804, p = .005 \). The effect size, as indexed by \( \eta^2 \), was
.04. In addition, because the mean for the attitude scores of the combinatorics group and
the discrete mathematics group were higher than the mean of all 183 cases (i.e., mean >
2.66), the two groups were combined. The mean \( (M_1 = 2.83) \) of the group who chose
combinatorics or discrete mathematics \( (n_1 = 18, SD = 0.43) \) was significantly higher than
the mean \( (M_2 = 2.64) \) of the group \( (n_2 = 165, SD = 0.37) \) of individuals who did not
choose any of these two areas, \( t(181) = 1.987, p = .047 \). The effect size, as indexed by \( \eta^2 \),
was .02.

Age

To answer S10 (does instructor’s age explain disposition regarding software
use?), the researcher performed a general linear model (GLM). The results reported
below are for the original data only and no pooled statistics was provided. First, the
researcher compared the mean scores (as presented in Table 26) among participants in the
following groups:

Group 1: Participants whose age is below 35 years

Group 2: Participants whose age is 35–45 years

Group 3: Participants whose age is 46–55 years

Group 4: Participants whose age 56–65 years

Group 5: Participants whose age more than 65 years.
Table 26

Descriptive Statistics for Each Age Group

<table>
<thead>
<tr>
<th>Age</th>
<th>n</th>
<th>Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 35</td>
<td>20</td>
<td>2.73</td>
<td>.075</td>
</tr>
<tr>
<td>35–45</td>
<td>42</td>
<td>2.51</td>
<td>.057</td>
</tr>
<tr>
<td>46–55</td>
<td>43</td>
<td>2.80</td>
<td>.062</td>
</tr>
<tr>
<td>56–65</td>
<td>46</td>
<td>2.71</td>
<td>.051</td>
</tr>
<tr>
<td>&gt; 65</td>
<td>32</td>
<td>2.56</td>
<td>.063</td>
</tr>
</tbody>
</table>

To examine any violation of assumptions, descriptive statistics ensured that the groups had relatively similar sample size and no group had less than 10 cases. Then, Levene’s test for homogeneity of variance indicated that the assumption of homogeneity of variance was not violated, $F(4,178)=0.636$, $p = .637$. The overall $F$ statistics for the GLM test was statistically significant, $F(4,178)=4.33$, $p = .002$ with a medium effect size of $R^2 = .089$. In addition, the post hoc Tukey’s range test compared the groups pairwise. The results indicated that mean score of Group 2 was significantly lower than the mean of Group 3. In addition, the mean score of Group 3 was significantly higher than the mean of Group 5. Table 27 shows the parameter estimates given by the GLM, and Table 28 shows the mean differences and probabilities for all pairwise comparisons.
Table 27

Parameter Estimates for Each Age Group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.555</td>
<td>.065</td>
<td>39.202</td>
<td>&lt;.001</td>
<td>.896</td>
</tr>
<tr>
<td>&lt; 35</td>
<td>0.173</td>
<td>.105</td>
<td>1.645</td>
<td>.102</td>
<td>.015</td>
</tr>
<tr>
<td>36–45</td>
<td>−0.041</td>
<td>.087</td>
<td>−0.480</td>
<td>.632</td>
<td>.001</td>
</tr>
<tr>
<td>46–55</td>
<td>0.247</td>
<td>.086</td>
<td>2.865</td>
<td>.005</td>
<td>.044</td>
</tr>
<tr>
<td>56–65</td>
<td>0.162</td>
<td>.085</td>
<td>1.908</td>
<td>.058</td>
<td>.020</td>
</tr>
</tbody>
</table>

Table 28

Mean Differences and Probabilities Among Groups of Different Ages

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Mean Difference (I–J)</th>
<th>Std. Error</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>My age is below 35</td>
<td>My age is 35–45</td>
<td>0.214</td>
<td>.101</td>
<td>.208</td>
</tr>
<tr>
<td>My age is 35–45</td>
<td>My age is 46–55</td>
<td>−0.074</td>
<td>.099</td>
<td>.947</td>
</tr>
<tr>
<td>My age is 46–55</td>
<td>My age is 56–65</td>
<td>0.011</td>
<td>.099</td>
<td>1.000</td>
</tr>
<tr>
<td>My age is 56–65</td>
<td>My age is above 65</td>
<td>0.173</td>
<td>.106</td>
<td>.471</td>
</tr>
<tr>
<td>My age is 35–45</td>
<td>My age is 46–55</td>
<td>−0.288</td>
<td>.079</td>
<td>.004</td>
</tr>
<tr>
<td>My age is 46–55</td>
<td>My age is 56–65</td>
<td>−0.203</td>
<td>.079</td>
<td>.078</td>
</tr>
<tr>
<td>My age is 56–65</td>
<td>My age is above 65</td>
<td>−0.041</td>
<td>.087</td>
<td>.989</td>
</tr>
<tr>
<td>My age is 46–55</td>
<td>My age is 56–65</td>
<td>0.085</td>
<td>.078</td>
<td>.815</td>
</tr>
<tr>
<td>My age is 56–65</td>
<td>My age is above 65</td>
<td>0.247</td>
<td>.086</td>
<td>.037</td>
</tr>
<tr>
<td>My age is 56–65</td>
<td>My age is above 65</td>
<td>0.162</td>
<td>.085</td>
<td>.317</td>
</tr>
</tbody>
</table>
Background

To answer S11 (do cultural background, educational background, and teaching background influence academic mathematicians’ dispositions toward software use when teaching mathematics?), the researcher performed several tests on the six items that constitute this factor. First, the researcher considered the groups of different lengths of teaching experience. The result of the Levene’s test indicated that we could not assume equal variances, as shown in Table 29. Hence, a robust test of equality of means (Welch) compared the means of the attitude score among the following groups:

Group 1: participants who have been teaching college mathematics for 0–5 years
Group 2: participants who have been teaching college mathematics for 6–15 years
Group 3: participants who have been teaching college mathematics for 16–25 years
Group 4: participants who have been teaching college mathematics for 26–35 years
Group 5: participants who have been teaching college mathematics for more than 35 years

The result indicated that the mean of the attitude score is not the same among groups. Table 30 gives the test result and Table 31 summarizes the mean scores

Table 29

*Test of Homogeneity of Variance for Length of Teaching Experience*

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df₁</th>
<th>df₂</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.450</td>
<td>4</td>
<td>178</td>
<td>.002</td>
</tr>
</tbody>
</table>
Table 30

*Welch Test for Length of Teaching Experience*

<table>
<thead>
<tr>
<th>Welch Statistic(^a)</th>
<th>(df_1)</th>
<th>(df_2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.670</td>
<td>4</td>
<td>49.473</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Table 31

*Descriptive Statistics for Lengths of Teaching Experience*

<table>
<thead>
<tr>
<th>Length of Teaching Experience</th>
<th>(n)</th>
<th>Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5 years</td>
<td>10</td>
<td>2.67</td>
<td>.159</td>
</tr>
<tr>
<td>6–15 years</td>
<td>41</td>
<td>2.56</td>
<td>.040</td>
</tr>
<tr>
<td>16–25 years</td>
<td>52</td>
<td>2.73</td>
<td>.068</td>
</tr>
<tr>
<td>26–35 years</td>
<td>44</td>
<td>2.73</td>
<td>.043</td>
</tr>
<tr>
<td>&gt; 35 years</td>
<td>36</td>
<td>2.59</td>
<td>.060</td>
</tr>
<tr>
<td>Total</td>
<td>183</td>
<td>2.66</td>
<td>.028</td>
</tr>
</tbody>
</table>

Then, the Games-Howell test reported on all possible pairwise comparisons. Games-Howell test is one of the post hoc tests available in SPSS that could be used when the equal variance assumption is violated. The result indicated that the mean score of Group 2 (I have been teaching college mathematics for 6–15 years) is statistically lower than Group 4 (I have been teaching college mathematics for 26–35 years), with mean differences of −0.173. All other pairwise comparisons yielded no significant results. This result is not different from the results received when using the other available post hoc tests such as Tamhane or Dunnett T3.
Then, two bivariate regressions were performed to evaluate if a professor’s attitude score is correlated and predicted from the following variables:

- Education with regard to software use
- Teaching with regard to software use

First, a bivariate correlation test assessed the relation between the attitude score and the “education with regard to software use” variable for \( N = 183 \) cases. The zero-order Pearson \( r \) was statistically significant, \( r(181) = .390, p < .001 \). In addition, the regression model indicated that \( r^2 = .158 \). In other words, the extent to which a professor used software in past educational experience was significantly predictive of the attitude score, \( t = 5.731, p < .001 \) which supports the rejection of the null hypothesis that the raw slope coefficient \( b = 0.211 \) is equal to 0. Second, the relation between the attitude score and “teaching with regard to software use” variable was assessed for \( N = 183 \) cases. The zero-order Pearson \( r \) was statistically significant, \( r(181) = .686, p < .001 \). In addition, the regression model indicated that \( r^2 = .479 \), which means that 47.9% of the variance in the attitude score is explained by this factor. The \( t \) statistics supported the rejection of the null hypothesis that the raw slope coefficient \( b = 0.277 \) is equal to 0. The extent of an individual’s use of software in past teaching experience was significantly predictive of the attitude score, \( t = 11.941, p < .001 \).

Next, GLM tests explored the effect of the “educational background with regard to culture” and the “teaching background with regard to culture” variables. The results reported below are for the original data only and no pooled statistics was provided. First, a GLM compared the mean scores among participants in the following groups:
• Group 1: Participants studied for 0–4 years at U.S. institutions ($n_1 = 36, M_1 = 2.59, SD = 0.40$)

• Group 2: Participants studied for 5–8 years at U.S. institutions ($n_2 = 28, M_2 = 2.67, SD = 0.46$)

• Group 3: Participants studied for 9–12 years at U.S. institutions ($n_3 = 38, M_3 = 2.67, SD = 0.32$)

• Group 4: Participants studied for more than 12 years at U.S. institutions ($n_4 = 81, M_4 = 2.68, SD = 0.36$)

Prior to the analysis, descriptive statistics examination ensured that there are almost equal numbers of participants in each group with at least 10 participants in a group. Levene’s test for homogeneity of variance indicated that the assumption of homogeneity of variance was not violated, $F(3,179) = 0.87, p = .46$. The overall $F$ statistic was not statistically significant, $F(3,179) = 0.47, p = .70$, with effect size $R^2 = .008$. Next, the researcher combined the group of participants who taught for 0–4 years at U.S. institutions with the group of participants who taught for 5–8 years at U.S. institutions because the former had only 6 participants. A second GLM test compared the mean scores among participants in the following groups:

• Group 1: Participants taught for 0–8 years at U.S. institutions ($n_1 = 36, M_1 = 2.60, SD = 0.35$)

• Group 2: Participants taught for 9–12 years at U.S. institutions ($n_2 = 14, M_2 = 2.59, SD = 0.27$)
Group 3: Participants who taught for more than 12 years at U.S. institutions

\( n_3 = 141, M_3 = 2.68, SD = 0.39 \)

The Levene’s test for homogeneity of variance indicated that the assumption of homogeneity of variance was not violated, \( F(2,178) = 0.87, p = .42 \). The overall \( F \) statistic was not statistically significant, \( F(2,178) = 0.75, p = .47 \), with effect size \( \eta^2 = .008 \).

Finally, the frequencies of the demographic item that divided the participants into seven cultures indicated that two categories (American Indian and Native Hawaiian) had no cases; White, Caucasian included 165 cases and only 18 cases in the remaining four categories. Hence, the researcher combined all the remaining four categories in one. The \( t \) test that compared the attitude score of the two groups indicated that the mean difference of .035 is not significance, \( t(181) = 0.373, p = .71 \). In other words, culture is not a factor that influence attitude.

In sum, among the six variables in the background factor, three were statistically significant predictors of attitude: education with regard to software use, teaching with regard to software use, and length of teaching experience. The other three variables (education background with regard to culture, teaching background with regard to culture, and cultural background) were not significant as predictors of attitude.

Because the length of teaching experience is a categorical variable, the researcher created four dummy variables to represent the five groups of different lengths of teaching experience. A regression model was performed when entering the following variables:

1. Education background with regard to software use;
2. Teaching background with regard to software use;
3. The four dummy variables of length of teaching experience.

From the original data, the overall model was significant, $R = .732$, $R^2 = .536$, adjusted $R^2 = .520$, $F(6,170) = 32.763$, $p < .001$. This means that more than 50% of the variance in attitude is accounted for by the use of software in previous years either as a student or as a teacher and the length of teaching experience. Looking at the contribution of each predictor, it was found that the educational background factor is statistically significant, $t(170) = 4.457$, $p < .001$, and the teaching background factor is significant $t(170) = 10.818$, $p < .001$. None of the dummy variables that represented the length of teaching experience factor was significant.

