DEPENDABILITY AND ACCEPTABILITY OF HANDHELD COMPUTERS IN SCHOOL-BASED DATA COLLECTION

A Dissertation

by

TUFAN ADIGUZEL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2008

Major Subject: Educational Psychology

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Approved by:

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ABSTRACT

Dependability and Acceptability of Handheld Computers in School-Based Data Collection. (August 2008)

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Given the increasing influence of technology and the explosion in data collection demands, the acceptance and assimilation of new paradigms and technologies require today's educators, researchers, and evaluators to select appropriate tools and apply them effectively. One of these technologies—handheld computers—makes the benefits of computerized data collection more accessible to field-based researchers. Three related studies were conducted to evaluate handheld-based data collection system for use in special education settings and to highlight the acceptability factors to effectively use this emerging technology.

The first study reviewed the recent literature on the dependability and willingness of teachers to adopt handheld data collection systems and emphasized five important factors: (1) perceived ease of use; (2) perceived usefulness; (3) intention to use; (4) dependability; and (5) subjective norms.

The second study discussed the dependability of handheld computers used by special education teachers for collecting self-report data by addressing four dependability attributes: reliability, maintainability, availability, and safety. Data were collected from five sources: (1) self-reports of time use by 19 special education teachers using Pocket PC computers, (2) observations of time use from eight external data collectors, (3) teacher interviews, (4) technical reports prepared by the researcher, and (5) teacher satisfaction. Results indicated that data collection via handheld computers yielded accurate, complete, and timely data, and was appropriate for these four dependability attributes.

The last study investigated teachers' acceptance of handheld computer use by testing the relationship among five factors that influence intention to use this technology which was based on a modified version of the technology acceptance model using the handheld computer acceptance survey responses from 45 special education teachers. The results showed that intention to use handheld computer was directly affected by the devices' perceived usefulness and perceived ease of use. The issue of dependability had a direct and indirect statistically significant effect on perceived ease of use and usefulness, and intention to use a handheld computer, respectively.

Overall, three studies demonstrated that handheld computers can be effectively used in the direct observation of behavior in a school environment, without requirements of any settings.

DEDICATION

This dissertation is dedicated to my family for the support, love, affection, and encouragement they have given me.

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I would like to express my sincere gratitude to those individuals who provided invaluable support in so many ways during my adventurous dissertation journey.

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CHAPTER I

INTRODUCTION

Today's changing learning paradigms and the technology goals of the No Child Left Behind (NCLB) Act require new forms of educational resources and techniques that utilize associated new technologies. Education has become increasingly independent of the historical constraints of time, distance, computing platform, and classroom size. Technology is increasingly indispensable in education, offering new and interesting advances to address these requirements. The acceptance and assimilation of new paradigms oblige today's educators to select the appropriate required technologies (Heins & Himes, 2002). An increasing number of technologies are being developed to contribute to the best practice for educational administrators, teachers, and students.

Handheld computing technology has emerged as an alternative mobile computer solution and has been adopted by professionals across the education spectrum who are involved in implementing effective instruction in schools. Handheld computers with wireless support provide a platform for teaching, learning, assessment, and administration and are not constrained by time or the physical location of classrooms (Clarke & Philips, 2001; Jones & Johnson, 2002; Shields & Poftak, 2002; Yuen & Yuen, 2003). In the classroom, specifically, wireless handheld computers can facilitate independent learning while supporting instruction and classroom management.

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Furthermore, new uses for handheld computers in educational settings have been developed, such as educational games, simulations, data collection, just-in-time learning, and online searches of reference materials (Jones, Johnson, & Cold, 2002). One of these new methods is the use of handheld computers as an alternative to traditional paper-based data collection systems.

Data collection, a widely used technique in education, through the direct observation of behavior is one of the most effective and comprehensive methods of gathering information of a dynamic and interactive nature. Stakeholders in education historically have preferred paper-and-pencil data collection methods to gather information regarding students' academic and behavioral performance and to fulfill administrative purposes (Airasian, 2001; Bell & Beedle, 1993; Donat, 1991; Farrell, 1991; Kahng & Iwata, 1998). While data collection via paper-and-pencil methods is perceived as cost effective and requiring minimal technical knowledge, several problems have been identified in its use: the tendency of respondents and evaluators to leave data fields blank (Stanton, 1998); poor internal consistency (Ployhart, Weekley, Holtz, & Kemp, 2003); difficulty in maintaining, managing, storing, and retrieving data over a long period of time (Emmelkamp, 2005); and a lack of clarity that prevents accurate coding of written responses, which leads the evaluator to apply his or her own judgment and/or consider discarding data that are illegible (Vispoel, Boo, & Bleiler, 2001). Various technologies have been developed to prevent or remedy these potential problems. Among the benefits these technologies offer are improved reliability and validity (Tourangeau & Smith, 1996); improved use of time and resources (Bliven, Kaufman, & Spertus, 2001); and improved capacity for data storage, analysis, accessibility, and retrieval over a longer period of time (Hammond & Sweeney, 2000).

Despite the benefits, teachers and students face difficulties when using some of these technologies in data collection, notably a lack of accessibility to the computers because of single-computer classrooms and over-scheduled computer labs. Laptop computers have been introduced in some schools to address these concerns, but these computers have been found to be bulky, expensive, and less mobile, as well as requiring longer to boot and having a shorter battery life. A new technology—the handheld computer—may make these difficulties obsolete. Many advantages of handheld computers, including relatively low cost ($100 to $400), portability, ease of use (minimum computer skills required), flexibility (ready availability), and battery life (typically, six hours) have made these computers an essential data collection technology (Fletcher, Erickson, Toomey, & Wagenaar, 2003; Trapl et al., 2005). These technologies and associated data entry techniques offer a fast and accurate method of data collection in any location, moving research away from the stand-alone computer and replacing time-consuming paper-and-pencil data collection methods. Handheld computers can interact with several devices and make information accessible through a wireless connection to a server computer (Batten, Crowdhury, & Drew, 2003; Dixon, 2003; Ice, 2004). Thus, daily recordings of class performances can be entered and retained on the handheld computer and then downloaded onto a disc or transferred to a server at the end of the day (Stacey, 2000). Handheld computers are also valuable tools for special education teachers who need to walk around, monitor, and record what they see in a variety of settings. These small, portable devices may help teachers record a more accurate and comprehensive picture of student behavior.

These advantages have led numerous schools to add handheld computers to their inventory of desktop and laptop computers (Batten et al., 2003; Greene, 2001; Hampshire, 2001; Weber & Roberts, 2000) without conducting systematic research on the correct and effective use of these devices. The use of technology in the classroom is not likely to succeed unless teachers accept the new technology and actually use it to perform instructional and administrative tasks (Ching, 1999). To address this constraint, many subsequent studies have found that teacher acceptance is a key factor in the effective implementation of technology in general to support instruction (Kellenberger & Hendricks, 2003; Koohang, 1989; Lawton & Gerschner, 1982). On the other hand, the adoption or acceptance of any new technology, including handheld computers, is a challenging task. Therefore, to increase the acceptance and use of handheld computers and to accelerate their integration in schools, administrators and policy makers should focus on the potential factors affecting these goals, such as teachers' perceptions of the devices, and the devices' dependability vis-à-vis the goal of data collection in a classroom setting.

The purpose of this research was threefold: (1) to review the literature and identify key factors influencing the use of handheld computers for data collection in school settings; (2) to investigate the dependability of handheld computers for use in school-based data collection; and (3) to investigate factors influencing the acceptability of handheld computers by special education teachers.

Progression of the Research

Three related studies were conducted to evaluate handheld-based data collection system for use in special education settings and to highlight acceptability factors to effectively use this emerging technology. The first study reviews the recent literature examining the use of handheld computers as data collection tools and emphasizes the five important factors that influence teachers' willingness to adopt handheld data-collection systems: (1) perceived ease of use; (2) perceived usefulness; (3) intention to use; (4) dependability; and (5) subjective norms. The second study discusses the dependability of handheld computers used by special education teachers for collecting self-report data. The study utilizes five different sources (special education teachers' self-reports, observations by external data collectors, interviews with special education teachers, technical reports, and self-reported satisfaction levels) to test four dependability attributes (reliability, maintainability, availability, and safety). The last study investigates teachers' acceptance of handheld computer use, and tests the relationship among five factors that influence intention to use this technology which is based on a modified version of the technology acceptance model.

Research Questions

1. Is the use of a handheld data-collection system a dependable method for collecting school-based student observational data and a viable alternative to traditional paper-and-pencil methods?
2. What is the effect of special education teachers' prior experience using handheld computers for data collection on their acceptance of this technology?

a. What are the major factors that affect special education teachers' intention to accept handheld computers?

b. What are the relationships amongst these factors that affect special education teachers' intention to use handheld computers?

Significance of the Research

Research on handheld computer use overwhelmingly has focused on content delivery and information design. Applications range from clinical work (Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003), to news retrieval (Albers & Kim, 2000), and to academic activities for students (Luchini, Quintana, & Soloway, 2003). When new technologies are integrated into existing settings or processes, there is a risk that they may not be adequately utilized or that they may be misused. Adoption and adaptation of such resources are dependent on factors such as acceptance by the individuals required to use them and their familiarity with the technology components, the availability of appropriate resources, and the design of the user interface and data entry formats. Accordingly, an unplanned and inappropriately applied electronic data-collection system can create resistance to use as well as inaccurate data gathering and analysis. In special education, particularly, there is a need for dependable and objective assessments that accurately measure a student's strengths and weaknesses, and provide appropriate information to the teacher, parent and student. Consequently, hardware, software and user satisfaction must all be considered for the dependable implementation of the system.

It is believed that developing a greater understanding of the usability of handheld computer applications will have two benefits. First, studying this device's dependability and acceptability can help schools and institutions make informed and reasonable decisions when purchasing new technologies. Second, fully understanding the potential advantages and disadvantages of existing technology will lead to the development and use of more effective and more sophisticated technology applications in the future.

Definition of Terms

Acceptability: How much special education teachers enjoy, like, or are interested in learning about or working with (handheld) computers.

Adoption: A process of implementing a new device, which can occur with or without users' acceptance of the device.

Appropriation: The act of taking possession of or assigning purpose to properties or ideas.

Dependability: The trustworthiness of a handheld computer that justifies reliance on the service it delivers. Dependability includes reliability, safety, security, availability, and maintainability.

Desktop Computer: A personal computer made for use on a desk in an office or home as distinguished from portable computers such as laptops or personal digital assistants (PDAs).

Handheld Computer: A computer device that is small in size and portable, and that performs most of the functions of a desktop or laptop.

Intention to Use: The decision whether or not to become a user of a handheld computer.

Laptop Computer: A laptop computer (or simply laptop, or notebook computer or notebook), is a small, portable computer that usually weighs between 2.2 to 18 pounds (1 to 6 kilograms), depending on size, materials, and other factors.

Mobile Computing: A generic term describing one's ability to use technology untethered, facilitated by devices which provide mobile computer functionality.

Personal Digital Assistant (PDA): See Handheld Computer.

Perceived Ease of Use: “[T]he degree to which a [teacher] believes that using a [handheld computer] would be free of effort” (Davis, 1989, p. 320).

Perceived Usefulness: “[T]he degree to which a [teacher] believes that using a [handheld computer] would enhance his or her job performance” (Davis, 1989, p. 320).

Pocket PC: See Handheld Computer.

Portability: A characteristic attributed to a computer program that can be used in operating systems other than the one in which it was created without requiring major rework.

Router: A device (or in some cases, computer software), that determines the next network point to which a packet should be forwarded toward its destination.

Special Education: Direct instructional activities or special learning experiences designed primarily for students identified as having exceptionalities in one or more aspects of the cognitive process or as being underachievers in relation to general level or model of their overall abilities. Such services usually are directed at students with the following conditions: (1) physical handicap, (2) emotional handicap, (3) cultural differences, (which also are addressed through compensatory education), (4) mental retardation, and (5) learning disabilities. Programs for the mentally gifted and talented also are included in some special education programs.

Stand-alone Computer: A personal computer that is not connected to any other computer or network, except possibly through a modem.

Stylus: A pointing and drawing device shaped like a pen and intended for use with a digitizing tablet or touch screen.

Subjective Norm: A teacher's perception of opinions or suggestions regarding the significant referents that relate to his or her acceptance of a handheld computer.

Synchronization: The process by which the desktop computer and the handheld exchange and update information.

Wireless: A description of a computer network that uses a radio connection between sender and receiver, but no physical connection (through either copper cable or fiber optics).

CHAPTER II

THE USE AND EFFICACY OF HANDHELD COMPUTERS FOR SCHOOL-BASED DATA COLLECTION: A LITERATURE REVIEW

Overview

Today's changing educational practice and research settings require a variety of resources and tools, many of which utilize associated new technologies. Given the increasing influence of technology and the explosion in data collection demands, the acceptance and assimilation of new paradigms and technologies require today's educators, researchers, and evaluators to select appropriate tools and apply them effectively. One of these technologies, handheld computers, also known as personal digital assistants (PDAs), makes the benefits of computerized data collection more accessible to field-based researchers. An evaluation of handheld computers as data collection tools in research settings requires an understanding of their use from different perspectives in existing research. This study examines the dependability and willingness of teachers to adopt handheld data collection systems by focusing on five main features: (1) ease of use, (2) usefulness, (3) intention to use, (4) dependability/reliability, and (5) subjective norms.

Introduction

Data collection through the direct observation of behavior is one of the most effective and comprehensive methods of gathering information of a dynamic and interactive nature. However, teachers and educational researchers still rely heavily on paper-and pencil-methods for collecting behavioral observations, even though these methods are time-consuming, cumbersome, and prone to human error. Consequently, researchers have sought ways to simplify the collection of direct-observation data (Dumont & Chafouleas, 1999). Various technologies, including desktop and laptop computers, as well as portable handheld computing devices, have been incorporated into observational data collection systems in an attempt to provide these improvements (Kahng & Iwata, 1998). The perception that people have become familiar with the vast array of new technology and adopted it in their everyday lives is common. However, the scholarly literature indicates that a considerable gap exists between the awareness of such technology and its actual implementation (Spiegler, 2003). This study addresses these gaps in educational research and practice and explores the potential factors influencing the use of handheld computers for data collection in school settings.

Background

Researchers and practitioners in many disciplines must collect and analyze data. The collection of field-based data performs multiple functions; specifically, it provides single point or longitudinal raw data that allow evaluation of the performance of individuals, groups, policies, practices, or programs (Jenkins, 1999). Once the researcher has collected the desired data, he or she conducts a quantitative or qualitative analysis and produces a summary of findings that provides guidance for recommendations regarding improvements of existing circumstances or conditions (Schalock, 2001).

For educators, data collection and evaluation has become an increasingly important component in the areas of job expectation and teacher accountability (Linn, Baker, & Dunbar, 1991; Mahoney & Zigler, 2006; Worthen & Sanders, 1991, Vannest, Madahaven, Mason & Harvey, in press). The No Child Left Behind Act has increased the number of required assessment and accountability measures for teachers and administrators (Linn, Baker, & Betebenner, 2002). As Linn et al. observed, “The No Child Left Behind Act . . . substantially increases . . . accountability standards for schools, districts, and states with measurable adequate yearly progress (AYP) objectives for all students and subgroups . . . defined by socioeconomic background, race–ethnicity, English language proficiency, and disability” (p. 3). The AYP benchmarks have increased each year since the passage of the No Child Left Behind Act, and the government’s goal is that 100% of children in the United States will perform at state-defined proficiency levels by the year 2012 (Linn et al.).

Although standardized achievement and performance tests are used by most schools as a means of tracking students’ acquisition and application of knowledge, teachers also perform periodic formal and informal assessments in their classrooms (Oosterhof, 2001). These assessments are conducted for various purposes, including tracking students’ academic growth and behavior in the classroom (Merrell, 2003; Shapiro, 2004). Often, teachers must rely on their memory, which can be unreliable, when recording their observations (Stiggins & Conklin, 1992).

Assessments, if crafted carefully, are more reliable data-collection instruments than impressions recorded subjectively and retained in the teacher’s memory (Stiggins & Conklin, 1992). Assessments are standard evaluations that apply the same set of criteria to all subjects being examined. As Stiggins and Conklin explained, “While many [teachers] strive to remain objective, they fail to understand that vague performance criteria often give rise to unreliable judgments. . . .” (p. 141). Written assessments, they concluded, improve the validity and reliability and utility of the data collected.

Teachers historically preferred paper-and-pencil assessments for collecting data regarding their students’ academic and behavioral performance (Airasian, 2001; Bell & Beedle, 1993; Donat, 1991; Farrell, 1991; Kahng & Iwata, 1998). While paper-and-pencil assessments may be cost effective and require minimal technical knowledge, recent research has exposed a considerable number of problems associated with their use, thus turning administrators’ and researchers’ attention to the use of electronic devices as instruments in data collection. Several problems have been identified in the use of paper-and-pencil assessments: the tendency of respondents and evaluators to leave data fields blank (Stanton, 1998); poor internal consistency (Ployhart, Weekley, Holtz, & Kemp, 2003); the difficulty of maintaining, managing, storing, and retrieving data over a long period of time (Emmelkamp, 2005); and the frequent lack of clarity that prevents accurate coding of written responses, which leads the evaluator to apply his or her own judgment and/or consider discarding data that are illegible (Vispoel, Boo, & Bleiler, 2001). These limitations have been noted across a wide number of professional disciplines, including education, medicine (Palermo, Valenzuela, & Stork, 2004), and psychology (Pettit, 1999), to name just a few.

In addition to potentially preventing or remedying these problems, the increasing availability and affordability of both software and hardware make data collection via technological devices a compelling alternative. The early literature on the use of computer-based tools for data collection in the educational environment suggests that these tools offer teachers and administrators, as well as other stakeholders, an array of benefits over the traditional paper-and-pencil methodology. Among them are improved reliability and validity (Tourangeau & Smith, 1996); improved use of time and resources (Bliven, Kaufman, & Spertus, 2001); and improved capacity for data storage, analysis, accessibility, and retrieval over a longer period of time (Hammond & Sweeney, 2000).

In their review of computer-based observational systems, Kahng and Iwata (1998) concluded that such systems can be used to collect data from several dimensions of the target behavior, such as frequency, duration, inter-response time and latency. Although the use of desktop computers eliminates the need for transcription inherent in paper forms and maintains the integrity of the data from collection to analysis, transporting computers from one location to another is problematic. Pace and Staton (2005) explored two main benefits of using electronic data collection systems for practice-based research: portability (i.e., the feasibility of on-site data collection using laptop or handheld computers) and immediate validation with no subsequent manual data entry. Although laptop computers provided portability and standardization of equipment across all the studies reviewed, they also require sufficient electrical outlets, which may not be available in many schools. In addition, laptops require more secure transportation because of their cost and size (Trapl et al., 2005). Spinuzzi (2003) also articulated problems using laptop computers in data collection, describing them as bulky, obtrusive and less mobile technologies that take much longer to boot and have much shorter battery life.