**Overall Picture**

In this step, and based on the results of the previous tests, linear regression tests in subsequent models examined the significant factors and subfactors. In Model 1, the regression test included the following variables, all entered at the same time

- the perceived effect factor;
- the software factor;
- the personality factor.

Model 2 included the variables in Model 1 and

- educational background with regard to software use;
- teaching background with regard to software use;

Model 3 included the variables in Model 2 and the dummy variables of the following items:
• “my decision to use software depends on students’ major;”
• “software could be used in any level.”

Finally, Model 4 included the variables in Model 3 and the four dummy variables that represented the different groups of age.

From the original data only, Model 1 was significant, $R = .942$; $R^2 = .887$ and \( \text{adjusted}R^2 = .885 \). Model 2 was significant, $R = .953$, $R^2 = .908$, \( \text{adjusted}R^2 = .905 \). In addition, \( R^2\text{change} = .021 \) was significant, $p < .001$. This means that the variables in Model 1 explained 88.7% of the variance in attitude, and the additional variables in Model 2 explained an additional 2.1% of the variance. Model 3 was significant, $R = .955$, $R^2 = .912$, and \( \text{adjusted}R^2 = .908 \). Moreover, \( R^2\text{change} = .004 \) was significant, $p = .017$. Model 4 was significant, $R = .956$, $R^2 = .913$, \( \text{adjusted}R^2 = .908 \). However, \( R^2\text{change} = .001 \) was not significant, $p = .646$. This means that the variables in Model 3 explained an additional 0.4% of the variance than what was explained by Model 2. Nevertheless, the age factor did not explain any extra variance than what was explained by the variables in Model 3.

The researcher examined all regression assumptions, such as multicollinearity and independence, for all the regression models performed in this section. Moreover, diagnostic tests were performed to see if the model fit the data and to ensure that there were no influential cases. At last, all the tests performed on \( N = 183 \) were performed when deleting the outlier cases that were identified in Figure 6 and Figure 14. There was no difference in results in all tests.
Open-Ended Responses

This dissertation followed a mixed-methods approach. Phase 1 collected data through open-ended interviews. Phase 3 was designed to collect close-ended data seeking information about the particular factors that were discovered in Phase 1. Hence, there were no open-ended questions in the survey instrument that was used in the full study (Schensul et al., 1999). However, three respondents sent e-mail messages explaining that they were not satisfied by responding to the survey instrument and that they wanted to state their open-ended opinions. Although this was not the initial design of the study, ignoring the open-ended data meant ignoring valuable data that might have benefited the study, especially when these data enhanced the factors that were discovered in Phase 1. In other words, the researcher invoked an emergent design (Patton, 2002). Two of the three participants—Participants X and Y—did not give their permission to use their e-mail messages as quotes. Hence, their opinions are only interpreted, while specific quotes are used from the third participant (Participant Z) only. The following paragraph summarizes the open-ended data.

Participant X indicated that the effectiveness of software use depends on students’ level and major. According to the participant, it is crucial for engineers and scientists to be familiar with tools such as software, which could also help upper division classes to explore problems that are impractical to tackle without software. The participant added that the use of software in lower division classes is becoming basically an approach to compensate for the problem of having too many students in one calculus section. The participant also pointed out that software use negatively affects students’ ability to
critique, reason, and communicate their understating. Although the attitude score of this participant is not determined, it was clear from the open-ended response that the participant has rather a negative attitude with regard to software use in teaching. This open-ended opinion supported the test results about the effect of students’ major and level and the perceived effect of software on students’ learning.

On the other hand, Participant Y pointed out at the challenge of learning the different features of software. The effectiveness of using software in mathematics instruction depends on the instructor and students’ interest and knowledge about software. The participant argued that there is too much time and work to be done to use the software effectively. Even in that case, whatever students learned about the different features of certain software would need to be learned again the very next year. This opinion coincides with the results of the interview data and the survey data that software knowledge is a major influence on attitude. Participants X and Y pointed out the effect of students’ level, students’ major, perceived effect, and knowledge about software. Participant Z, on the other hand, commented on the effect of the institution a professor is working at and the identity factor.

I learned at a university where research is king. Accordingly, I have witnessed such horrible teaching it is hard to believe. The problem stems from the fact that those faculty are hired for one thing only, and that has nothing to do with teaching. It is compounded by the insidious pressure for grants and publications, forcing typical faculty members to ditch any good intentions they may have had for good teaching. Only
by serendipity would we find a good teacher at such a research
institution. (Participant Z)

Participant Z agreed with the interview participants in Phase 1 that a person’s
identity, a researcher versus a teacher of mathematics, is a major influence on the level of
involvement and interest in teaching. Whether the institution is a teaching-oriented place
or a research-oriented place is also an effect. It is interesting that Participant Z mentioned
this factor without being directly asked about it and without directly connecting it to
software use. The results of Phase 3 indicated that the institution factor was correlated
with the attitude score, but it was not a predictor of it.

Summary

This chapter reported on the tests and analyses that were performed on the survey
data to answer Research Question 1 and the supplementary questions S1–S11. These
analyses examined the attitude scores of the participants and explored the results of the
tests that were performed to measure if the identified eight factors from the interview data
were predictive of attitude. The reader is reminded that the items used to measure two of
these factors were part of the attitude scale and the items used to measure the remaining
six factors were developed by the researcher. The following paragraphs summarize these
results.

First, descriptive statistics showed that the mean of the participants’ attitude score
was primarily neutral with some tendency towards agreement. The consensus in the items
that constitute the attitude scale suggested that the participants acknowledged the
potential benefits of software use, but were concerned about the misuse of software and
the potential harm of its use on students’ learning. Approximately half of the participants not only implied that software was not important, but also indicated that the traditional approach (i.e., using paper and pencil only with no software integration) is better for students. Furthermore, although most participants indicated that they know how to use software effectively in teaching and have access to software, more than half of them elected to not use it in classrooms.

Descriptive statistics also showed that the participants did not consider students’ level or students’ major as factors that influence the use of software in classrooms, but considered the course content as an influence on their decision to use software. The results of the $t$ tests suggested that beliefs about the importance of considering students’ major and level when using software were dependent on a mathematician’s attitude, whereas the importance of looking at the course content was not related to attitude. A linear regression model indicated that software characteristics, the perceived effect, and instructor’s personality were predictive of the attitude score, even when controlling for the other two factors. The institution factor was shown to be correlated with the attitude score but not predictive of it.

In addition, $t$ tests were used to detect any differences between the means of the attitude score among groups with different research interests. The $t$ tests were significant in some of the research areas, such as applied mathematics, analysis, algebra and topology, and mathematics education with small effect sizes in most cases. The $t$ tests failed to detect any significant differences for other areas, such as differential equations. GLM test showed that the difference among the mean attitude scores was statistically
significant among the groups of different age. However, when used as dummy variables in a regression model with other variables, such as “educational background with regard to software use” factor and the “teaching background with regard to software use” factor, none of the age group was significant. Linear regressions, ANOVA, and a t test were used to explore each of the six items that represented the background factor. The results showed that the “educational background with regard to software use” and the “teaching background with regard to software use” were predictive of attitude. However, all tests performed on the items that represented the culture effect were not statistically significant. Moreover, the difference among the mean attitude scores was statistically significant among the groups of different lengths of teaching experience. Nevertheless, when used as dummy variables in a regression model, the length of teaching experience factor diminished when controlling for the “educational background with regard to software use” factor and the “teaching background with regard to software use” factors. Finally, subsequent regression models examined each of the significant factors and subfactors.

In sum, among all 8 factors and 16 subfactors that were tested in Phase 3, the test results supported the perceived effect, software characteristics, instructor’s personality, and the educational and the teaching backgrounds with regard to software use, with large effect sizes when each factor tested individually. Students’ major and level found to be predictive of attitude with small and medium effect sizes respectively. In addition, the research interest factor was supported in some areas. Moreover, the institution factor was found to be correlated with the attitude score but not predictive of it.
Chapter 8: Triangulation, Discussion, and Recommendations

Many mathematics educators, researchers, and policy makers have advocated for the use of software in mathematics instruction (CUPM, 2004; Heid, 1988; Hollebrands et al., 2010). Yet, many mathematicians regard the use of software in undergraduate mathematics classrooms as not only unnecessary but also harmful to students’ learning (Quinlan, 2007). Nevertheless, little research investigated mathematicians’ dispositions regarding software use in undergraduate classrooms (Quinlan, 2007; Ralston, 2004). This study advanced the research-based knowledge about these dispositions and uncovered the reasons underlying them.

This study created an initial model (Figure 3, p. 81) by adopting Fishbein and Ajzen’s (1975) framework and then building on it based on a synthesis of opinions, anecdotal evidence, research results, and theoretical perspectives. This study, then, followed a mixed-methods design and collected data through three phases. Phase 1 followed a qualitative approach with an ethnographic orientation to collect interview data from key informants in the field. The results of the interview data pointed to the possible influence of eight factors on attitude regarding software use in teaching: the course being taught, software characteristics, perceived effect, instructor’s personality, the institution, research interest, age, and background.\(^5\) Phase 2 involved developing and piloting a survey, which then was used in Phase 3 to measure the attitude variable and the effect of these eight factors on attitude while working with a wider sample of mathematicians.

\(^5\) Detailed descriptions of these factors and their subfactors are reported in Chapter 5.
Recall that the sample in Phase 3 included 183 TTT, full-time faculty members from 50 PhD-granting mathematics departments in the U.S. Although the selection of participants was not random, the selection of departments was (see the delimitations section in Chapter 1 for more details). Overall, this mixed-methods design is similar to Creswell and Plano Clark’s (2011) conceptualization of an exploratory-sequential approach.

The following section compares and contrasts the results among the initial model, the interview results, and the survey results. The rest of the chapter then deals with reflexivity, lessons learned, implications, and recommendations for future research.

**Triangulation and Discussion**

**Research Question 1: What are academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?** The results of the interview data and the survey data, as well as the reviewed research in Chapters 2 and 3 indicated that most academic mathematicians have a rather moderate skeptical attitude with regard to software use in undergraduate mathematics classrooms. A minority of mathematicians either completely opposes software use in teaching or entirely advocates for its use. Most mathematicians appreciate the many benefits of software but are concerned about its potential harm and still value the traditional instructional methods.

Some researchers have indicated that not all mathematicians are proponents of software use in mathematics instruction (LaBerge, 1997; Quinlan, 2007). Most of the 26 mathematicians in LaBerge’s study disagreed with the NCTM’s assumptions for Grades 9–12 that “scientific calculators with graphing capabilities will be available to students at
all times” (NCTM, 1989, p. 124). Recently, Quinlan reported that only 50% of the participating mathematics professors in his study believed that mathematical software was important. This result coincides with Phase 1 participants’ points of view. Eight of the 11 participants were skeptical and critics of software use. Three participants6 (A, F, H) believed that software should be used only in restricted situations for certain majors or levels, if any; whereas five participants (C, D, J, K, L) believed that software could be beneficial, but not without considerable limitations. Participant D, for example, thought that software could negatively affect students’ learning: “They [students] do not like ‘no calculator’ policy…they are being addicted…they cannot use the potential of their brain” (Participant D). Some of the participants stated that software was not important. For example, Participant J stated, “I wouldn’t say that it [software] necessarily enhances the learning of the traditional materials that much.” Participant C indicated that technology might motivate students to learn but also stated that it was not crucial when it comes to students understanding the mathematical concepts:

I actually did some research on how preservice teachers incorporate technology into their developing of mathematics understanding and it was pretty questionable…I taught the [XXX] course in a traditional way for a number of years, and I also taught [it], sort of, the group and technology way…Because the content of the course does not change much,…we quite often have [almost] the same questions…in exams; so,…I re-graded the

6 Recall that the interview participants were identified by letters (i.e., A, B).
questions…to see if I can detect any difference in performance and there
was essentially none. (Participant C)

In addition, the participants in Phase 1 stated that not all mathematicians advocate
for software use. Participant C believed that many mathematicians have a moderate
position: “I think you will find many people, kind of, in the middle; you do not use
software for every possible thing;” whereas Participant J argued, “out of a 100, I would
say that…it would probably be about evenly split between for and against, but neither
one will have good justification for it.”