Handheld computers have emerged as one of the most promising new technologies, bringing the advantages of desktop and laptop computers to field-based researchers in support of learning and, particularly, data collection. Specifically, a handheld computer's relatively low cost ($100 to $400), portability, ease of use (minimum computer skills required), flexibility (ready availability), and battery life (typically, six hours) make it an essential data collection technology (Fletcher, Erickson, Toomey, & Wagenaar, 2003; Trapl et al., 2005). These technologies and associated data entry techniques offer a fast and accurate method of data collection in any location, moving research away from the stand-alone computer and replacing time-consuming paper-and-pencil versions. Handheld computers can interact with several devices and make information accessible through a wireless connection to a server computer (Batten, Crowdhury, & Drew, 2003; Dixon, 2003; Ice, 2004). Thus, daily recordings of class performance can be entered and retained on the handheld computer and then downloaded onto a disc or transferred to a server at the end of the day (Stacey, 2000).

One of the most common handheld computers for the capture and storage of data in an educational setting is the Pocket PC. This small computer allows teachers to input data either in real time as it is collected, or at some later time (Davis, 2002; Hoppe, Joiner, Milrad, & Sharples, 2003). As Davis noted, handheld computers offer educators clear and compelling benefits when compared with traditional paper-and-pencil methods: the ability to instantly assess students' performance and other behavioral characteristics; the ability to present data to students as immediate and direct feedback; the ability to transfer data directly to students in highly technologized classrooms; and the ability to share data among teacher groups and, in some cases, with parents and other stakeholders (Davis, 2002). This researcher also noted several benefits for students whose teachers use handheld computers, including “anonymity of data submission to the group and the ability to see their data displayed in the group space” (p. 31). Accordingly, any similarly sized and highly connectable computers with equivalent data collection capacities can achieve the same results.

Clearly, portability—both of the computer itself and of the transmission of collected data—permits teachers to collect types of data that might not be possible with paper-and-pencil methods (Greenwood, Carta, Kamps, Terry, & Delquadri, 1994). As Greenwood et al. explained, the portability of the computers and the increasing diversity of the number and types of software programs that permit teachers to collect data and provide new opportunities for behavioral and academic performance monitoring, both as short-term and long-term tasks. The ecobehavioral assessment software described by Greenwood et al., for instance, is just one example of a software application that permits teachers to track multiple data streams for multiple measures in a compact and manageable format.

Although the documented benefits of handheld computers for collecting data in a wide variety of environments are substantial, the use of these computers, particularly in the field of education, is not yet widespread. As Curtis, Luchini, Bobrowsky, Quintana, and Soloway (2002) have pointed out, “the primary, and most powerful uses of handheld computers, have not been for organizational purposes” (p. 23). In order to understand the dynamics that influence the dependability and acceptability of handheld data collection systems for classroom-based observations performed by teachers and administrators, it is important to summarize the recent literature on this subject.

The literature on the subject of the dependability of handheld data collection systems and users' willingness to adopt these systems focuses on five main topics: (1) the potential user's perceptions regarding the ease of using the handheld computer; (2) the potential user's perceptions regarding the usefulness of the handheld computer for this purpose; (3) the potential user's level of commitment to using the handheld computer, also known as intention to use; (4) the potential user's perceptions of the handheld computer's dependability and reliability; and (5) subjective norms. Each of these topics will be discussed in this review of the literature. The assumption underlying the discussion is that administrators who are responsible for implementing handheld computers for data collection in classrooms must consider each of these five variables and how they influence the use and efficacy of technology in general and of handheld computers in particular.

Perceptions Regarding Ease of Use

Ease of use is particularly important with respect to technology adoption and continued use (Davis, Bagozzi, & Warshaw, 1989). The phrase "ease of use" refers to the extent to which a person believes that using a technology will be free from excessive mental and physical effort (Davis et al.). In particular, ease of use is the potential user's confidence that he or she will not be required to invest substantial time, energy, or effort to learn the skills required to use the technology and to maximize its functional capabilities. While training is always an important part of any technology adoption program, the user needs reassurance that the information provided in the training is accessible, easy, convenient, and fast (Davis et al.), narrowing as much as possible the gap between non-use and adoption and application.

This finding appears to be particularly true for adults—including teachers—who might be more adaptable and eager for knowledge compared to peers in other professions. Research has found that—in addition to a lack of formal training in software and hardware usage and limited exposure to such technologies when compared to younger adults, adolescents, and children–adults, particularly those who are older and who have been in the teaching profession for a longer time, vastly underestimate their ability to operate technological devices (Marquie, Jourdan-Boddaert, & Huet, 2002; Russell, Bebell, O'Dwyer, & O'Connor, 2003). Furthermore, older adults tend to express far less confidence in their ability to master such technologies, even if they accept the potential utility and advantages of those technologies (Marquie et al.).

In addition to the abstract but important variable of teachers' general lack of confidence in utilizing technologies easily, there is the equally important and more tangible issue of limited training in technology, particularly for the purposes of observation, assessment, and evaluation in the classroom (Wild, 1996). Pre-service teachers are beginning to receive pedagogical and curricular instruction in using technology in the classroom for a variety of purposes, including observation, evaluation, and monitoring. Overall, however, teachers' beliefs, attitudes, and abilities regarding technology use vary considerably, especially among seasoned teachers who have not received technology training. Teachers may well feel compelled to learn about technology independently if they believe that its use will benefit teaching, classroom management, and student outcomes; however, administrators' expectation that teachers will pursue these opportunities on their own may be unrealistic given that many teachers already are overextended.

Perceptions regarding the ease of use of software and hardware technologies, then, are influenced not only by objective factors, such as the teacher's ability to manipulate a device and use it for an intended purpose, but also by psychological factors, including the teacher's beliefs about the device's usefulness and its role in the classroom (Windschitl & Sahl, 2002). These researchers identified several beliefs that influence the adoption and successful use of technology in the classroom, including "interrelated belief systems about learners in their school, about what constituted 'good teaching' in the context of the institutional culture, and about the role of technology in students' lives" (p. 165). They pointed out that significant variables influencing teachers' perceptions of the ease of use of these devices include the degree to which school administrators believe in teachers' abilities to use the technology effectively and the value they place on it. The tone that is established and conveyed by the institutional culture, then, is a significant predictor of the perception that technology is easy to use and that learning how to use it effectively is possible (Windschitl & Sahl, 2002).

Ease of use is not limited, however, just to initial perceptions among teachers. Many handheld computers that are available for data collection in educational settings have scalable capabilities. This means that they not only can perform basic data collection functions, but, in many cases, can also be used to perform data analysis functions, as well as related storage, sharing, and maintenance tasks (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004). As more functions are introduced, however, technology users are more likely to feel overwhelmed by the learning curve they face. Furthermore, as the number of potential functions increases, so do new users' anxiety and fear of failure or feelings of inability to master the technology (Hackbarth, Grover, & Yi, 2002). In turn, as anxiety and fear of failure escalate, perception of ease of use tends to decline (Hackbarth et al.).

To establish an organizational culture in which technology use for assessment purposes is encouraged, school administrators and policy makers could consider how teachers' perceptions of the ease of use of software and hardware technologies can best be managed. Because the extent to which the benefits of handheld data collection are exploited may depend largely on the user's level of technological experience and expertise, school administrators need to consider how they can facilitate the process of helping users become more comfortable with technology. As part of a plan to manage these perceptions, administrators and planners should consider numerous variables. First, how will technology be introduced? Will teachers be "forced" to adopt handheld data collection technologies, or will teachers participate in decisions about their use? Second, how will teachers be introduced to these technologies? Will they receive orientation and initial training including a baseline assessment of familiarity and ease of use? Third, once basic training has been provided, will teachers have access to technical support to help with problems? Related concerns include whether available technical support is clear and understandable, and whether it provides opportunities for teachers to learn how to leverage the computers for multiple purposes over time. All of these variables, of course, must also be considered, along with the fact that teachers have numerous responsibilities and limited time, and that learning about new technologies, while useful and potentially time-saving in the long run, may be viewed initially as burdensome (Hargreaves, 2000).

Perceptions Regarding the Usefulness of Handheld Computers

In addition to the variable of teachers' perceptions regarding the ease of use of handheld computers, teachers' perceptions regarding the very usefulness of handheld computers is also an important factor influencing technology use. According to Zhao and Cziko (2001), teachers' perceptions about the utility of handheld computers and other computer technologies for classroom use are influenced by three principal beliefs: (1) that technology "can more effectively meet a higher-level goal than what[ever other means have] been used," (2) that the use of such a computer will not disrupt classroom instruction and other "higher-level goals that the he or she thinks are more important than the one being maintained," and (3) that he or she will receive the training and ongoing support necessary to make the computer a useful tool (p. 5). Again, establishing an organizational culture that embraces technology use, and—more importantly—provides compelling empirical and anecdotal evidence substantiating its value, ease of use, and usefulness, plays a significant role in shaping teachers' perceptions about the utility of handheld computers.

In their study of teachers' acceptance and use of technology, Hu, Clark, and Ma (2003) determined that there is a predictable trajectory of incidents that occur to influence teachers' perceptions of the usefulness of handheld computers and electronic technologies in general. As they noted, “the significant core influence path” is initiated with “job relevance, [proceeds] to perceived usefulness [and terminates] with technology acceptance,” after which technology is deemed useful by the teacher (Hu et al., p. 227). Interestingly, Hu and his colleagues also determined that “teachers appear to consider a rich set of factors in initial acceptance [of technological device usage in the classroom] but concentrate on fundamental determinants (e.g., perceived usefulness and perceived ease of use) in their continued acceptance” (p. 227). Ultimately, Hu et al. concluded that teachers want to know that their adoption and utilization of technology will not only help them meet the goals of their schools, but also of their own individual classrooms. Thus, the utility of technological devices to achieve both micro-level (classroom) and macro-level (school/district) goals must be considered, and administrators and policy makers should determine how they can leverage existing evidence, both empirical and anecdotal, to convince teachers that handheld-based data collection tools are, in fact, useful for both types of goal achievement.

In the larger scheme of technology adoption and use, teachers’ perceptions regarding the utility of handheld computers may become less important. Considering the fact that most schools are moving toward intense technology adoption and integration for teaching and assessment purposes in response to social pressures and expectations, technological developments, and federal mandates about technology use, teachers may have little autonomy or decision-making power in this matter. Even if this turns out to be the case, however, administrators and policy makers must consider teachers’ perceptions and think about how teachers’ attitudes about the usefulness of technological devices will influence the successful and meaningful use of handheld computers and other electronic data collection technologies.

Whether policy makers present empirical or anecdotal evidence to teachers or administrators—or ideally, both—they must take a broad approach to the definition of usefulness. While one stakeholder group may consider the usefulness of handheld computers to be related primarily to the devices' portability, multiple functionalities, and the storage, access, and transfer of data, the teacher stakeholder group is likely to want to know how handheld computers will help them fulfill their classroom tasks and responsibilities. In addition, teachers want to know if the technology will enhance their overall job performance, as they assess it themselves, and also as assessed by their school administrators (Davis et al., 1989; Ma, Andersson, & Streith, 2005). Such evidence can be provided by empirical studies, but often is also profoundly influenced by anecdotal accounts and the recommendations of other technology users. The recommendations that are most influential for teachers examining their perceptions of the ease of use and the utility of technological devices for data collection purposes are those obtained from colleagues who have direct experience using such devices (Mumtaz, 2000). Thus, as administrators and policy makers attempt to convince teachers that handheld computers and other electronic technologies are useful in data collection, they should consider obtaining recommendations from teachers who already use these technologies. First-person accounts and testimonials that convey the usefulness of the technology for the achievement of micro- and macro-level goals will be more persuasive to teachers than other arguments.

Potential User Commitment to the Handheld Computer

The teacher's decision to use a handheld computer for the purposes of data collection may ultimately exert less of an influence on eventual use of the computer than it does at present, particularly as both informal and formal elements of American culture demand the integration of technology in the country's classrooms (Cradler & Cradler, 2002). The No Child Left Behind Act signed into law by President George W. Bush in the beginning of this decade made provisions for the expanded role of technology in American schools (Cradler & Cradler). The No Child Left Behind Act emphasizes in particular the importance of technology in special education classrooms, compelling teachers in this area to address the question of whether and how they would incorporate technology, not only for instruction, but also for observation, monitoring, and evaluation purposes (NCLB, 2002).

As Hu, Chau, Liu Sheng, and Tam (1999) pointed out, however, mere adoption of technology is not necessarily equivalent to its implementation, much less its consistent and effective use. Teachers have varying beliefs not only about the value and utility of technology, but also about its ease of use. Teachers also have varying levels of confidence in their own ability to use technology. Therefore, a teacher's intention and commitment to use a handheld computer or other technological resource in the classroom depend on a number of factors. Administrators and policy makers who realize that a conceptual and pragmatic gap often exists between one's intention to use technology—which, in many cases, is dictated by the district and the school—and one's commitment to use it, will be better able to address these issues. A teacher may well intend to use the handheld computer for data collection purposes, and may actually do so in compliance with administrators' expectations and demands. Intention and use however, should not be mistaken as indicators or confirmation that a technology is being used appropriately or optimally.

For these reasons, stakeholders charged with determining the extent to which handheld computers are implemented in classrooms need to attach some observable outcome criteria and measurements to the use of these technologies. Without making oversight punitive, administrators should ensure that technologies are being used correctly and for the appropriate reasons, and that their utility is being leveraged to support the teacher's and school's overall instructional and achievement goals. Otherwise, the potential utility of the technology may be either be undermined or underexploited.

Commitment to technology and its usage can be assessed in numerous ways. Teachers could complete technology user satisfaction surveys, which administrators could use to identify any challenges and difficulties. Communication and feedback loops are important components of the handheld computer data collection monitoring process; more communication with teachers who are using computers will lead to greater troubleshooting and problem prevention by administrators and technical support staff. Administrators will also want to make a plan to periodically evaluate the data collected by teachers to ensure that the data meet the school's or district's collection criteria. The data's value is ensured only to the extent to which data collection methods have integrity, use appropriate procedures, and are used for appropriate purposes.

Perceptions Regarding Dependability and Reliability of the Handheld Computer

Dependability refers to the technology's ability to perform consistently. It is also defined as "the system property that integrates [the] attributes [of] reliability, availability, safety, security, survivability, [and] maintainability" (Avizienis, Laprie, & Randell, 2005, p. 1). Dependability, both of hardware and of software, is a "desirable property of all computer-based systems," whether desktop, laptop, or handheld (Sterritt & Bustard, 2003, p. 247).

To measure dependability, users and researchers tabulate the incidents of "threats, faults, errors, and failures" that prevent the end user from utilizing the technology to fulfill its intended purpose (Avizienis et al., p. 1). Although dependability has improved considerably as technology has grown more sophisticated, it remains a critical variable that determines both a user's interest in a technology and his or her ability to utilize it consistently, particularly because the same evolutionary technology that has improved dependability has simultaneously created more opportunities for dependability to be threatened (Avizienis et al.). While technical support ideally is available, the user also wants to know that the hardware and software are both dependable and reliable, with minimal intervention from technical support staff or reference materials.

Dependability and reliability are critical variables that help predict a technology's useful lifespan and the accuracy, validity, and reliability of the data it is used to collect (Fitzgerald, 2002). Hutter, Muller, Stephan, and Ullmann (2003), for instance, reported that dependability related to data quality must be assured through regular audits of information that has been entered into the computer. Hutter et al. posited that some concerns about dependability of data entered into handheld computers exist because the user of a handheld computer is likely to be multi-tasking. The same portability that makes the computer so appealing may also compromise data quality, as well as the completeness of the data set and inter-agreement (Hutter et al.).

Technology abandonment is alarmingly common in the nation's schools, which presents problems regarding the achievement of the school's strategic, instructional, and academic outcomes goals, and also squanders the school's investments in purchasing, maintaining, and upgrading its technology. Considerable financial investments are also made in teacher orientation and training on the new technology. Technology abandonment is an important issue, and its likelihood can be minimized if one first understands its causes (Edyburn, 2001).

In addition to the obstacles for optimal use of technology used for data collection (teachers' perceptions regarding its ease of use and the utility and the extent of their commitment its thoughtful use), the experience teachers have when using the technology will in large part determine their continued and effective usage (Edyburn, 2001). If a teacher using a handheld computer experiences difficulties concerning dependability and reliability in data collection, then he or she is likely to use the computer less frequently, to use it incorrectly, to generate skewed data sets, or even to abandon its use altogether (Edyburn). Thus, in addition to ensuring that teachers are trained to use the computer appropriately, that they are satisfied with its performance, and that they believe it to be both simple to use and meaningful for the realization of their own and the school's goals, it is crucial that administrators and policy makers regularly check with teachers to ensure that the computers are functioning properly. Furthermore, provisions must be made for performing system upgrades only during times when data collection is not necessary. While technology dependability and reliability are not direct technical support issues, making teachers aware of the protocol to be followed when they experience technological inconsistency or failures is important. Notifying the responsible administrators if data have been compromised in any way due to dependability and reliability issues is particularly important.

Subjective Norms

The term subjective norms refers to a broad category that includes a teacher's perceptions about, opinions regarding, or suggestions influencing his or her adoption and use of a handheld computer or other technology for the purposes of data collection (Ajzen, 1988; Hu et al., 2003; Ma et al., 2005; Taylor & Todd, 1995). For the most part, as the term suggests, these norms are specific to each user, and are largely subjective, influenced not by empirical information about a technology's utility, ease of use, or functionality, but by anecdotal accounts of others' experiences with the technology and one's perceptions and projections about the technology based on one's own previous experiences with it (Marcinkiewicz & Regstad, 1996). The more negative experiences one has had, the more likely one is to resist, reject, or misuse the technology being introduced, even if it has been proven to have compelling benefits for both micro- and macro- level goals (Marcinkiewicz & Regstad).

In addition, the user is unaware of many of the subjective norms that influence technology adoption and use (Yuen & Ma, 2002). For instance, Yuen and Ma reported on the subtle but important influence of gender norms on beliefs regarding handheld computer and their adoption and use. Generally, females tend to feel less competent and confident in their technical abilities than their male counterparts. These authors made three even more critical discoveries about this subjective norm:

> (a) perceived usefulness will influence intention to use computers more strongly for females than males, (b) perceived ease of use will influence intention to use computers more strongly for females than males, and (c) perceived ease of use will influence perceived usefulness more strongly for males than females (p. 365).

Therefore, administrators responsible for policies related to technology need to be aware of the extent to which subjective norms can influence technology adoption and use. Besides gender (Yuen & Ma, 2002), Kwon and Chidambaram (2000) identified age, race, level of education, and extent of professional experience as subjective norms that exert statistically significant spheres of influence on the adoption of certain technologies by adults. Although it is unlikely that administrators will be able to control for or mitigate all of the subjective norms that influence technology adoption and use, they should, at the very least, acknowledge the potential influence of each of these subjective norms.