The survey results indicated that the mean attitude score was slightly positive.
Approximately 63.9% of the responses had a positive attitude (i.e., mean > 2.5), and only
12.0% had scores greater than 3.0. Overall, most of the respondents had a moderate
position. In addition, a deep exploration of the consensus of the attitude items gives a
better picture of the participants’ perceptions and beliefs: For example, 83.1% disagreed
with the statement “mathematical software is a tool only for solving the problems more
quickly,” and 90.2% disagreed with “mathematical software should be used only to check
work once the problem has been worked out on paper.” This can be interpreted to mean
that most participants felt that software was not a useless tool. In addition, a large
percentage (81.9%) agreed that “more interesting problems can be done when students
have access to mathematical software,” which implies that the majority thought that
mathematical tasks, and hence mathematical teaching, might be better with software. Yet,
almost half of the participants (49.7%) thought that the use of mathematical software
would cause students to lose basic computational skills, and 65.7% still value and
preferred the paper and pencil approach. Not only that, but more than half of those surveyed (53.1%) did not use software in their undergraduate classrooms, and almost half of them (43.7%) did not think that all students should learn using mathematical software. This last result aligns with the findings of Quinlan (2007) and with the participants’ attitudes in the interview phase.

In sum, the triangulation among Phase 1, Phase 3, and the reviewed research indicated that most mathematicians have a moderate attitude and a slightly skeptical tendency with regard to software use in undergraduate mathematics classrooms. A small percentage of mathematicians consider software an entirely useless tool in mathematics classrooms, and a small percentage look at software as an effective replacement of the traditional approach. Most of the participants in the interview and survey phases, although they saw the potential benefits of software, were considerate of the potential harm and preferred traditional instructional methods; they did not see software as an essential tool. About half of the mathematicians in the sample, in both phases, did not favor or use software in their teaching.

**Research Question 2: What are the reasons underlying academic mathematicians’ dispositions toward software integration in undergraduate mathematics classrooms?** Chapter 3 reported on studies that addressed factors that influence instructors’ attitude with regard to software use, such as culture, the course being taught, and educational and teaching experiences. The interview phase elaborated on these factors, but also shed light on other factors and subfactors that were not directly identified as influential on attitude, such as age, institution, and identity. Moreover, two
unforeseen factors emerged—perceived effect on learning and research interest. Phase 3 statistically examined all factors suggested by Phase 1. The following paragraphs triangulate the results regarding these factors among the reviewed research, results of Phase 1, and results of Phase 3. The reader is reminded, though, that the interview data were collected from a convenience sample, and hence were not necessarily representative. Moreover, data were collected in Phase 3 in an exploratory fashion with repeated tests, which means that Type I error is of concern\(^7\) (Warner, 2008). However, the triangulation process in this section aims to find consistency of results among phases and past research and hence, support the prediction relationship between the eight factors and attitude.

1. The course being taught. Data collected in this research and past results pointed out at the effect of the course being taught, including course content, students’ level, and students’ major, on software use and attitude toward its use. Several researchers recommended using software in specific courses, implying that course content matters. Many scholars focused on calculus classrooms when addressing the effect of software on mathematics teaching and learning (Girard, 2002; McCallum, 2007; Speer, 2001) indicating that calculus is one area in mathematics that is influenced by the available software (Tall et al., 2008). Some mathematicians believed that applied mathematics courses should incorporate software to be taught effectively (Lopez, 2005), but others believed that software was effective even in teaching abstract concepts

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\(^7\) Descriptive statistics and statistical results are reported in Chapter 7.
(Borwein et al., 2004). The participants in Phase 1 agreed; participants with conservative attitude (e.g., Participant H), moderate attitude (e.g., Participant D), and positive attitude (e.g., Participant E), all argued that course content mattered. “[In] one course, Math [MMM], that is taught in a computer lab…basically, I taught for 10 minutes and then they [students] were working on problems on the computer. [For] calculus…I do not use any technology” (Participant H); “depending on the course, I prefer to use technology from time to time” (Participant D); “if they are applied mathematicians they are going to use tools to help them solve these things….it depends on the course” (Participant E). Furthermore, more than 90% of the participants in Phase 3 thought that the content of the course was a major factor that influenced their decisions to use software. Moreover, a t test indicated that the mean difference of 0.008 between the group of participants who considered course content when deciding on software use and the group who did not consider it was not significant, which suggests that the belief about the effect of course content was independent of attitude. Hence, past research, Phase 1 and Phase 3 results, all indicate that most mathematicians believe that course content is an important factor to be considered when making decisions about the use of software in classrooms and that this belief is not related to their general attitude about software use.

Students’ level and major were other subfactors related to the course being taught. Past research suggests that some mathematicians believed that the appropriateness of software use in instruction “‘depends on what profession the student chooses’” (Quinlan, 2007, p. 220) and the level of students: “‘Don’t use technology until the student reaches a certain level of maturity’” (Quinlan, 2007, p. 228). Ellis (2001) commented that
opponents of software use stressed that students should master paper and pencil
procedures first. Davis et al. (1986) connected the course content effect to students’
major and the use of software and argued that because of the essential role of calculus in
most science majors, it was crucial to use software so students would experience the tools
they need in their future careers. The survey results in Phase 3 indicated that the majority
of participants felt that students’ level and major were not important factors. Moreover,
the mean difference of 0.29 between individuals who disagreed that students’ level
should be considered and individuals who agreed was statistically significant; in addition,
the mean difference of 0.15 between individuals who disagreed that students’ major
should be considered and individuals who agreed was statistically significant, although
the reader is reminded that the null hypotheses were tested in an exploratory fashion and
these findings could be due to an elevated Type I error. With this being said, there is
consistency between Phases 1 and 3. Participants with conservative attitude (A, H, F)
argued that we should not use software unless students were mature enough and needed it
in their career. Participants with positive attitude (B, E, G) claimed that software could be
used with any level and for any major. Therefore, the results of past research, Phase 1,
and Phase 3 offer initial evidence that mathematicians with conservative attitude consider
students’ level and major when deciding on software use in teaching, but those who
advocate software use likely do not regard major or level as a deciding factor.

2. Software characteristics. Many educators reported that instructor’s knowledge
and experience with using software was one important factor that contributed to an
instructor’s attitude regarding the use of such tool (Jackson, 2011, Jackson & Hundley,
2011; Wilburne et al., 2009). In fact, Jackson and Hundley (2011) claimed that some faculty might not use software because they considered learning to use the software as an extra burden on them. The reflections from the interview participants matched this result.

   I do not have the confidence in myself technologically to get it right in the classroom, so I prefer not to do it…even people who are expert when they get in front of audience, things do not go right, so I think it is just better left undone. (Participant J)

   “You certainly will get some who are just not very comfortable with technology and won’t use it for that reason….ease of use is a big thing” (Participant H). Participant G talked about the availability of software, “we do not have things like that [Mathematica or Maple] available for teaching in class….MATLAB is the one software we have available on the computers,” and the importance of the knowledge about software, “this is one of the problems I have with MATLAB, is that I am not trained on it.” In addition, Participant L admitted that the reason for not using software was that “it takes lots of time.” Finally, the linear regression that was performed in Phase 3 suggested that software characteristics was a predictor of attitude with more than 50% of the variance in attitude explained by it. Hence, past results, the interview results, and the survey results agreed about the effect of software characteristics on attitude.

   3. Perceived effect. The perceived effect on learning factor unexpectedly emerged from the analysis of the interviews and was not among the factors in the initial model (Figure 3, p. 81). This finding is reminiscent of Stein, Remillard, and Smith’s framework—Temporal Phases of Curriculum Use (2007). This framework acknowledged
the effect of an instructor’s perceptions and beliefs on what the instructor intended to teach and eventually on students’ learning. The analysis of the interview data indicated that the interviewees intuitively understood aspects of the Stein et al. framework when they connected their perceived effect of software use on students’ learning to their intentions and behaviors regarding software use. This led the researcher to connect Stein et al.’s framework to Fishbein and Ajzen’s (1975) framework, indicating that perceived effect not only influences instructors’ intentions and behaviors but also influences their attitude. This link is evidenced in the participants’ reflections.

Participants with a positive attitude (B, E, G) stated the reasons for advocating software use, which were related to their perceived benefits of software use on students’ understanding of mathematics. For example, Participant G stated, “students cannot visualize the abstract ideas just based on what you say on the chalkboard or the pictures you draw. Sometimes you need to be able to animate things.” On the other hand, participants with a more conservative attitude (A, F, H) revealed why they oppose software use and the perceived harm on students’ learning. “I once witnessed a student calculating the square root of 1 in their calculator. So there are certainly some students who will use the calculators instead of thinking” (Participant H). The participants emphasized the importance of the perceived effect factor: “It is one of these situations where it is only going to be effective if you believe it will be effective” (Participant G); “if the person perceives that it will pay off, then they will continue to spend the extra energy to explore the new pedagogical style” (Participant C). The results of Phase 3 agreed with what was suggested by past theories and what was concluded from Phase 1;
the perceived effect factor was found to be predictive of attitude, with 80% of the attitude score explained by the perceived effect factor. Theory-data triangulation supports the perceived effect factor as a predictor of attitude.

4. Instructor’s personality. Although the personality factor was not included in the initial model (Figure 3), Chapters 2 and 3 reported on studies that have addressed some subfactors of it. Many scholars have long acknowledged that mathematicians do not necessarily attend formal courses in mathematics teaching methods (Bass, 1997; Speer et al., 2005), and are not always aware of the reform in mathematics teaching (LaBerge, 1997). Bass (1997) and A. C. Tucker (1999) argued that “knowledge for mathematics teaching” was not always among mathematicians’ interests or priorities. In addition, T. W. Tucker (1999) stated that resistance to reform likely to lead to resistance to software integration in mathematics classrooms, and A. C. Tucker (1999) argued that software integration challenges one’s typical teaching methods and indicated that one important factor that supports instructors in changing their pedagogical approaches is their interests and time devoted to teaching. A. C. Tucker further claimed that best teaching comes from committed researchers and that research mathematicians need to prove this claim by showing their teaching talents in classrooms.

The interview participants reflected on the effect of the personality factor on attitude with regard to software use. For example, Participant J stated, “if you have more interest in teaching, then you are willing to take the time to investigate whether or not you might want to use technology for this or that.”
Another factor is how interested a mathematician is in teaching; how concerned a mathematician is about teaching. So, if he thinks that his job is research but teaching is something to bear, and there are teachers like that, you know, teaching is like a burden, it is not your main job, then, you have a different attitude. (Participant B)

Participant G indicated that the interest in teaching subfactor does not always imply positive attitude about software. Instead, an instructor’s resistance to change is the reason: “I know enough people that are quite interested in their teaching who would never touch software….It is all about how willing you are to experiment with things” (Participant G). Others implied that the time factor was the real reason why teaching faculty were more interested in innovative teaching than research faculty: “As far as your time goes, there is some give and take because teaching well and doing research well both require time” (Participant J). Yet, others implied that the identity factor, whether a professor perceived himself as a researcher or as a teacher of mathematics, was the main influence: “Most of the ones [mathematicians] who continue learning mathematics, who continue research, will say that they appreciate technology but….if you put the question from the point of view of teaching, they will object” (Participant A). So, the interviewees reflected on different subfactors of an instructor’s personality, but there was no full consensus on one of them.

Phase 3 explored the effect of instructor’s personality on attitude with regard to (a) knowledge about mathematics teaching, (b) interest in teaching, (c) resistance to change, and (d) the identity. The regression model indicated that the personality factor
was a strong predictor of attitude, with 44% of the attitude score accounted for by the personality factor when it was the only variable in the model, and 20% of the attitude score accounted for by the personality factor when other variables were modeled. Moreover, the interest in teaching and knowledge about mathematics teaching variables were predictive of the attitude score; 11.5% of the attitude variance was explained by these two subfactors. The resistance to change variable also explained 25.4% of the variance of the attitude variable. The consensus among results in Phases 1 and 3 and past studies suggests that personality is a factor that influence attitude. However, the aspects of this influence and the degree of influence of each subfactor varied in that Phase 1 participants did not all agree on all subfactors (see Chapter 5 for more details).

5. The institution. To the researcher’s knowledge, no study addressed the effect of the type of the institution on faculty members’ attitude regarding software use (see Chapters 2 and 3 for a reminder of the literature regarding this issue). It was reported, however, that two-year colleges and small four-year colleges’ use of technology in mathematics classrooms, was more than that of large PhD-granting departments (CTUM, 1990; Ellis, 2001; Kirkman, 2012; Lutzer et al., 2007). On the other hand, Beisiegel (2009) indicated that large research universities do not value teaching skills, whereas small teaching-oriented departments view high-quality teaching skills as a major requirement for a faculty member position. The NRC (1991) acknowledged that mathematics faculty in liberal arts colleges are required to dedicate time and energy to teaching. Moreover, A. C. Tucker (1999) addressed factors that support instructors in changing their pedagogical approaches in classrooms, including using appropriate
software, and indicated that successful experiences from colleagues could convince others to accept the challenge of change.