Empirical Evidence Regarding Electronic Devices versus Paper-and-Pencil Data Collection Methodologies

One of the ways to address the aforementioned obstacles that often prevent the successful adoption and utilization of handheld computers and other technological resources for classroom data collection is to review empirical studies of the relative utility of these computers compared to traditional paper-and-pencil measures. As Epstein, Klinkenberg, and McKinley (2001) observed, “A growing number of studies have investigated the equivalence of data collected over the Internet and data gathered using traditional assessment methods” (p. 339). While these researchers acknowledge that “Many of these studies . . . have had methodological limitations such as using non-equivalent comparison groups and inappropriate data analytic strategies,” a review of recent empirical literature on the subject reveals remarkable consistency among the different researchers’ conclusions regarding technology adoption and efficacy (Epstein et al., p. 339). Several of these studies are reviewed here.

In one early study of the efficacy of electronic devices versus paper-and-pencil instruments used to collect data, Stanton (1998) administered a Web-based questionnaire to one set of employees and a traditional paper-and-pencil questionnaire to a comparison group. Although the sample sizes were not comparable—50 participants completed the electronic questionnaire, while 181 completed the hard-copy version—the author claimed to have compensated for the discrepancy as a potentially confounding variable. After doing so, Stanton concluded that “Analyses of the [two] data sets supported [further] exploration of the viability of World Wide Web data collection” (p. 709), which produced fewer missing values than the paper- and-pencil data collection.

Like Stanton (1998), Ployhart, Weekley, Holtz, and Kemp (2003) compared the response integrity and efficacy of a group of participants responding to a Web-based survey to the response integrity and efficacy of a group responding to a paper-and-pencil survey. Ployhart et al. reported five important findings. “Relative to the applicants completing the paper-and-pencil measures,” they wrote, “the Web-based measures showed (a) better distributional properties, (b) lower means, (c) more variance, (d) higher internal consistency reliabilities, and (e) stronger intercorrelations” (Ployhart et al., p. 733).

Fouladi, McCarthy, and Moller (2002) also analyzed the relative value of responses of Internet-administered questionnaires versus paper-and-pencil instruments. Although they were less conclusive than Stanton (1998) and Ployhart et al. (2003) in asserting that Internet-administered questionnaires hold greater value than traditional paper-and-pencil measures, they did conclude that Web-based and other technological devices used for data collection demonstrate “viability . . . for assessing . . . psychological phenomena” (p. 204).

Although these studies did not use a handheld computer, relying instead on participants to input their questionnaire responses onto a Web-based form on a computer provided by the researchers, their findings are consistent with research that has confirmed that the incidence of missing values and error rates (in terms of reading and logging responses as raw data) are far lower for data collected through electronic means when compared to paper-and-pencil measures, which are more difficult for the researchers to read and which frequently require the researchers to provide interpretation of a respondent’s answer.

Handheld computers are one of the most promising technologies in many fields because of their ability to provide efficient, reliable and accurate data collection and management (Batten et al., 2003; Greene, 2001; Hampshire, 2001; Weber & Roberts, 2000). Pascoe, Ryan, and Morse (2000) successfully collected data with handheld computers in archaeological and ecological fieldwork. Similarly, Blake (2002) tracked animals via a Palm-based system designed for semiliterate animal trackers. In addition, Johannes et al. (2000) compared data from handheld computers to data collected with paper forms. They found less missed data with handheld computers, and their participants preferred handheld computers over the paper version. In their medical study, Lal et al. (2000) found data collection with handheld computers to be 23% faster, with 58% fewer errors, than data collection via paper forms. Berthelsen and Stilley (2000) administered a 78-item health history questionnaire to dental patients via both a paper form and a handheld computer. The patients responded positively to using a handheld computer and provided data with 93% reliability across the two data collection methods.

Fletcher et al. (2003) compared data collected with paper forms to data collected with handheld computer-based forms in a field observation study of alcohol purchase and obtained a greater than 95% agreement between two forms. Gravlee, Zenk, Woods, Rowe, and Schulz (2006) evaluated the use of handheld computers to collect neighborhood observational data by investigating hardware and software considerations, observer training and implementation strategies, and observer perceptions. They concluded that handheld computers, when their instrument interface is appropriately designed, facilitated the data collection process and minimized missing data and inter-observer error. Sarkar et al. (2006) successfully observed and recorded the social interactions of 573 preschool children with socializing agents (peers, siblings, and neighbors) in one-hour sessions using computerized observational software installed on a Palm handheld computer. Their results indicated that almost all kinds of behavior, from children's social behavior to interactions in an unrestrictive setting, can be recorded through this data collection system.

Researchers have studied similar applications of handheld computers in educational settings. In one study, teachers and students used handheld computers in classroom activities such as quizzes, writing and instructional activities (Crawford & Vahey, 2002). At the end of the study, the researchers found that 96.5% of teachers believed handheld computers were effective instructional tools and that 93% stated that the use of handheld computers contributed positively to the quality of the learning activities. Trapl et al. (2005) used an audio-enhanced personal digital assistant (APDA) system to collect baseline data from a sample of 645 seventh grade students enrolled in a school-based intervention study. They checked for differences among three groups: students new to the United States who spoke English as a second language; special education students; and students not new to the United States who received regular education in data administration and data quality. They found the APDA system was appropriated by students, offered improvements in data administration (increased portability and time to completion), and reduced missing data. Teachers in special education settings in particular use handheld computers to document and assess students in areas such as how they meet the goals stated on their Individualized Education Program (IEP), and use this technology in contexts where instruction and supervision occur without the need for extra devices or accessories (Schaff, Jerome, Behrmann, & Sprague, 2005).

Conclusion

Although technology is rapidly becoming more sophisticated, pervasive and accepted in school settings, just as it has in society at large, McDonald (2002) pointed out that "studies of score equivalence have largely ignored individual differences such as computer experience, computer anxiety and computer attitudes," all of which have been substantiated by the literature as potential obstacles inhibiting the adoption and application of handheld computers for data collection (p. 299). Accordingly, an unplanned and inappropriately applied electronic data-collection system can create resistance to use as well as inaccurate data gathering and analysis. Consequently, hardware, software and user satisfaction must all be considered in the implementation of any technology.

Although teachers may rightly be perceived as more open than others to learning new skills, technology adoption is a complicated area of learning, and its success is often influenced by existing beliefs and perceptions. Those responsible for implementing and overseeing handheld computer use may not be able to manage all these beliefs and perceptions effectively, but awareness of their existence could be a minimum expectation.

While awareness and training are important strategies administrators could use to prepare teachers for optimal leveraging of technology for data collection purposes (Schulenberg & Yutrzenka, 2004), they are by no means the only, or even the most important, considerations. Each of the five areas identified in this paper must be considered to successfully and dependably prepare, plan, and implement handheld computers for data collection.

CHAPTER III

ARE HANDHELD COMPUTERS DEPENDABLE? A NEW DATA COLLECTION SYSTEM FOR CLASSROOM-BASED OBSERVATIONS

Overview

Very little research exists on the dynamics that influence the dependability of handheld computers and these computers' applications for specific educational practices. This study addresses four dependability attributes—reliability, maintainability, availability, and safety—to evaluate an optimized data-collection tool on a handheld computer. Data were collected from five sources: (1) self-reports of time use by 19 special education teachers using handheld computers, (2) observations of time use from eight external data collectors, (3) teacher interviews, (4) technical reports prepared by the researcher, and (5) teacher satisfaction. Results revealed that this data collection tool yielded accurate, complete and timely data, and was appropriate for these four dependability attributes. The study also found that when handheld computers are dependable, they can replace paper-based data collection in research and educational settings.

Introduction

Data collection through direct observation of behavior is one of the most effective and comprehensive methods of gathering information of a dynamic and interactive nature. The education field still relies heavily on time-consuming, cumbersome, and error-prone paper-and-pencil methods for notating observations of behavior. Consequently, researchers have sought to simplify the collection of such data (Dumont & Chafouleas, 1999) through various technologies, including desktop and laptop computers, as well as portable handheld computing devices (Kahng & Iwata, 1998). Although the use of desktop computers eliminates the need for transcription from paper formats and maintains the integrity of the data from collection to analysis, transporting these computers from one location to another is difficult. Laptop computers that have wireless capability provide more portability and thus permit coding of more interactions and behaviors, but are costly and require significant upkeep.

Data collection systems for handheld computers have been developed to improve the way observations and assessments are conducted in research and classroom settings (Dirr, 2002). Handheld computers' portability and the compatibility of their software applications with desktop and laptop computers give researchers the ability to quickly record and access data anywhere and at any time. A new generation of handheld computers with the wireless option can enhance data validation at the time of data collection through wireless synchronization, provide a platform-free environment, and enable researchers to detect problems and report data instantly via the World Wide Web. Current research on handheld computer use for data collection has verified this device's viability and benefits vis-à-vis hardware, software, and user satisfaction. However, none of these studies focused on the dependability of handheld computers for observational data collection applied to specific educational practices (Crawford & Vahey, 2002; Parr, Jones, & Songer, 2002; Spinuzzi, 2003). This study addresses these gaps in the literature and provides insights into the dynamics that influence the dependability of handheld computers for direct observation in applied special-education settings.

Theoretical Background

Today's ever-changing educational practices and research settings require a variety of resources and tools, many of which utilize associated new technologies (Bouzeghoub, Carpentier, Defude & Duitama, 2003; Karagiannidis, Sampson & Cardinali, 2001). Given technology's increasing influence and the explosion in data collection, the acceptance and assimilation of new paradigms and their associated technologies also require today's educators, researchers, and evaluators to select appropriate tools (Becta, 2004; Heins & Himes, 2002). One of these technologies consists of handheld computers, also known as personal digital assistants (PDA), which make computerized data collection more accessible to field-based researchers (Crowe & Hooft, 2006; Gravlee, Zenk, Woods, Rowe, & Schulz, 2006).

Computerized Data-collection Systems

There have been numerous attempts during the past 20 years to simplify the collection, analysis and management of field data in a multitude of application areas (Dixon, 2003; Ice, 2004; Miltenberger, Rapp, & Long, 1999; Reschly & Ysseldyke, 2002; Spinuzzi, 2003). Federal laws such as the Individuals with Disabilities Education Act (IDEA, 2004) and No Child Left Behind (NCLB, 2002) require data collection and data applications in a variety of forms in education settings. Computerized data collection systems (CDCS) have become increasingly functional, user-friendly, and portable solutions for both collecting and analyzing data. They offer five key benefits relative to traditional, time-consuming paper-and-pencil methods: (1) less missing data, (2) accurate data recording, (3) more timely transmission of data, (4) less need for post-collection editing and coding, and (5) ongoing monitoring of data quality (Couper & Nicholls, 1998; deLeeuw & Nicholls, 1996; Emerson, Reeves, & Felce, 2000; Gravlee, 2002; Kahng & Iwata, 1998; Preece, Rogers, & Sharp, 2002; Trapl et al., 2005).

In their review of computer-based observational systems, Kahng and Iwata (1998) concluded that such systems have the potential to collect data from several dimensions of the target behavior, such as frequency, duration, inter-response time, and latency. In their discussion of electronic data collection systems for practice-based research, Pace and Staton (2005) identified two main benefits: portability (i. e., on-site data collection is possible with a laptop or handheld computer) and immediate validation with no subsequent manual data entry. Although laptop computers are a great solution vis-à-vis portability and standardization of equipment across all the studies reviewed, they also require sufficient electrical outlets, which may not be available in all schools. In addition, laptop computers incur security issues because of their cost and size (Trapl et al., 2005). Spinuzzi (2003) described laptop computers used for data-collection purposes as being bulky, obtrusive and less-mobile technologies that also take much longer to boot and have a much shorter battery life.

Handheld computers. Handheld computers have several benefits as data-collection technology: relatively low cost ($100 to $400), portability, ease of use (with minimum computer skills required), flexibility (ready availability), and relatively long battery life (six hours) (Fletcher, Erickson, Toomey, & Wagenaar, 2003; Trapl et al., 2005). Furthermore, these technologies and associated data entry techniques offer a fast and accurate method of data collection regardless of location, a huge leap forward from stand-alone computers and time-consuming paper-and-pencil techniques. Handheld computers can interact with several devices and make information accessible through a wireless connection to a server computer (Batten, Crowdhury, & Drew, 2003; Dixon, 2003; Ice, 2004). Thus, daily recordings of class performance can be entered and retained on the handheld computer and then downloaded onto a disc or transferred to a server at the end of the day (Stacey, 2000).

One of the most common handheld computers used for the capture and storage of data in an educational setting is the Pocket PC. This computer, and equivalent small computers with data collection capacities, allows teachers to input data either in real time as it is collected or at some later time (Davis, 2002; Hoppe, Joiner, Milrad, & Sharples, 2003). As Davis noted, handheld computers offer educators clear and compelling benefits over traditional paper-and-pencil methods. Among them are the ability to instantly assess student performance and other behavioral characteristics, to present data as immediate and direct feedback to students, to transfer data directly to students in highly technologized classrooms, to share data among teacher groups, and, in some cases, to share data with parents and other stakeholders. Davis also noted that teachers' use of handheld computers for data collection also provides several benefits for students, including "anonymity of data submission to the group and the ability to see their data displayed in the group space" (p. 31).

Clearly, portability—both of the computer itself and of the collected data—permits teachers to collect types of data that might not be possible with paper- and-pencil methods (Greenwood, Carta, Kamps, Terry, & Delquadri, 1994). As Greenwood et al. explained, the portability of computers and the increasing diversity of the number and types of software programs that permit teachers to collect various kinds of data provide new opportunities for behavioral and academic performance monitoring, both as short-term and long-term tasks. The ecobehavioral assessment software described by Greenwood et al., for instance, is just one example of a software application that permits teachers to track multiple data streams for multiple measures in a compact and manageable format.

The ability to collect and manage data efficiently, reliably, and accurately has led officials at a number of schools and other institutions, as well as researchers in many other fields, to use handheld computers (Batten et al., 2003; Greene, 2001; Hampshire, 2001; Weber & Roberts, 2000). For example, Pascoe, Ryan, and Morse (2000) successfully collected data with handheld computers while conducting archaeological and ecological fieldwork. Similarly, Blake (2002) tracked animals via a Palm-based system designed for semiliterate animal trackers. In addition, when Johannes et al. (2000) compared data from handheld computers to data collected with paper forms, they found less missed data with handheld computers, and found that their participants preferred handheld computers over the paper version. In their medical study, Lal et al. (2000) found data collection via handheld computers to be 23% faster, with 58% fewer errors, than data collection using paper forms. A 78-item health history questionnaire was administered to dental patients both on a paper form and via handheld computer by Berthelsen and Stilley (2000). The patients responded positively to using a handheld computer and provided data that had 93% reliability across the two data collection methods.

When Fletcher et al. (2003) compared data collected with paper forms to data collected with handheld computer-based forms in a field observation study of alcohol purchase, they obtained a greater than 95% agreement between the two forms. Gravlee et al. (2006) evaluated the use of handheld computers to collect neighborhood observational data by investigating hardware and software considerations, observer training and implementation strategies, and observer perceptions. They concluded that handheld computers facilitate the data collection process and minimize missing data and inter-observer error when the instrument interface is designed appropriately. Sarkar et al. (2006) successfully observed and recorded the social interactions of 573 preschool children with socializing agents (peers, siblings, and neighbors) in hour-long sessions using computerized observational software installed on a Palm handheld computer. Their results indicated that almost all kinds of behavior, from children's social behavior and interactions in an unrestricted setting, can be recorded through this data collection system.

Researchers have studied similar applications of handheld computers in educational settings. In a study investigating the effective uses of handheld computers, teachers and students used handheld computers in classroom activities such as quizzes, writing and instructional activities (Crawford & Vahey, 2002). At the end of the study, the researchers found that 96.5% of teachers believed handheld computers were effective instructional tools and 93% stated that the use of handheld computers contributed positively to the quality of learning activities. Trapl et al. (2005) used an audio-enhanced personal digital assistant (APDA) system to collect baseline data from a sample of 645 seventh grade students enrolled in a school-based intervention study. They checked for differences in data administration and data quality among three groups of students: those new to the United States who spoke English as a second language, special education students, and those not new to the United States who received regular education. They found the APDA system was appropriated by students and offered improvements in data administration (increased portability, time to completion) and reduced missing data. This is particularly true in special education settings, where teachers document and assess students using handheld computers vis-à-vis the goals stated on their Individualized Education Program (IEP), and use this technology in other contexts where instruction and supervision occur without the need for extra devices or accessories (Schaff, Jerome, Behrmann, & Sprague, 2005).

Technology Dependability

Dependability refers to the technology's ability to perform consistently and integrates such attributes as reliability, availability, safety, security, survivability, and maintainability (Avizienis, Laprie, & Randell, 2005). Dependability of both hardware and software is a "desirable property of all computer-based systems," whether desktop, laptop, or handheld (Sterritt & Bustard, 2003, p. 247). To measure dependability, users and researchers tabulate incidents of "threats, faults, errors, and failures" that prevent the end user from fully utilizing the technology for its intended purpose (Avizienis et al., p. 1).

Although dependability has improved considerably as technology has grown increasingly sophisticated, it remains a critical variable that determines both a user's interest in a technology and his or her ability to utilize it consistently, particularly because the same evolutionary technology that has improved dependability has simultaneously created more opportunities for dependability to be threatened (Avizienis et al.). While technical support ideally is available, the user also wants reassurance that the hardware and software are both dependable and reliable with minimal intervention from technical support staff or reference materials.

Dependability and reliability are critical variables that predict the technology's longevity and the accuracy, validity, and reliability of the data it collects (Fitzgerald, 2002). Hutter, Muller, Stephan, and Ullmann (2003), for instance, reported that dependability related to data quality must be assured through regular audits of information entered into the computer. Hutter et al. posited that concerns about the dependability of data entered into handheld computers exist because the user of a handheld computer is likely to be multi-tasking. The same portability that makes the computer so appealing may also compromise data quality, as well as the completeness of the data set and inter-agreement (Hutter et al.).

Preventing technology abandonment is important, and the reasons for it must first be understood (Edyburn, 2001). Teachers who experience difficulties regarding dependability and reliability when using a handheld data collection computer are more likely than others to use the computer less frequently, to use it incorrectly, to generate skewed data sets, or even to abandon the use of the computer altogether (Edyburn). Thus, in addition to ensuring that teachers are trained to use the computer, that they are satisfied with its performance, and that they believe it is both simple to use and meaningful for the realization of their own and their school's goals, administrators and policy makers must regularly ensure that the computers are functioning properly. Furthermore, provisions must be made for retrieving computers for system upgrades only when they are not needed for data collection. While technology dependability and reliability are not direct technical support issues, making users aware of the protocol to be followed when they experience inconsistency or failures pertaining to the dependability and reliability of the technological equipment with which they have been provided is important. Informing the responsible administrators if data have been compromised in any way due to dependability and reliability issues is of particular importance.