Phase 1 participants agreed with past research; Participant B, who was teaching at a small teaching-oriented department stated, “in a school like this, it [software] is really encouraged and welcomed…teaching is of course the most important concern here.” Participant G indicated that professors’ behaviors at a research department are strongly influenced by their obligations and commitments: “If you are under pressure to get…three papers a year, then you know, maybe figuring out how to use MATLAB is not such an attractive proposition.” On the other hand, the colleagues’ effect was also mentioned as an influence on attitude; “you might be more likely to use it because everyone else is using it” (Participant J); “if you see other people doing this and see them have successful experience, that is very compelling” (Participant G).

The instrument used in Phase 3 explored the effect of the institution. The result indicated that the institution factor was correlated with attitude but it was not predictive of it. However, one open-ended response supported the effect of the intuition as reported in Chapter 7 (pp. 182–183). Hence, there is inconsistency between the result of the regression model from one side and the results of Phase 1, the open-ended response in Phase 3, and past research from the other side. The reason for this inconsistency might be due to the fact that Phase 3 focused only on research PhD-granting departments. To investigate the institution factor in depth, the researcher explored the responses on the institution scale. It appeared that most of the survey respondents had similar departmental environment where there was no encouragement or expectation with regard to software
use. For example, 73.8% disagreed or strongly disagreed with the item “my department expect faculty to use software when teaching.” This invariability might be the reason behind the associated insignificant result \( t = 1.763, p = .078, \eta^2 = .017 \) of the regression model.

6. Research interest. Some participants in Phase 1 suggested that a mathematician’s area of research is an influence on attitude regarding software use in teaching; “if I know his [a mathematician] area of research, I can say something about what he might think about teaching using software” (Participant D); “someone who, for example, does work in set theoretic topology, this is such an incredibly abstract area that it is really does not seem likely to be open to using software” (Participant L). Other participants believed that, depending on the research area, software could become less or more important. “For some research areas, it [software] will be more useful, and even necessary, and for some other research areas, it [software] may not be necessary or may be totally not necessary” (Participant B); “there are certainly some branches of mathematics…you must have computers to do” (Participant H). Quinlan (2007) supported Participants’ B and H arguments; 22% of mathematicians, who participated in Quinlan’s study, said that software use was not important to their particular field. Moreover, Quinlan acknowledged that a mathematician’s research area influences the use of software in research. However, the research interest factor was not included in the initial model (Figure 3), and to the researcher’s knowledge, there is no study that addressed the effect of research interest on attitude toward software use in teaching.
$T$ tests in Phase 3 compared the mean attitude score of groups with certain research interest with the rest of the participants. The results indicated that there were statistically significant mean differences with relation to some of the groups of research interest, although the effect sizes were small (medium in the case of those interested in mathematics education). These are as follows:

- Analysts had a significant lower attitude than the rest of the participants.
- Applied mathematicians had a significant higher attitude than the rest of the participants.
- Mathematics educators had a significant higher attitude than the rest of the participants.
- Algebraist and topologists (combined) had a significant lower attitude than the rest of the participants.
- The group of discrete mathematics and combinatorics had a significant higher attitude than the rest of the participants.

However, tests used with other groups, such as logic, failed to detect any differences. Because the research interest factor emerged from the analysis of Phase 1 and was not initially expected, the design of this study did not ensure homogeneity of groups’ sample size with regard to areas of research, as shown in Table 25 (p. 170). This lack of homogeneity might be the reason behind the lack of statistical power. In addition, the significant $t$ test results matched the characteristics of most interviewees in Phase 1; for example, Participant A is an algebraist who opposes software use. However, the results contradicted what might be inferred from two participants in Phase 1: Participant
G was a topologist, yet advocated the use of software in teaching; Participant H has interest in numerical analysis, but was against the use of software in teaching, although both participants (G and H) suggested that the area of research was an influence on attitude regarding software use in teaching. Considering that the comparison here between aggregate group versus individual opinions, this discrepancy is not much of a concern. Moreover, Participant H is a heavy user of software in research, but did not advocate software use in teaching undergraduate classes. This past result raises questions about the difference between mathematicians’ attitude regarding software use in research and their attitude regarding software use in teaching and whether there is correlation between the two. Hence, although there is data in Phases 1 and 3 that suggest that research interest influences attitude, the limited knowledge in the literature and the heterogeneity among groups of research interest in this study call for more investigation with regard to the effect of areas of research on attitude.

7. Age. The age factor has been mentioned by several researchers as an influence on attitude regarding software use, although not directly. Stevens (2007) stated that new PhDs were more eager to use software. It might, therefore, be inferred that new PhDs were mostly young professors of mathematics. Stevens commented that new PhDs might have used software in their past experience, and so were familiar with it. At the school level, Baek et al. (2008) indicated the experienced elementary school teachers used technology in teaching only if they had to. Although Baek et al. addressed Grades K–12 and technology in general, given the lack of other studies in undergraduate level, Baek et al.’s findings are important. In Phase 1, almost all participants immediately mentioned
age when they were asked about the factors that influence attitude regarding software use. However, they connected the age effect with past experience. Agreeing with Stevens (2007), the participants pointed out that older mathematicians would have conservative attitude toward software use because they did not experience such tools in their education.

If you ask someone over 55 and they grew up without it… you are not going to change their mind…If you get someone 30–40…they grew up in a generation where they grew up with that, I would say that age is a big factor. (Participant E)

The relation between the age factor and the background factor is supported by the results of the survey. The GLM test that compared groups of different age indicated that age was a significant factor (Tables 27 and 28), however, this significance vanished when age was combined with other factors, such as education and teaching background (see pp. 179–180). Thus, past studies, Phase 1, and Phase 3 indicated that age is not a factor that influence attitude when controlling for the background effect.

8. Background. The background factor is composed of three subfactors: (a) culture, (b) past education, and (c) teaching experience. As noted in Chapters 2 and 3, each of these has been explored in past research. It has been acknowledged that some cultures do not advocate software use in mathematics instruction (Habre, 2011). Moreover, the length of teaching experience has been mentioned as one factor that influence teaching strategies in general (Bransford et al., 2000), and attitude regarding software use in specific (Stevens, 2007). In addition, Hollebrands et al. (2010)
acknowledged that future mathematicians did not use software in their arguments because they learned mathematics traditionally by using formal proofs. The findings from these studies were not different from what the interviewees implied, “of course, you are affected by the environment you grew up in, and the way you were educated is very important for decision making” (Participant D).

It also depends on where someone was educated. I mean, students who have come up the American system, have seen a lot of this stuff and are more comfortable than someone from Eastern Europe….If you have got 20 years teaching in a certain system and you come here, then you view anything that is outside that as a threat. (Participant G)

However, the interview participants indicated that the effect of the length of teaching experience and culture were related to the educational and teaching backgrounds. In sum, past experience—as a student or as a teacher of mathematics—is the major influence, “so if the person came through with a very traditional lecture/exam approach to learning mathematics, they will do the lecture/exam thing” (Participant C).

The interviewees’ argument is supported by the results of Phase 3. ANOVAs, a t test, and linear regressions were used on the different items that constitute the background factor (see pp. 174–179). The several statistical tests suggested that educational and teaching backgrounds predicted the attitude score and no significant variance was explained by culture or the length of teaching experience. Thus, the triangulation of results among Phase 1, Phase 3, and past research support the educational background and teaching background with regard to software use.
Summary of the triangulation process with regard to Research Question 2. The triangulation process compared and contrasted the results among existing theories, reviewed research results, and the results of Phases 1 and 3 with regard to each of the eight suggested factors and their subfactors in Figure 4 (p. 126). The results of this triangulation process supported three factors:

- software characteristics;
- perceived effect;
- instructor’s personality.

The triangulation results also supported certain subfactors of the background factor:

- educational background with regard to software use;
- teaching background with regard to software use.

Moreover, the results transformed the course being taught factor to:

- students’ level;
- students’ major.

On the other hand, the triangulation results did not fully support

- the research interest factor;
- the institution factor.

Overall, the results of the triangulation process suggest that the research interest factor was an influence on attitude, but only with regard to certain areas and with unmatched results in certain cases. Moreover, the institution was not supported in Phase 3 as a predictor, and the age factor was not found to be predictive of attitude.
Transformation From the Expanded Model to the Final Model

The results of the triangulation process transformed the expanded model (Figure 4, p. 126) to the final model (Figure 15, p. 207), which is the model that summarizes the results of this research and reflects on possible factors that influence mathematicians’ dispositions toward software use based on these results. This study suggests that software characteristics, perceived effect on learning, instructors’ personality, educational background with regard to software use, teaching background with regard to software use, students’ level, and students’ major are all reasons that give insight into a mathematicians’ attitude regarding software use. The findings indicate that the institution and the research interest factors might be influential on attitude. The solid arrows in Figure 15 reflect the suggested predictive relationships, with the thickness of the arrow representing the strength of the suggested influence. The dashed arrows indicate that the predictive relationship was not supported by all phases of the research and that further investigation is needed.

Reflexivity and Lessons Learned

At the start of this study, I had several conjectures about software use in mathematics instruction and the reasons that might influence a mathematician’s attitude about software use. The literature supported some of these conjectures, and they were included in the initial model (Figure 3, p. 81). However, during the interview process, my thinking shifted toward other emerging factors, such as the perceived effect on student learning and research interest. Moreover, because the results of this study supported the findings of past studies about the possible limitations of software, I believe that a focus of future research should be on addressing such limitations. Software integration in
mathematics classrooms is expected to increase given the overall impact of technology on our lives. Hence, future research should address how to minimize these limitations and maximize the benefits of software use.

*Figure 15: The final model.*
During the research process, some unanticipated limitations occurred. In Phase 1, the researcher met only once with each interviewee. Because each interview was used to guide the next one, some participants did not have the opportunity to reflect on certain emerging factors. A second round of interviews would have given these participants an opportunity for such reflection and may have enhanced the data obtained. Nevertheless, the member-check procedure allowed all of the interviewees to verify the researcher’s interpretations, and in two cases, to express their beliefs in detail, including reference to such emerging factors as perceived effect. In Phase 3, the researcher created the instrument tested the factors in the expanded model (Figure 4, p. 126); hence, the items of this instrument were closed-ended (Schensul et al., 1999). This rational was not communicated to the potential participants of Phase 3. The invitational letter to the participants did not inform them about the previous phases of the research. Considering the life style of the potential participants, the letter was concise and limited to essential information (Appendix I). Consequently, three survey respondents replied with e-mail messages indicating that they were unsatisfied because all of the items were closed-ended, and expressed their opinions on various issues related to software use. Moreover, 20 recipients started the survey and did not submit it. Hence, there is reasons to believe that the lack of open-ended response options may have affected the response rate.

**Implications and Recommendations**

This study advanced the existing knowledge base about academic mathematicians’ attitudes, beliefs, and perceptions toward software integration in undergraduate instruction. This study used a qualitative investigation to generate a list of
8 factors and 16 subfactors, then used a quantitative approach to explore them. Ultimately, 9 factors emerged as influential on attitude. The results of this study reported the perspectives of proponents, skeptics, and critics regarding why, how, and when to use software in mathematics classrooms. It also shed light on a set of factors that might contribute to mathematicians’ dispositions including background, personality, and software characteristics. However, the complexity of the relationships among factors suggests a need for further research. In addition, past studies mentioned and even investigated some factors, but new factors emerged. Hence, follow-up studies are recommended, some of which should investigate selected individual factors or sets of related factors.

This study identified nine factors as influencing attitude, but due to its exploratory nature, it did not confirm the effect of any of these factors. Hence, replication of this research with regard to individual factors or groups of factors is needed to clarify and strengthen the findings of this research. Follow-up studies should focus on the research interest factor, especially because the design of this study did not ensure homogeneity of sample size of groups of different research interests. Follow-up studies should also investigate the institution factor because this study focused only on PhD-granting departments, which led to a lack of knowledge on the attitude of mathematicians at other types of institutions. Hence, individual studies that are appropriately designed to specifically explore each of these factors would advance the results of this study.

Moreover, although the different tests in Phase 3 indicated that culture was not a factor that influence attitude, the heterogeneity among groups of different cultures calls
for further investigation. Additionally, this study used Fishbein and Ajzen’s (1975) framework, but focused only on attitude and did not look into mathematicians’ behaviors. Future studies might use classroom observation to compare an individual’s behavior with the individual’s attitude. This study initially did not include other frameworks such as Stein et al. (2007) curriculum framework and the antecedent work of Stein, Smith, Henningsen, and Silver (2000). Hence, the researcher recommends replication of this study with a focus on cross-theory triangulation in model development related to software use.

Gender is a factor that often is considered in educational research. As noted in Chapter 1, gender was not included in the initial model or the expanded model because it was not identified in past research or the interview data as an influence on attitude regarding software use in collegiate classrooms. However, because there is no evidence that suggests eliminating gender as a factor, investigating it in future research is recommended.

The purpose of this research was not to call for more software integration in undergraduate instruction. Rather, this study aimed for in-depth understanding of both opponents and advocates’ perspectives. However, improving the level of awareness and involvement of academic mathematicians with regard to teaching topics in general, and software use in specific, is recommended. Undergraduate instruction will benefit from mathematicians’ input. Opponents, skeptics, and supporters’ opinions, suggested solutions, and interventions should be discussed at the departmental level, the institutional level, and the national level. They should be shared not only with the communities of mathematicians and mathematics educators, but also with software
developers and policy makers at the school level and the collegiate level. As Rodi (1986) suggested for calculus instruction, changes in undergraduate classrooms are never possible without considerable attention from mathematicians to what is taught and how it is taught. Up to 60% of the respondents in Phase 3 reported reading research articles in mathematics education less than once a year. Given that only a subset of these articles would concern software use in teaching mathematics, mathematicians likely are not well-informed about such matter. As emphasized in Chapter 1, some mathematicians believe that students come from high school with an inappropriately low level of skills (Ralston, 1999; Quinlan, 2007). Increasing the level of mathematicians’ involvement might not only address this concern, but also address the lack of alignment between school and undergraduate classrooms with regard to software integration.

However, mathematicians’ involvement requires adequate support at the institutional level. Given the many responsibilities of research mathematicians, the results of this study recommend that research departments support their faculty members in their teaching responsibilities. Academic mathematicians deserve to have sufficient time to investigate and explore innovative pedagogy, and hence decide on software use according to what is appropriate for them and their students. Several participants in Phase 1 and Phase 3 expressed their concern regarding the time factor. In addition, Bass (1999), Beisiegel (2009), Kehoe (2009), and participants of this study (F, G, H, Z) commented that researchers devote insufficient attention to their teaching. This certainly should not be the case; to the contrary, mathematics researchers should be the best mathematics teachers, and only they can make this so (A. C. Tucker, 1999).
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Appendix A: Ohio University Consent Form

Title of Research: Academic Mathematicians’ Dispositions Toward Software Use in Mathematics Instruction: What Are the Underlying Reasons?
Researcher: Heba Bakr Khoshaim

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in this study. You should receive a copy of this document to take with you.

Explanation of Study
This study aims to investigate academic mathematicians’ dispositions toward mathematical software use in mathematics instruction and the reasons underlying their dispositions.
If you agree to participate, you will be asked to participate in a 1–2 hour interview that will be conducted according to your availability and preference. After the interview, and upon analyzing the data, you will receive a copy of the transcripts and the analysis requesting your agreement on the interpretation of the results. You will also be asked to respond to a survey later on in the study. Your participation in the study will end by responding to this survey.

Risks and Discomforts
There are no anticipated risks in this study. Your participation is voluntary; there is no obligation to complete the interview and you may quit the interview process if you change your mind partway the process.

Benefits
This study is important to mathematics society and mathematics education society because there is limited research on academic mathematicians’ dispositions toward software use when teaching mathematics, and the reasons that have influenced these dispositions. Hence, this study is intended to advance the existing knowledge base. Most prior work that has addressed this issue has focused on university professors’ attitudes toward software use while working with those who were already using software in their teaching, thus potentially ignoring both skeptics and critics. The findings of this study could then have implications both for better understanding of the dispositions of these individuals and potential reform regarding software implementations in the future. Yet, because most studies focused on school level with little attention given to undergraduate classrooms this study will expand the literature about the collegiate level.
Confidentiality and Records
The information that you will provide will be kept confidential. The recording will be securely stored in a closed cabinet that is accessible only to me. The transcripts will not contain names and will be coded by letters. The code list will be stored in a password protected PC. The recording and the code list will not be shared with any one. However, the coded transcripts might be shared with colleagues for analysis purposes and quotes from the transcripts might be used in later publications of this study.

Compensation
As compensation for your time and effort, you will receive a gift card from Barnes and Noble.

Contact Information
If you have any concerns or need any further clarifications, please do not hesitate to contact me by e-mail at hk329008@ohio.edu or by telephone at 740–591–2282, or contact my adviser Dr. Gregory D. Foley by e-mail at foleyg@ohio.edu or by telephone at 740–593–4430.

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740) 593-0664.

Thanks for your valued assistance and cooperation.

By signing below, you are agreeing that:

• you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered
• you have been informed of potential risks and they have been explained to your satisfaction.
• you understand Ohio University has no funds set aside for any injuries you might receive as a result of participating in this study
• you are 18 years of age or older
• your participation in this research is completely voluntary
• you may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you and you will not lose any benefits to which you are otherwise entitled.

Signature_________________________________Date_________________________

Printed Name____________________________________________________________
Appendix B: Semistructured Interview Protocol

The following are the open-ended prompts that were used in approximately 60 min interviews with 11 informants in Phase 1. The prompts were not used in this particular order. In addition, follow-up prompts were used as appropriate.

1. Let’s start by talking about your background in teaching and teaching experience.

2. One issue caught my interest in the literature is that some researchers believe that mathematics and mathematics education are two different cultures and communities, that they have different interests, and that they speak different languages about mathematics. Would you please reflect on your perceptions regarding mathematics and mathematics education communities. Do you consider yourself a mathematician, or a teacher? Or both?

3. Would you please elaborate on your typical teaching style for undergraduate mathematics courses, and whether it involves any kind of software integration.

4. What thoughts do you have about the effectiveness of software use in undergraduate mathematics instruction? To what extent is using software in undergraduate mathematics instruction important?

5. What is your believe about the effectiveness of a programming software such as ISETLE?

6. Since the 1980s, there have been calls to reform the teaching of undergraduate mathematics. One such call was known as Calculus Reform Movement. Please share with me your opinion about mathematicians’ involvement, commitments,
and attitudes regarding these calls for reform. In your view, how are these calls
for reform connected to software use in classrooms?

7. What, in your opinion, may influence a professor’s decision regarding software
integration in undergraduate classrooms, either positively or negatively?

8. Where, in your opinion, does the academic mathematics community stand
regarding software use in undergraduate mathematics instruction?

9. There have been some studies that investigated the effect of certain factors on
instructors’ attitudes and classroom behaviors. These factors include

• The instructor’s cultural background

• The nature and level of the course being taught

• The instructor’s prior education and experience

• The instructor’s beliefs and knowledge about mathematics teaching and
learning

Please share with me your thoughts regarding these factors and how they might
influence a mathematics professor’s disposition regarding software use.

10. What, in your opinion, are other factors that might influence a mathematics
professor’s disposition regarding software use?

11. Who, in your opinion, would be a useful informant regarding the issue that we
have discussed today?

12. What would be a good name for the survey that might help increase the response
rate among skeptics and address the nonresponse bias?
### Appendix C: Comprehensive Chart

#### Table C1

*Sample Section of the Comprehensive Chart*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Key Quotes</th>
<th>Interpretation</th>
<th>Related Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational and cultural background</td>
<td>“Learning and teaching with a calculator has become more of a culture than a conviction…mathematicians…who were not born here…they will not think it’s a necessity and they will be against looking at it as necessity” (Participant A). If you have been taught in a traditional way…then of course it will be difficult to start using it…[However] the way you have been taught is not the only indicator of how you are going to teach” (Participant B). If the person came through with a very traditional lecture/exam approach to learning mathematics, they will do the lecture/exam thing; where if someone was grown up being familiar with these thing, then they will be more incline to use them…I would probably say that the group most likely that would not incorporate technology is the group from Eastern Europe” (Participant C). You are affected by the environment you grew up in, and the way you were educated…but it may not be a dominant factor” (Participant D). If you are coming from a country where you are not used to…it, then you might be more incline to not use it” (Participant F). It also depends on where someone was educated. I mean, students who have come up the American system, have seen a lot of these stuff…than someone from Eastern Europe” (Participant G). They [mathematicians] could be coming from the culture where they’re encouraging conformity, in which case, just trying something different maybe discouraged in that culture” (Participant H). “The experience as a student has a big influence” (Participant J).</td>
<td>Almost all participants agreed that culture could be a factor that influences a mathematician’s attitude toward software use. However, this influence is related to the educational background. The educational background is the real reason behind the resistance to use software from non-American mathematicians. The length of the mathematician’s experience with the traditional approach, or the limited experience with the new approach, is also related to the effect of cultural background.</td>
<td><em>We teach the way we were taught is the basic principle for many mathematicians, future mathematicians, and teachers in general (Sandholz et al., 2000; Shulman, 2004; Stigler &amp; Hiebert, 1999). Mathematics teaching methods in the United States are different from those used in other countries (Stigler &amp; Hiebert, 1999). Beyer (1997) took the position that culture influences individual’s motivation and practice in higher education. Shao (2010) indicated that in the Chinese culture, students are expected to strengthen their ability in mental computation and not to depend on calculators.</em></td>
</tr>
</tbody>
</table>
Appendix D: Attitude Instrument for Mathematics and Applied Technology

[AIM-AT]

The following instrument was used by Fleener (1995) to measure instructors’ attitude regarding the use of calculators in classrooms. The instrument consists of three categories: cognitive, experimental, and affective. The rest of Appendix D have been copied from Fleener (1995, pp. 484–485)

1) Students should not be allowed to use a calculator while taking math tests.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

2) Calculator use will cause a decline in basic arithmetic facts.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

3) Calculators are motivational.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

4) Calculators make mathematics fun.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

5) When students work with calculators, they don’t need to show their work on paper.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

6) Mathematics is easier if a calculator is used to solve problems.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

7) More interesting mathematics problems can be done when students have access to calculators.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree
8) Students understand mathematics better if they solve problems using paper and pencil.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

9) Students should not be allowed to use calculators until they have mastered the concept or procedure.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

10) All students should learn to use calculators
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

11) Using calculators will make students try harder.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

12) Calculators should be used only to check work once the problem has been worked out on paper.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

13) Calculators should be used on mathematics homework.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

14) Using calculators will cause students to lose basic computational skills.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

15) Using calculators makes students better problem solvers.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

16) Continued use of calculators will cause a decrease in student estimation skills.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

17) I have calculators available for my class(es) to use.
(A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
18) Most of my students have access to their own calculators.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
19) Calculators are only tools for doing calculations more quickly.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
20) I have used graphing calculators in my classroom before.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
21) I am proficient at using scientific calculators.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
22) I know ways I can use the calculators effectively in my classroom.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree
23) I have lots of ideas about how I can make use of calculators.
   (A) Strongly agree  (B) Agree  (C) Disagree  (D) Strongly Disagree

Category 1 (Cognitive Description)
Beliefs about effect and appropriate use of the calculator. Items: 1, 2, 5, 6, 8, 9, 10, 12, 13, 14, 15, 16, 19

Category 2 (Experiential Description)
Experience with and use of calculators in teaching. Items: 17, 18, 20, 21, 22, 23

Category 3 (Affective Description)
Beliefs about affective results of using calculators in the classroom. Items: 3, 4, 7, 11
Appendix E: Modified Draft of the AIM-AT Instrument

The following instrument is a modified version of the AIM-AT instrument. The word calculator has been substituted with the word software in all items. Specifically, items 2, 3, 5, 6, 10, 16, 19, 21, 22, and 23 have been reworded.

1. Students should not be allowed to use any kind of software while taking math tests.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

2. Software use causes a decline in computational skills.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

3. Software motivates students to learn mathematics.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

4. Software makes mathematics fun.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

5. When students work with software, they don’t need to explain their work.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

6. Mathematics is easier for students if software is used to solve problems.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

7. More interesting mathematics problems can be done when students have access to software.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree

8. Students understand mathematics better if they solve problems using paper and pencil.
   (A) Strongly agree     (B) Agree     (C) Disagree     (D) Strongly Disagree
9. Students should not be allowed to use any kinds of software until they have mastered the concept or procedure.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

10. All students should learn to use mathematical software.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

11. Using software will make students try harder.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

12. Software should be used only to check work once the problem has been worked out on paper.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

13. Software should be used on mathematics homework.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

14. Using software will cause students to lose basic computational skills.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

15. Using software makes students better problem solvers.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

16. The use of software causes a decrease in student estimation skills.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

17. I have software available for my class(es) to use.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

18. Most of my students have access to their own software.
    (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree
19. Software is only a tool for solving a problem more quickly.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

20. I have used graphing calculators in my classroom before.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

21. I am proficient at using mathematical software.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

22. I know ways I can use software effectively in teaching.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree

23. I have lots of ideas about how to teach using mathematical software.
   (A) Strongly agree   (B) Agree   (C) Disagree   (D) Strongly Disagree
Appendix F: Permission to Use the AIM-AT Instrument

Re: Seeking your permission
Jayne Fleener [fleener@ncsu.edu]

You replied on 8/31/2011 10:55 PM.

Sent: Wednesday, August 31, 2011 10:53 PM
To: Khosain, Heba

Dear Heba,

Thank you for letting me know of your interest in using the AIM-AT. I am pleased to provide my permission for your use. Let me know how your study comes out. Good luck!!