Method

Participants

This study was conducted in south-central Texas in fall 2005 and winter 2006. Participants were 19 fully licensed and certified special education teachers from two school districts who were involved in the grant project (see Table 3.1). Participants in the study taught students with high-incidence disabilities through one of four instructional arrangements: (a) instruction delivered in adaptive behavior settings, (b) resource instruction/assistance provided in a pull-out setting, (c) co-teaching with a general education teacher in a general education classroom, or (d) instruction delivered in life skill settings. Of the 19 participating teachers, 11 were placed in resource settings, four in adaptive behavior settings, two in life skills, and two in co-teaching settings. Of the 19 original participants in fall 2005, 18 continued with the study in winter 2006. The study also included eight data collectors who were graduate students from three educational psychology programs (school psychology, counseling psychology, and special education) at the same university and worked in the D2K project.

Participants were all female teachers at 13 schools certified by the state as academically acceptable, seven of which have wireless networks. They had no prior experience with handheld computers in their school settings. Participants and data collectors were trained using the same materials pertaining to codes and procedures. They were also given instructions on accessing the Internet on their Pocket PCs both wirelessly and wired through their schools' network connection, and on the forms themselves. They also received a one-page summary of the steps (see Appendix A) for submitting their activities for any interval and at any time.

Instrumentation

One two-media instrument, designed by the principal investigators of the grant project, was used in the study: the Teacher-Time Use (TTU) instrument (Vannest, Hagan-Burke, & Parker, 2006) in electronic and hard-copy form, which was a printed copy of the electronic version and used by some external data collectors for observing participants' behaviors. The TTU instrument was utilized to evaluate a special education (SPED) teacher's entire work day to be represented by 12 activity codes with corresponding expenditures of teacher time.

Table 3.1

Participants and Time Sample by Settings

Program	# Participants	# Hours	# Intervals
	Fall 10/14/05 – 11/18/05, 19 Participants, 4929 Intervals, 1232:15 Hours		
Adaptive Behavior	4	227:15	909
Co-Teaching	2	136	544
Life Skills	2	149:45	599
Resource	11	719:15	2877
	Winter 01/23/06 – 02/27/06, 18 Participants, 994 Intervals, 994 Hours		
Adaptive Behavior	4	234	234
Co-Teaching	2	109	109
Life Skills	2	129	129
Resource	10	522	522

The codes that were face validated through focus groups with teachers were academic instruction, non-academic instruction, instructional support, discipline, supervision, IEP meetings, paperwork, consult/collaborate, assessments, personal time, planning/preparing, and other responsibilities (see Appendix B). Both the TTU hard copy and electronic forms have a five-point (six-point in winter 2006) Likert-type scale to measure teacher time spent on pre-defined and pre-validated activities in 12 code categories.

Participants recorded their self-report of time use data using an electronic form of TTU (see Figure 3.1) designed on Microsoft® Windows-powered Pocket PC handheld computers. These devices were chosen because they provide a more flexible and portable environment, which results in improved data accuracy and management (Luchini, Quintana, & Soloway, 2003). Pocket PC computers with wireless support were used in the study despite being more expensive than their PalmOS rivals, which dominate the market and have many shareware applications (Ice, 2004; Suliburk, 2003). A Pocket PC uses the Microsoft Windows CE® operating system, which is a portable version of the desktop Windows operating system, and accommodates optimized versions of many popular Microsoft desktop software programs such as Word®, Excel®, and Outlook® (Dixon, 2003). In addition, Pocket PC computers with advanced multimedia capabilities and networking features are ideal for schools that require operating systems that have more power, are easier to use, and are more flexible in a wireless network setting (Suliburk, 2003).

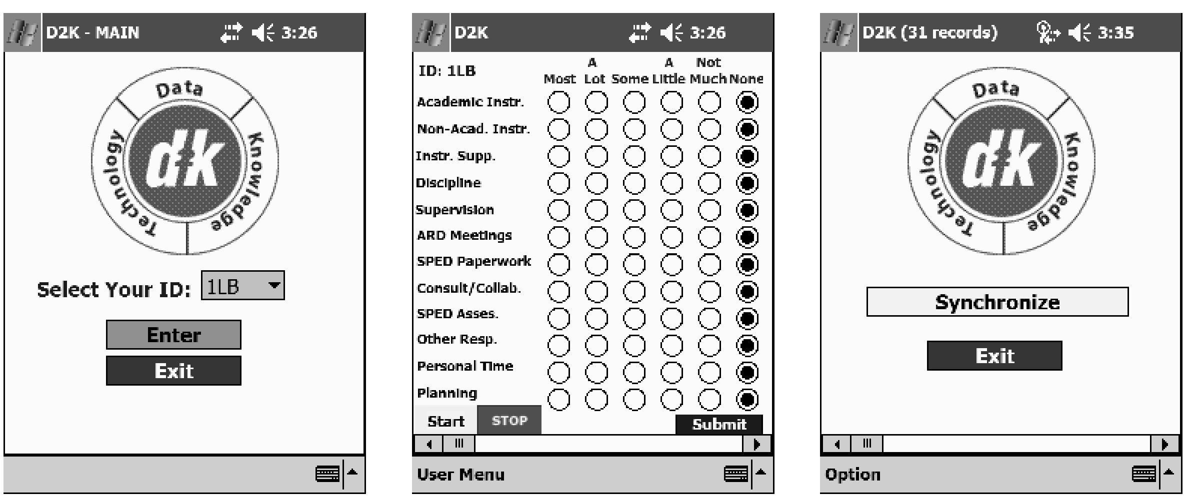

Figure 3.1. Screen snapshots from the electronic form of TTU

The TTU form was developed using the *Visual CE* database application tool from *SYWARE Inc*. *Visual CE* is compatible with all Pocket PC computers and MS Access®, as well as any other Open Data Base Connectivity (ODBC)-enabled program that manages administrative, processing, and reporting functions on a host PC. *Visual CE* has a fully relational database to centralize data and offers wide flexibility in data capture methods, form design, and database management, while enabling rapid application development without coding. Another *SYWARE* product, *mEnable* application, was integrated into the form for wireless synchronization between the handhelds and the desktop server. The *mEnable* communications software allows Windows CE® handhelds to wirelessly exchange data with any Windows server over a local or wide area network using the standard TCP/IP protocol. An *mEnable* icon was included on every screen of the handheld form to transmit handheld data to the Access application on the server.

This format was intended to achieve the design goals defined by Gong and Tarasewich (2004), and Berry (2000). Design constraints such as limited screen resolution, absence of keyboard, and pen-based manipulation were minimized in response to discussions in the current literature for this device (Karampelas, Akoumianakis, & Stephanidis, 2003). Guidelines for electronic forms (Dillman, 2000) were customized and implemented into the Pocket PC format to create small-resolution screens that were usable, functional and user-friendly (Hayhoe, 2001). To address accuracy, an interface was created to reduce the number of requests for data entry and prevent data-entry errors (Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003). The layout for buttons, labels and color coding was designed to maximize readability, visibility and categorization of the information on the small display (Luchini et al., 2004). Drop-down lists, radio buttons and push buttons were used to minimize requirements for manual input and allow paper forms to be easily adapted to fit onto the miniature handheld screen while still allowing a level of detail that is awkward or impossible to present on paper forms (Gong & Tarasewich).

Data Collection

To address the attributes of dependability of the Pocket PC computer as a data collection tool, qualitative and quantitative data were gathered from the following five sources.

Participants' self-report data. Data collection occurred randomly over a 10-week period in the fall and winter. Participants self-reported over the interval of 15 minutes in the fall and one hour in the winter, and were able to accurately tell what activities they had just completed using the Pocket PC data collection tool. At the end of every interval, the device alerted participants to report data on activities retrospectively. Participants selected their activities according to the time rankings of most (80-100%), a lot (60-79%), some (40-59%), a little (20-39%), not much (3-19%), or none. When an Internet connection was established, participants synchronized their daily data with a Microsoft Access central server database by using the application on their Pocket PCs. The system kept track of each handheld device and its assigned user, recognizing where each transaction came from and who performed it.

The data collected on the server were drawn daily to verify the numbers and quality of records submitted by each participant. The numbers of assigned data records were calculated by multiplying hours and days per participant to be used as a data source for incompleteness (de Mul & Berg, 2007; Mikkelsen & Aasly, 2005; Motro, 1990, Walker et al., 2004). The times that the data were received and saved in the Pocket PC computers and the server were also filtered to evaluate the timeliness of the data (Sarkar et al., 2006; Trapl et al., 2005). Missing data were coded from the total submitted records using the following rules:

- NoT: A record that did not have any start and stop times, or
- NoC: A record that had either start or stop times, and zero values for the activity codes.

External observer records. Two data collectors coded simultaneously with participants to collect data for reliability assessment of participant reporting. One data collector used the “gold standard” of continuous, concurrent observation and the other used paper copies of the computer screen that participants used to input data on the handheld Pocket PC. All observer data sheets were turned in to the project administrator within 24 hours and entered into the Access database. These data records were reformatted to correlate with participants’ self-report data for accuracy, based on agreement.

Participant interviews. De-briefing interviews were conducted by trained data collectors. Participants were asked 10 questions about the procedures of self-reporting, including the usability and functionality of the electronic data collection system in their classroom settings. These interviews were considered supporting data to provide more information about participants' use of the Pocket PC handheld computers, and electronic template information such as usability and design.

Technical reports. Technical support was logged and coded. Participants' technical and help requests pertaining to the technology setup and support sent through e-mails and phone calls were tracked. The researcher's school visits to provide technical support were also logged. The corpus of this data was coded, transformed, and quantified to support the maintainability attribute.

Self-report of satisfaction. Following the period of participant implementation of self-reporting, participants were given written evaluations of the technology. They answered five questions regarding the use of the software and hardware of Pocket PC computers for data collection and provided suggestions for improvement.