>>> "Khosain, Heba" <hk329008@ohio.edu> 8/31/2011 12:28 PM >>>

Dear Professor Fleener:

My name is Heba Bakr Khosain. I am a PhD candidate at Ohio University in Athens, Ohio, currently working under the direction of Dr. Gregory D. Foley, the Robert L. Morton Professor of Mathematics Education. My dissertation is titled: Academic Mathematicians' Dispositions Toward Software Use in Mathematics Instruction: What Are the Underlying Reasons? The goal of the study is not to emphasize a certain teaching method, but rather to clarify academic mathematicians' opinions regarding software use. The study will report the opinions of both advocates and skeptics regarding software use in teaching as well as the reasons for their opinions. After reviewing the literature for an appropriate instrument to measure academic mathematicians' attitude toward software use in teaching, I found that the Attitude Instrument for Mathematics and Applied Technology (AIM-AT) that you have adapted and used in your 1995 publication—A Survey of Mathematics Teachers' Attitudes About Calculators: The Impact of Philosophical Orientation—is suitable for my study.

I am sending this email to seek your permission to adapt the AIM-AT instrument for my study.

If you have any concerns or need any further clarifications, please do not hesitate to contact me by e-mail at hk329008@ohio.edu or hkhosain@gmail.com or by telephone at 740-591-2282.

Thank you for your valued assistance and cooperation.

Sincerely,

Heba Khosain
Appendix G: E-Mail Invitation to Each Participant in the Pilot Study

Dear professor:

My name is Heba Bakr Khoshaim. I am a PhD candidate at Ohio University, working under Dr. Gregory D. Foley, the Robert L. Morton Professor of Mathematics Education. I wish to invite you to participate in a pilot study that aims to test a survey instrument. The survey is developed to be used in my dissertation titled *Academic mathematicians’ dispositions toward software use in mathematics instruction: What are the underlying reasons?* The pilot study involves only the Department of Mathematics at Ohio University and its regional campuses. The full study will involve 50 of 185 PhD-granting departments in the United States.

**Purpose:**
The goal of the pilot study is to receive feedback about the appropriateness of the survey instrument. Specifically, your participation will help me identify any problems with regard to the clarity and flow of the items. Your participation will help improve the quality of the survey instrument.

**Participation:**
Your participation is voluntary and will be greatly appreciated. You may quit the survey if you change your mind partway through the process. If needed, you may stop partway through and return to complete the survey at a later time. The survey should take approximately 5–10 minutes. Please follow the link below to the survey.

**Compensation:**
Upon completing the survey you will get a chance to be one of five participants to win a $20.00 gift card from Barnes and Noble as compensation for your participation. There is no obligation to complete the survey.

**Confidentiality:**
A number code system will be used with the responses to maintain confidentiality. Please click on the link below to take the survey.

**Contact Information:**
If you have any concerns or need any further clarifications, please do not hesitate to contact me by e-mail at hk329008@ohio.edu or by telephone at 740–591–2282, or contact my adviser Dr. Gregory D. Foley by e-mail at foleyg@ohio.edu or by telephone at 740–593–4430. Thanks for your valued assistance and cooperation.
Appendix H: Groupings of U.S. PhD-Granting Mathematics Departments

PhD-granting mathematics departments have been divided in groups based on their scores in the NRC (1995) publication—*Research-Doctorate Programs in the United States: Continuity and Change* (Cleary et al., 2010).

Group I is composed of 48 doctoral-granting departments with scores in the 3.00–5.00 range. Group I Public and Group I Private are Group I doctoral-granting departments at public institutions and private institutions respectively. Group II is composed of 56 doctoral-granting departments with scores in the 2.00–2.99 range. Group III contains the remaining U.S. doctoral-granting departments, including a number of departments not included in the 1995 ranking of program faculty. (Cleary et al., 2010, p. 1317)

**Group I (A: 25 Departments—Public)**

1. City University of New York, Graduate Center
2. Georgia Institute of Technology
3. Indiana University, Bloomington
4. Michigan State University
5. Ohio State University, Columbus
6. Pennsylvania State University
7. Purdue University
8. Rutgers, the State University of New Jersey
9. State University of New York at Stony Brook
10. University of California, Berkeley
11. University of California, Los Angeles
12. University of California, San Diego
13. University of California, Santa Barbara
14. University of Illinois at Chicago
15. University of Illinois, Urbana–Champaign
16. University of Maryland, College Park
17. University of Michigan, Ann Arbor
18. University of Minnesota, Twin Cities
19. University of North Carolina at Chapel Hill
20. University of Oregon
21. University of Texas at Austin
22. University of Utah
23. University of Virginia
24. University of Washington
25. University of Wisconsin, Madison

**Group I (B: 23 Departments—Private)**

1. Boston University
2. Brandeis University
3. Brown University
4. California Institute of Technology
5. Carnegie Mellon University
6. Columbia University
7. Cornell University
8. Duke University
9. Harvard University
10. Johns Hopkins University, Baltimore
11. Massachusetts Institute of Technology
12. New York University, Courant Institute
13. Northwestern University
14. Princeton University
15. Rensselaer Polytechnic Institute
16. Rice University
17. Stanford University
18. University of Chicago
19. University of Notre Dame
20. University of Pennsylvania
21. University of Southern California
22. Washington University
23. Yale University

**Group II (56 Departments)**

1. Arizona State University
2. Auburn University
3. Case Western Reserve University
4. Claremont Graduate University
5. Clemson University
6. Colorado State University
7. Dartmouth College
8. Florida State University
9. Iowa State University
10. Kansas State University
11. Kent State University
12. Lehigh University
13. Louisiana State University, Baton Rouge
14. North Carolina State University, Raleigh
15. Northeastern University
16. Oregon State University
17. Polytechnic Institute of New York
18. Binghamton University, State University of New York
19. Syracuse University
20. Temple University
21. Texas A and M University
22. Texas Tech University
23. Tulane University
24. University at Albany, State University of New York
25. University of Arizona
26. University at Buffalo, State University of New York
27. University of California, Davis
28. University of California, Irvine
29. University of California, Riverside
30. University of California, Santa Cruz
31. University of Cincinnati
32. University of Colorado, Boulder
33. University of Connecticut, Storrs
34. University of Delaware
35. University of Florida
36. University of Georgia
37. University of Hawaii at Mano
38. University of Houston
39. University of Iowa
40. University of Kentucky
41. University of Massachusetts, Amherst
42. University of Miami
43. University of Missouri, Columbia
44. University of Nebraska, Lincoln
45. University of North Texas
46. University of Oklahoma
47. University of Pittsburgh
48. University of Rochester
49. University of South Carolina
50. University of Tennessee, Knoxville
51. University of Texas at Arlington
52. Vanderbilt University
53. Virginia Polytechnic Institute and State University
54. Washington State University
55. Wayne State University
56. Wesleyan University


1. Bowling Green State University
2. Clarkson University
3. Colorado School of Mines
4. Drexel University
5. George Washington University
6. Howard University
7. Idaho State University
8. Illinois State University
9. Missouri University of Science and Technology
10. New Mexico State University, Las Cruces
11. Northern Illinois University
12. Ohio University, Athens
13. Old Dominion University
14. Southern Illinois University, Carbondale
15. Southern Methodist University
16. St. Louis University
17. Stevens Institute of Technology
18. University of Alabama
19. University of Alabama, Huntsville
20. University of Louisiana at Lafayette
21. University of Maryland, Baltimore County
22. University of Mississippi
23. University of Rhode Island
24. University of South Florida
25. University of Texas at Dallas
26. University of Wisconsin, Milwaukee
27. University of Wyoming
28. Western Michigan University
Group III (B: 53 Departments Not Ranked by NRC (1995) Study)

1. Air Force Institute of Technology
2. Baylor University
3. Boston College
4. Brigham Young University
5. Bryn Mawr College
6. Central Michigan University
7. College of William and Mary
8. Emory University
9. Florida Atlantic University
10. George Mason University
11. Georgia State University
12. Indiana University–Purdue University, Indianapolis
13. Marquette University
14. Michigan Technological University
15. Mississippi State University
16. Montana State University, Bozeman
17. Naval Postgraduate School
18. New Mexico Institute of Mining and Technology
19. New Jersey Institute of Technology
20. North Dakota State University, Fargo
21. Oakland University
22. Oklahoma State University
23. Portland State University
24. Rutgers University, Newark
25. South Dakota State University
26. Texas State University, San Marcos
27. Tufts University
28. University of Akron
29. University of Alabama at Birmingham
30. University of Alaska, Fairbanks
31. University of Arkansas at Fayetteville
32. University of Central Florida
33. University of Colorado, Denver
34. University of Denver
35. University of Idaho
36. University of Kansas
37. University of Memphis
38. University of Missouri, Kansas City
39. University of Missouri, St. Louis
40. University of Montana, Missoula
41. University of Nevada, Las Vegas
42. University of New Hampshire
43. University of New Mexico
44. University of North Carolina at Charlotte
45. University of North Carolina at Greensboro
46. University of Northern Colorado
47. University of Southern Mississippi
48. University of Toledo
49. University of Vermont
50. Utah State University
51. West Virginia University
52. Wichita State University
53. Worcester Polytechnic Institute
Appendix I: Sample Letters to Department Chairs and Faculty Members

Sample Letter to Department Chairs

Dear Department Chair:

My name is Heba Bakr Khoshaim. I am a PhD candidate at Ohio University in Athens, Ohio, working under Dr. Gregory D. Foley, the Robert L. Morton Professor of Mathematics Education. I am collecting data for my dissertation study that aims to investigate academic mathematicians’ dispositions toward software use in mathematics instruction and the reasons underlying their dispositions. This study is intended for tenured or tenure-track full-time mathematics professors in PhD-granting mathematics departments in the United States. Through a random selection process, your department is one of 50 departments that have been chosen to participate. This letter is an invitation for you and your faculty to participate.

Purpose:
This study of dispositions is for academic purposes only, and it is my intention to publish the results in the Notices of the AMS. The goal of the study is not to emphasize a certain teaching method, but rather to clarify academic mathematicians’ opinions regarding software use. The study will report the opinions of both advocates and skeptics regarding software use in teaching as well as the reasons for their opinions.

Participation:
Participation in this study is voluntary; however, your and your department’s participation will be highly appreciated. Participation involves completing a survey that was developed specifically for this study. The survey is designed in a way that allow participants to quit the survey if they change their mind partway through the process. If needed, they may stop partway through and return to complete the survey at a later time. The survey should take only 10–20 minutes.

On November 10, 2011, you will receive an invitational e-mail titled “Invitation: What do mathematicians think regarding technology use in mathematics instruction?” The email will include the link to the survey. If it is agreeable to you, kindly forward the e-mail to all eligible faculty and encourage them to consider participating in this study. Eligible faculty will also receive an invitational e-mail that explains the study and includes the link to the survey.

Compensation:
The departments with the five highest response rates to the survey will receive three 12 oz bags of Seattle’s Best coffee.

Confidentiality:
A number code system will be used with the responses to maintain confidentiality.
Contact Information:
If you have any concerns or need any further clarifications, please do not hesitate to contact me by e-mail at hk329008@ohio.edu or by telephone at 740–591–2282, or contact my adviser, Dr. Gregory D. Foley, by e-mail at foleyg@ohio.edu or by telephone at 740–593–4430. Thanks for your valued assistance and cooperation.

Sincerely,
Invitation Email to Each Participant

Dear Professor:
My name is Heba Bakr Khoshaim. I am a PhD candidate at Ohio University in Athens, Ohio, working under Dr. Gregory D. Foley, the Robert L. Morton Professor of Mathematics Education. I am collecting data for my dissertation study that aims to investigate academic mathematicians’ dispositions toward software use in mathematics instruction and the reasons underlying their dispositions. This study is intended for tenured or tenure-track full-time mathematics professors in PhD-granting mathematics departments in the United States. Through a random selection process, your department is one of 50 departments that have been chosen to participate. This letter is an invitation for you to participate.

Purpose:
This study of dispositions is for academic purposes only, and it is my intention to publish the results in the Notices of the AMS. The goal of the study is NOT to emphasize a certain teaching method, but rather to clarify academic mathematicians’ opinions regarding software use. The study will report the opinions of both advocates and skeptics regarding software use in teaching as well as the reasons for their opinions.

Participation:
Participation in this study is voluntary; however, your participation will be highly appreciated. Participation involves completing a survey that was developed specifically for this study. The survey should take only 10–20 minutes and it contains only multiple-choice questions. You may quit the survey if you change your mind partway through the process and you may refuse to answer any of the questions except the 1st five questions. If needed, you may stop partway through and return to complete the survey at a later time. Please click on the link below to take the survey.

Compensation:
The departments with the five highest response rates to the survey will receive three 12 oz bags of Seattle’s Best coffee.

Confidentiality:
A number code system will be used with the responses to maintain confidentiality. Please click on the link below to take the survey.

Contact Information:
If you have any concerns or need any further clarifications, please do not hesitate to contact me by e-mail at hk329008@ohio.edu or by telephone at 740–591–2282, or contact my adviser Dr. Gregory D. Foley by e-mail at foleyg@ohio.edu or by telephone at 740–593–4430. Thanks for your valued assistance and cooperation.
Appendix J: Project Timeline

Table J1

*Time Frame for Each Research Activity in All Phases*

<table>
<thead>
<tr>
<th>Phase</th>
<th>Research Activity</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Research proposal presentation and approval</td>
<td>June 3, 2011</td>
</tr>
<tr>
<td>0</td>
<td>Addressing committee’s comments; Submitting IRB forms; IRB approval</td>
<td>June 3–June 17, 2011</td>
</tr>
<tr>
<td>1</td>
<td>Interviews: One-hour interviews with 11 informants; ongoing analysis;</td>
<td>June 17–September 20, 2011</td>
</tr>
<tr>
<td>1, 2</td>
<td>Refining the formative model; member-check with interviewees; peer debriefing; developing the instrument; administering the instrument with Phase 1 participants</td>
<td>September 20–October 10, 2011</td>
</tr>
<tr>
<td>2</td>
<td>Piloting the instrument; revising the instrument</td>
<td>October 10–November 5, 2011</td>
</tr>
<tr>
<td>3</td>
<td>Selecting 50 PhD-granting departments; preparing contact information and letters for department chairs; identifying all eligible participants in all 50 departments; sending letters to department chairs and e-mails to potential participants</td>
<td>November 5–10, 2011</td>
</tr>
<tr>
<td>3</td>
<td>Receiving responses; following-up on nonrespondents</td>
<td>November 10–30, 2011</td>
</tr>
<tr>
<td>3</td>
<td>Quantitative analysis; writing analysis results</td>
<td>December 1–31, 2011</td>
</tr>
<tr>
<td>3</td>
<td>Triangulation among interview results, initial model and, survey results; discussion</td>
<td>January 1–February 1, 2012</td>
</tr>
<tr>
<td>3</td>
<td>Revision</td>
<td>February 1–March 15, 2012</td>
</tr>
</tbody>
</table>
### Appendix K: Instrument Used in the Pilot Study

**Table K1**

*Summary of the Instrument Used in the Pilot Study*

<table>
<thead>
<tr>
<th>The Factor</th>
<th>Number of items in each scale</th>
<th>The Item(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course being taught</td>
<td>6</td>
<td>47, 48, 49, 50, 51, 52</td>
</tr>
<tr>
<td>The Software scale</td>
<td>7</td>
<td>21, 22, 23, 24, 25, 26, 27</td>
</tr>
<tr>
<td>Perceived effect scale</td>
<td>8</td>
<td>4, 5, 6, 7, 8, 9, 10, 11</td>
</tr>
<tr>
<td>Instructor’ personality scale</td>
<td>6-item scale</td>
<td>34, 35, 36, 37, 38, 39</td>
</tr>
<tr>
<td>The Institution scale</td>
<td>6-item scale</td>
<td>41, 42, 43, 44, 45, 46</td>
</tr>
<tr>
<td>Research interest</td>
<td>1 item for research interest</td>
<td>3</td>
</tr>
<tr>
<td>Age</td>
<td>1 item for age</td>
<td>40</td>
</tr>
<tr>
<td>Instructor’s background; demographic items</td>
<td>6</td>
<td>28, 29, 30, 31, 32, 33</td>
</tr>
</tbody>
</table>
### Table K2

*Instrument Used in the Pilot Study*

<table>
<thead>
<tr>
<th>#</th>
<th>The statement</th>
<th>The choices</th>
<th>The factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I am</td>
<td>(A) a professor of mathematics. (B) a PhD student in mathematics. (C) None of the above.</td>
<td>This item is to ensure the respondent is either a mathematics professor or a PhD student.</td>
</tr>
<tr>
<td>2</td>
<td>I am</td>
<td>(A) Tenured. (B) In a tenure-track position. (C) Other</td>
<td>This item will be displayed when (A) is chosen in the last question to ensure that the subject is from the population of interest.</td>
</tr>
<tr>
<td>3</td>
<td>My research interest is</td>
<td>(A) Algebra (B) Analysis (C) Applied Mathematics (D) Differential Equations (E) Dynamical Systems (F) Geometry (G) Mathematics Education (H) Statistics (I) Topology (J) Other</td>
<td>This item is to ensure that the subject is from the population of interest, in addition to identify the research interest.</td>
</tr>
<tr>
<td>3A</td>
<td>I have a PhD degree in</td>
<td>(A) Mathematics Education only. (B) Mathematics and mathematics education. (C) Mathematics only.</td>
<td>This item will be displayed when (G) is chosen for item number (3) to ensure that the subject is from the population of interest.</td>
</tr>
<tr>
<td>3B</td>
<td>I teach</td>
<td>(A) Mathematics and statistics courses. (B) Statistics courses only. (C) Mathematics courses only.</td>
<td>This item will be displayed when (H) is chosen for item number (3) to ensure that the subject is from the population of interest.</td>
</tr>
</tbody>
</table>
|   | Mathematical software is only a tool for solving problems more quickly. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
|---|---|---|---|
| 5 | Mathematics is easier for students if mathematical software is used to solve problems. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 6 | More interesting mathematics problems can be done when students have access to mathematical software. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 7 | Students understand mathematics better if they solve problems using paper and pencil. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 8 | Using mathematical software will cause students to lose basic computational skills. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 9 | Using mathematical software makes students better problem solvers. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 10 | The use of mathematical software causes a decrease in student estimation skills. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 11 | Mathematical software use causes a decline in computational skills. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Perceived effect |
| 12 | Mathematical software motivates students to learn mathematics. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 13 | Mathematical software makes mathematics fun. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Options</th>
<th>Category</th>
</tr>
</thead>
</table>
| 14| When students work with mathematical software, they don’t need to explain their work. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 15| Students should not be allowed to use any kind of software until they have mastered the concept or procedure. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 16| All students should learn to use mathematical software.                   | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 17| Using mathematical software will make students try harder.                | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 18| Software should be used only to check work once the problem has been worked out on paper. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 19| Students should not be allowed to use any kind of software while taking math tests. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 20| Mathematical software should be used on mathematics homework.             | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Attitude |
| 21| I am NOT proficient at using mathematical software.                       | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software |
| 22| I know ways I can use mathematical software effectively in teaching.     | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software |
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
<th>Category</th>
</tr>
</thead>
</table>
| Most of my students have access to their own mathematical software.     | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software     |
| I have lots of ideas about how to teach using mathematical software.    | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software     |
| Mathematical software is available for my class(es) to use.            | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software     |
| The available mathematical software is generally easy to use.          | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software     |
| The mathematical software that is available at my university is NOT user friendly. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Software     |
| I have been teaching college mathematics for….years.                   | (A) 0–5  
(B) 6–15  
(C) 16–25  
(D) 26–35  
(E) More than 35 | Background   |
| I have taught with mathematical software in my classroom before.       | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Background   |
| As a student, I used mathematical software in my mathematics classrooms. | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Background   |
| Which of the following statements best describe your educational background starting from Grade 9. | (A) I have studied for 0–4 years at U.S. institutions.  
(B) I have studied for 5–8 years at U.S. institutions.  
(C) I have studied for 9–12 years at U.S. institutions.  
(D) I have studied for more than 12 years at U.S. institutions. | Background   |
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
<th>Personality Type</th>
</tr>
</thead>
</table>
| 32 Which of the following statements best describe your teaching experience. | (A) I have taught for 0–4 years at U.S. institutions.  
(B) I have taught for 5–8 years at U.S. institutions.  
(C) I have taught for 9–12 years at U.S. institutions.  
(D) I have taught for more than 12 years at U.S. | Background |
| 33 Which of the following statements best describe your cultural background | (A) African American  
(B) American Indian  
(C) Asian  
(D) Eastern European  
(E) Hispanic/ Latino  
(F) Middle Eastern  
(G) West European  
(H) White/ Caucasian  
(I) Other | Background |
| 34 In my personal life, I tend to be among the first people to use new technologies. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Instructor’s personality |
| 35 I try to improve my teaching. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Instructor’s personality |
| 36 I read about topics in mathematics education. | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Instructor’s personality |
| 37 My teaching style is traditional. | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Instructor’s personality |
| 38 We teach the way we were taught. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Instructor’s personality |
| 39 The statement that best describes me is: | (A) I am a mathematics researcher.  
(B) I am a teacher of mathematics.  
(C) I am both a teacher of mathematics and a mathematics researcher.  
(D) None of the above describes me. | Instructor’s personality |
<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
<th>Options</th>
<th>Category</th>
</tr>
</thead>
</table>
| 40 | My age range is: | (A) Below 35  
(B) 35–45  
(C) 46–55  
(D) 56–65  
(E) Above 65 | Age |
| 41 | My department’s chair advocates the use of mathematical software when teaching. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Institution |
| 42 | The technical support service at my institution is poor. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Institution |
| 43 | The general trend in the department is NOT to use mathematical software when teaching. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Institution |
| 44 | Most of my colleagues DO NOT use mathematical software in classrooms. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Institution |
| 45 | My department expects faculty to use mathematical software when teaching. | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | Institution |
| 46 | In my department, the percentage of faculty members who advocate mathematical software use is: | (A) Less than 20%  
(B) 20%–40%  
(C) 41%–60%  
(D) 60%–80%  
(E) More than 80%  
(F) I do not know | Institution |
| 47 | Mathematical software should NOT be used when teaching (Check all that apply) | (A) Introductory level courses  
(B) Calculus level courses  
(C) Advanced level courses  
(D) Mathematical software might be used with all levels. | The course being taught |
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
<th>The course being taught</th>
</tr>
</thead>
</table>
| 48 Mathematical software should be used when teaching (Check all that    | (A) Engineering students  
(B) Math major students  
(C) Science major students  
(D) Future elementary and secondary school teachers  
(E) All majors  
(F) Mathematical software should NOT be used with any majors. | taught                  |
| apply)                                                                  |                                                                         |                          |
| 49 Mathematical software should NOT be used when teaching: (Check all    | (A) Freshmen  
(B) Sophomore  
(C) Junior  
(D) Senior  
(E) Any level  
(F) Mathematical software might be used at any level. | taught                  |
| that apply)                                                             |                                                                         |                          |
| 50 My decision to use mathematical software will depend on the students’ | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | taught                  |
| majors.                                                                 |                                                                         |                          |
| 51 The content of the course I am teaching influences my decision to    | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree | taught                  |
| use mathematical software.                                              |                                                                         |                          |
| 52 Mathematical software should be use when teaching (Check all that    | (A) Abstract Algebra  
(B) An applied mathematics course  
(C) A theorem-proving course  
(D) Calculus  
(E) College Algebra  
(F) Geometry  
(G) Logic  
(H) Numerical Analysis  
(I) Real Analysis  
(J) Other  
(K) Mathematical software should NOT be used with any course. | taught                  |
| apply)                                                                  |                                                                         |                          |
Appendix L: Reliability Results of Pilot Study

Table L1

Reliability of the Institution Scale

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.594</td>
<td>.672</td>
<td>6</td>
</tr>
</tbody>
</table>

Table L2

Item-Total Statistics for the Institution Scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale mean if item deleted</th>
<th>Corrected item-total correlation</th>
<th>Cronbach's Alpha if item deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>My department expects faculty to use mathematical software when teaching.</td>
<td>12.35</td>
<td>.612</td>
<td>.436</td>
</tr>
<tr>
<td>My department’s chair advocates the use of mathematical software when teaching.</td>
<td>11.77</td>
<td>.148</td>
<td>.605</td>
</tr>
<tr>
<td>The technical support service at my institution is poor.</td>
<td>12.06</td>
<td>-.313</td>
<td>.855</td>
</tr>
<tr>
<td>The general trend in the department is NOT to use mathematical software when teaching.</td>
<td>12.12</td>
<td>.814</td>
<td>.322</td>
</tr>
<tr>
<td>In my department, the percentage of faculty members who advocate software use is:</td>
<td>12.35</td>
<td>.645</td>
<td>.383</td>
</tr>
<tr>
<td>Most of my colleagues do NOT use mathematical software in classrooms.</td>
<td>12.2941</td>
<td>.644</td>
<td>.416</td>
</tr>
</tbody>
</table>
Table L3

**Reliability of the Software Scale**

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.662</td>
<td>.662</td>
<td>7</td>
</tr>
</tbody>
</table>

Table L4

**Item-Total Statistics for the Software Scale**

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale mean if item deleted</th>
<th>Corrected item-total correlation</th>
<th>Cronbach's Alpha if item deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical software is generally easy to use.</td>
<td>16.56</td>
<td>−.075</td>
<td>.729</td>
</tr>
<tr>
<td>Most of my students have access to their own mathematical software.</td>
<td>16.89</td>
<td>.321</td>
<td>.642</td>
</tr>
<tr>
<td>Mathematical Software is available for my class(es) to use.</td>
<td>16.22</td>
<td>.561</td>
<td>.584</td>
</tr>
<tr>
<td>I am NOT proficient at using mathematical software.</td>
<td>16.17</td>
<td>.680</td>
<td>.521</td>
</tr>
<tr>
<td>Mathematical software that is available at my university is NOT user friendly.</td>
<td>16.33</td>
<td>−.039</td>
<td>.710</td>
</tr>
<tr>
<td>I know ways I can use mathematical software effectively in teaching.</td>
<td>16.06</td>
<td>.554</td>
<td>.566</td>
</tr>
<tr>
<td>I have lots of ideas about how to teach using mathematical software.</td>
<td>16.44</td>
<td>.607</td>
<td>.536</td>
</tr>
</tbody>
</table>
Table L5

*Reliability of the Software Scale With Five Items Only.*

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.802</td>
<td>.808</td>
<td>5</td>
</tr>
</tbody>
</table>

Table L6

*Reliability of the Personality Scale*

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>Number of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.542</td>
<td>.532</td>
<td>6</td>
</tr>
</tbody>
</table>

Table L7

*Item-Total Statistics for the Personality Scale*

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale mean if item deleted</th>
<th>Corrected item-total correlation</th>
<th>Cronbach's Alpha if item deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>I try to improve my teaching.</td>
<td>12.74</td>
<td>.043</td>
<td>.581</td>
</tr>
<tr>
<td>I read about topics in mathematics education.</td>
<td>13.63</td>
<td>.178</td>
<td>.555</td>
</tr>
<tr>
<td>My teaching style is traditional.</td>
<td>14.16</td>
<td>.349</td>
<td>.464</td>
</tr>
<tr>
<td>My identity is</td>
<td>13.63</td>
<td>.389</td>
<td>.440</td>
</tr>
<tr>
<td>We teach the way we were taught.</td>
<td>13.79</td>
<td>.313</td>
<td>.484</td>
</tr>
<tr>
<td>In my personal life, I tend to be among the first people to use new technologies.</td>
<td>14.42</td>
<td>.470</td>
<td>.420</td>
</tr>
</tbody>
</table>
Appendix M: Revised Instrument Used in the Full Study

Table M1

Summary of Items Used in the Full Study

<table>
<thead>
<tr>
<th>The Factor</th>
<th>Number of items in each scale</th>
<th>The Item(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude scale (AIM-AT): Cognitive, Experiential, Affective</td>
<td>23</td>
<td>4–25 + 27</td>
</tr>
<tr>
<td>Attitude scale (AIM-AT): Cognitive</td>
<td>13</td>
<td>Cognitive: 4, 5, 7, 8, 9, 10, 11, 14, 15, 16, 18, 19, 20</td>
</tr>
<tr>
<td>Attitude scale (AIM-AT): Experiential</td>
<td>6</td>
<td>Experiential: 21, 22, 23, 24, 25, 27</td>
</tr>
<tr>
<td>Attitude scale (AIM-AT): Affective</td>
<td>4</td>
<td>Affective: 6, 12, 13, 17</td>
</tr>
<tr>
<td>Course Being Taught</td>
<td>6</td>
<td>45, 46, 47, 48, 49, 50</td>
</tr>
<tr>
<td>Software scale</td>
<td>5-item scale</td>
<td>21, 22, 23, 24, 25</td>
</tr>
<tr>
<td>Perceived effect scale</td>
<td>8-item scale</td>
<td>4, 5, 6, 7, 8, 9, 10, 11</td>
</tr>
<tr>
<td>Instructor’ Personality scale</td>
<td>8-item scale</td>
<td>32, 33, 34, 35, 36, 37, 38, 51</td>
</tr>
<tr>
<td>The Institution scale</td>
<td>5-item scale</td>
<td>40, 41, 42, 43, 44</td>
</tr>
<tr>
<td>Research interest</td>
<td>1 item for research interest</td>
<td>3</td>
</tr>
<tr>
<td>Age</td>
<td>1 item for age</td>
<td>39</td>
</tr>
<tr>
<td>Instructor’s Background</td>
<td>6 items</td>
<td>26, 27, 28, 29, 30, 31</td>
</tr>
</tbody>
</table>
Table M2

*Instrument Used in the Full Study*

<table>
<thead>
<tr>
<th></th>
<th>Item</th>
<th>Choices</th>
<th>The factor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The institution at which I work is:</td>
<td>Names of the 50 departments</td>
<td></td>
<td>This item is for compensation purposes only.</td>
</tr>
</tbody>
</table>
| 2A | I am a professor of mathematics. | (A) Yes  
(B) No | | This item is to ensure that the subject is from the population of interest. |
| 2B | I am | (A) tenured.  
(B) in a tenure-track position.  
(C) Other [Allow text entry] | | This item is to ensure that the subject is from the population of interest. |
| 3 | Which of the following best describes your primary area of research? | (A) Algebra  
(B) Analysis  
(C) Applied mathematics  
(D) Combinatorics  
(E) Differential equations  
(F) Discrete mathematics  
(G) Geometry  
(H) Logic  
(I) Mathematics education  
(J) Statistics  
(K) Topology  
(L) Other [allow text entry] | | This item is to ensure that the subject is from the population of interest and to identify the research interest. If (I) is chosen, item 3A will be displayed; if (J) is chosen, item 3B will be displayed. |
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Options</th>
<th>Perceived Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>I have a PhD degree in mathematics education only.</td>
<td>(A) mathematics education only. (B) mathematics and mathematics education. (C) mathematics only.</td>
<td>Exclude from the analysis if (A)</td>
</tr>
<tr>
<td>3B</td>
<td>I teach</td>
<td>(A) mathematics and statistics courses. (B) statistics courses only. (C) mathematics courses only.</td>
<td>Exclude from the analysis if (B)</td>
</tr>
<tr>
<td>4</td>
<td>Mathematical software is a tool only for solving problems more quickly.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>5</td>
<td>In general, mathematics is easier for students if mathematical software is used to solve problems.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>6</td>
<td>More interesting mathematics problems can be done when students have access to mathematical software.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>7</td>
<td>In general, students understand mathematics better if they solve problems using paper and pencil.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>8</td>
<td>Using mathematical software will cause students to lose basic computational skills.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>9</td>
<td>Using mathematical software makes students better problem solvers.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Options</td>
<td>Scale</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>10</td>
<td>The use of mathematical software causes a decrease in student estimation skills.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>11</td>
<td>Mathematical software use causes a decline in computational skills.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Perceived effect 8-item scale</td>
</tr>
<tr>
<td>12</td>
<td>Mathematical software motivates students to learn mathematics.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>13</td>
<td>Mathematical software makes mathematics fun.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>14</td>
<td>When students work with mathematical software, they don’t need to explain their work.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>15</td>
<td>Students should not be allowed to use any kind of software until they have mastered the concept or procedure.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>16</td>
<td>All students should learn to use mathematical software.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>17</td>
<td>Using mathematical software will make students try harder.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>18</td>
<td>Software should be used only to check work once the problem has been worked out on paper.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td>19</td>
<td>Students should not be allowed to use any kind of software while taking math tests.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Attitude 23-item scale</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Response Options</td>
<td>Scale</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
</tbody>
</table>
| 20| Mathematical software should be used on mathematics homework.           | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Attitude 23-item scale |
| 21| I am NOT proficient at using mathematical software.                     | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Software 5-item scale |
| 22| I know ways I can use mathematical software effectively in teaching.   | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Software 5-item scale |
| 23| Most of my students have access to their own mathematical software.     | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Software 5-item scale |
| 24| I have lots of ideas about how to teach using mathematical software.    | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Software 5-item scale |
| 25| Mathematical software is available for my class(es) to use.            | (A) Strongly Agree  
(B) Agree  
(C) Disagree  
(D) Strongly Disagree  | Software 5-item scale |
| 26| Please indicate the number of years you have taught college mathematics.| (A) 0–5  
(B) 6–15  
(C) 16–25  
(D) 26–35  
(E) More than 35 | Background |
| 27| As a teacher of mathematics, I have taught with mathematical software in my classroom. | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Background |
| 28| As a student, I used mathematical software in my mathematics classrooms. | (A) Often  
(B) Sometimes  
(C) Rarely  
(D) Never | Background |
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 Which of the following statements best describes your educational background starting from Grade 9?</td>
<td>(A) I studied for 0–4 years at U.S. institutions. (B) I studied for 5–8 years at U.S. institutions. (C) I studied for 9–12 years at U.S. institutions. (D) I studied for more than 12 years at U.S. institutions.</td>
<td>Background</td>
</tr>
<tr>
<td>30 Which of the following statements best describes your teaching experience?</td>
<td>(A) I have taught for 0–4 years at U.S. institutions. (B) I have taught for 5–8 years at U.S. institutions. (C) I have taught for 9–12 years at U.S. institutions. (D) I have taught for more than 12 years at U.S.</td>
<td>Background</td>
</tr>
<tr>
<td>31 Which of the following best describes your cultural background?</td>
<td>(A) African American, Black (B) American Indian, Alaska Native (C) Asian, Asian American (D) Hispanic, Latino (E) Middle Eastern (F) Native Hawaiian, Pacific Islander (G) White, Caucasian (H) Other [Allow text entry]</td>
<td>Background</td>
</tr>
<tr>
<td>32 I read expository articles in mathematics education</td>
<td>(A) at least once a week. (B) at least once a month. (C) several time a year. (D) once a year. (E) less than once a year. (F) Never.</td>
<td>Personality 8-item scale</td>
</tr>
<tr>
<td>33 In my personal life, I tend to be among the first people to use new technologies.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
<td>Personality 8-item scale</td>
</tr>
<tr>
<td>34 I discuss my teaching strategies with my colleagues</td>
<td>(A) at least once a week. (B) at least once a month. (C) several times a year. (D) once a year. (E) less than once a year. (F) Never.</td>
<td>Personality 8-item scale</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Response Options</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>35</td>
<td>I read research articles in mathematics education</td>
<td>(A) at least once a week. (B) at least once a month. (C) several times a year. (D) once a year. (E) less than once a year. (F) Never.</td>
</tr>
<tr>
<td>36</td>
<td>My teaching style does not lend itself to using mathematical software.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
</tr>
<tr>
<td>37</td>
<td>We teach the way we were taught.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
</tr>
<tr>
<td>38</td>
<td>The statement that best describes me is:</td>
<td>(A) I am primarily a mathematics researcher. (B) I am a primarily a teacher of mathematics. (D) Neither of the above.</td>
</tr>
<tr>
<td>39</td>
<td>My age range is:</td>
<td>(A) below 35 (B) 35–45 (C) 46–55 (D) 56–65 (E) above 65</td>
</tr>
<tr>
<td>40</td>
<td>My department chair advocates the use of mathematical software when teaching.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree (E) I do not know.</td>
</tr>
<tr>
<td>41</td>
<td>The general trend in the department is NOT to use mathematical software when teaching.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree (E) I do not know.</td>
</tr>
<tr>
<td>42</td>
<td>Most of my colleagues DO NOT use mathematical software in classrooms.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree (E) I do not know.</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>(A) Strongly Agree</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>43</td>
<td>My department expects faculty to use mathematical software when teaching.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>In my department, the percentage of faculty members who advocate mathematical software use is</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>(Check all that apply) Mathematical software should NOT be used when teaching</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>(Check all that apply) Mathematical software could be used when teaching</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>(Check all that apply) Mathematical software should NOT be used when teaching</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>My decision to use mathematical software depends on the students’ majors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>49</td>
<td>The content of the course I am teaching influences my decision to use mathematical software.</td>
<td>(A) Strongly Agree (B) Agree (C) Disagree (D) Strongly Disagree</td>
</tr>
<tr>
<td>50</td>
<td>(Check all that apply) Mathematical software could be use when teaching</td>
<td>(A) abstract algebra. (B) an applied mathematics course. (C) a theorem-proving course. (D) calculus. (E) college algebra. (F) differential equations. (G) geometry. (H) logic. (I) numerical Analysis. (J) real Analysis. (K) any course. (L) Other (M) Mathematical software should NOT be used with any course.</td>
</tr>
<tr>
<td>51</td>
<td>I attend conference presentations that discuss mathematics education topic</td>
<td>(A) more than once a year. (B) once a year. (C) once every several years. (D) Rarely. (E) Never.</td>
</tr>
</tbody>
</table>