Data Analysis

Both qualitative and quantitative data analysis techniques were used to test dependability of the handheld data collection system (Johnson & Onwuegbuzie, 2004). The analysis techniques were performed separately, but the results were combined at the interpretive stage.

Reliability data were collected on the TTU instrument over a period of 10 weeks within 19 special education teachers' classrooms, for a total of 189 direct observation hours. Participants' retrospective Pocket PC ratings yielded ordinal data, as did independent observer ratings using the same scale. Continuous observations of start and stop times for all participant behaviors yielded interval-level data. To estimate reliability, participant judgment was compared to the gold standard of continuous, concurrent observation by an external data collector in the classroom and a separate data collector who concurrently observed and coded using a hard copy of the electronic version. Reliability involved three comparisons: (1) between two independent observers (the gold standard of continuous observation against the end-of-each-interval observation), (2) participant ratings against the continuous gold standard, and (3) participant ratings against independent observer ratings using a hard copy of the instrument. The inter-observer agreement based on participants' self-report of time use (n = 19 special education teachers, 2226.15 recorded hours) and data collectors' observational data (n = 8 data collectors, 189 observed hours) was calculated using Pearson's *r*, a continuous data measure for the combination of ordinal and interval data, and Cohen's Kappa for categorical agreement. In addition, simple percent agreement was calculated for occurrences and non-occurrences.

Descriptive statistics were used to examine the total, missing, incomplete and on-time records (Fletcher et al., 2003; Trapl et al., 2005). Participants' hour commitment and timestamps per record were compared with their actual number of records submitted and the time they were submitted. This provided insights into the timeliness and incompleteness of the data, respectively. The results from inter-observer agreement and descriptive statistics were combined for interpretation of data quality.

The three remaining attributes—maintainability, availability, and safety—were assessed using participant interviews, self-report of satisfaction, and systematically recorded technical reports. Data consolidation, transformation, and coding techniques were used to evaluate these attributes based on the qualitative data stream (Anfara, Brown, & Mangione, 2002). Constant comparative analysis was used to categorize the data into emergent themes. As shown in Table 3.2, multiple sources of data collection were triangulated (Onwuegbuzie & Leech, 2006) to describe and summarize these multiple complex categories of dependability in a manageable way. Interface issues were also analyzed by constant comparison of pre-defined universal design principles with the handheld interface.

Table 3.2

Findings and Sources for Data Triangulation

	Sources of Data					
	PS	EOR	PI	TR	SS	UDP
Reliability						
1. Data Quality						
a. Incompleteness	x	x				
b. Missingness	x	x				
c. Timeliness	x	x				
d. Accuracy	x	x				
2. Design and Usability			x	x	x	x
Maintainability						
1. Synchronization						
a. System			x	x	x	
b. Wireless			x	x	x	
c. Firewall			x	x	x	
2. Alarm			x	x	x	
Availability			x	x	x	
Safety						
1. Battery			x	x	x	

Note. PS = Participant Self-report of time use, EOR = External Observer Records, PI = Participant Interviews, TR = Technical Reports, SS = Self-report of satisfactions, UDP = Universal Design Principles

Results

The dependability attributes of reliability, maintainability, availability, and safety will be discussed as they pertain to the value of using handheld technologies in classroom observations.

Reliability

Incompleteness. The numbers of assigned data records and retrieved records by participants were summarized and paired both per participant and in total (see Table 3.3). The calculated assigned records for fall were 280 per participant, for a total of 5,320 assigned records, and for winter, 70 assigned records per participant, for a total of 1,008 total records.

Table 3.3

Participant Self-report Records with Assigned and Retrieved Data Records

Data Records	Fall	Winter	Total
Assigned	5320	1008	6328
Retrieved	4929 (92.65%)	994 (98.61%)	5923 (93.6%)

Participants submitted a total of 4,929 (92.65%) records for fall, but 994 (98.61%) in winter, a substantial increase. The total results indicate that 5,923 (93.6%) of the 6,328 records were completed by participants and successfully retrieved by the server for subsequent analyses.

Missingness. Table 3.4 provides the ranges of missing self-report data based on two applied rules (NoT and NoC), in total and per participant. The total rate of both missed start and stop time values (NoT) in the fall was 5.25%, whereas there were no missing time values in the winter. Although total missing code records (NoC) in the fall and winter appear to be similar, six participants have no missing data and the rate of NoC for four participants was approximately 1% in winter. For example, overall rates of NoC by participants ranged from 4% to 22% in the fall and 0% to 29% in the winter. Of additional note that is the rates of NoC from all participants, except for one in the fall, were less than or around 10%, as well as the low rates of missing data by 15 participants from fall to winter. Finally, NoT rates for participant 12 decreased from 22% to 3% between fall and winter while the same rates for participant 5 increased from 9% to 29%.

Table 3.4

Participant Self-report Records with Missing Values

	Fall			Winter	
Participants	# Records	% NoT	% NoC	# Records	% NoC
Participant 1	253	7.91	10.28	28	10.71
Participant 2	246	2.85	5.28	73	8.22
Participant 3	312	7.05	13.46	73	1.37
Participant 4	304	.66	6.25	33	.00
Participant 5	276	3.26	9.06	48	29.17
Participant 6	202	.00	5.45	104	2.88
Participant 7	335	3.88	12.84	12	.00
Participant 8	337	1.19	8.01	43	4.65
Participant 9	295	8.81	5.08	96	.00
Participant 10	235	.85	9.79	79	1.27
Participant 11	305	1.31	8.20	49	.00
Participant 12	239	6.69	22.18	60	3.33
Participant 13	185	1.08	8.65	53	3.77
Participant 14	181	6.63	9.39	69	.00
Participant 15	329	6.38	11.55	76	1.32
Participant 16	230	3.48	5.22	14	7.14
Participant 17	243	34.16	6.58	29	.00
Participant 18	246	.81	4.07	*	*
Participant 19	176	3.41	16.48	55	7.27
Total	4929	5.25	9.33	994	4.02

* indicates no records

Timeliness. Table 3.5 shows the number of participant records sent to the server on the same day that they were saved on Pocket PC computers compared with total saved records. Participants synchronized only 10.02% of their saved records with server on the same day in the fall, but this increased to 96.08% in the winter. The combined results from both fall and winter show that only 24.46% of saved records were synchronized with the server on the same day they were collected.

Table 3.5

Participant Self-report Records with On-time Submitted Data Records

Data Records	Fall	Winter	Total
Total	4929	994	5923
On-time	494 (10.02%)	955 (96.08%)	1449 (24.46%)

Accuracy. Reliability coefficients are presented in Table 3.6. Both continuous and categorical indices were calculated for agreement between participants and observers. Participants' Pocket PC retrospective entry agreed at Pearson r = .75 in the fall and r = .78 in the winter with the independent observer. Similar agreement scores were obtained between participants' data entry and the gold standard of continuous observation—Pearson's r = .74 in the fall and r = .77 in the winter. Against the same standard, the independent observers agreed at r = .93 in the fall and r = .90 in the winter.

This agreement between trained external observers using two different strategies was considered the "best possible agreement." It is reasonable to conclude that, given their ample training and the lack of distractions during their observations, the raters showed a consistency and that the less time-consuming hard-copy coding can provide excellent results. Categorical indices for agreement between participants and independent observers were Cohen's Kappa (chance corrected agreement index) = .54 and .48, and percent agreement = .85 and .73 in the fall and winter, respectively. Due to the chance factor, percent agreement for total non-occurrences = .83, and percent agreement for total occurrences = .60 were also calculated. These results indicated that there were no meaningful variations in observations of participants by external data collectors.

Table 3.6

Inter-rater Reliability Indices

	Pearson *r*			Percent Agreement	Kappa
	Part. – Obs. Int.	Part. – Obs. Cont.	Obs. Int. – Obs. Cont.	Part. – Obs. Int.	Part. – Obs. Int.
Fall	.745*	.741*	.925*	.85	.54
Winter	.781*	.77*	.903*	.73	.48

* Correlation is significant at the 0.01 level (2-tailed).

Design and usability of software application. Findings from different analyses were included here to evaluate whether the electronic form of TTU on the Pocket PC is usable for the target sample. Constant comparative analysis of the electronic form of TTU and design principles for electronic forms and handheld interfaces revealed that the TTU form on the Pocket PC follows most of the design principles included in the current literature (see Tables 3.7 and 3.8). For example, offering selection controls instead of requiring typing, and using drop-down, radio buttons and push buttons with pre-filled text fields to reduce data entry, were based on design principles that promote usability. Having a layout design that reduces the memory load and number of steps, while increasing the visibility and readability of the content, was also a critical design element of handheld computers. The results from participant interviews, technical reports, and self-report of satisfaction revealed one overarching theme: the ease of use of the software application. All participants reported that data coding was simple and quick. One typical comment was, “Collecting data was fine. It was an awesome program. Much easier than paper/pencil [methods] I have done before. This was very, very nice.”

Maintainability

The themes that emerged from participant interviews, technical reports, and self-reports of satisfaction of the Pocket PC served as the “trigger” to determine when to start coding and data synchronization with the server. Most of the phone calls, school visits and e-mails from participants were related to data synchronization problems, especially in the fall.

Table 3.7

Constant Comparative Analysis of Electronic Form of TTU for Form Interfaces

Design Guidelines for Form Interfaces	TTU
Use controls consistently	x
Provide a prompt for each control or group of related controls	x
Use controls that allow users to choose rather than type	x
Avoid using selection controls for actions	x
Choose the correct control for the situation	
1. Text fields	
2. Check boxes	
3. Radio buttons	x
4. Drop-down boxes	x
5. Push Buttons	x

Table 3.8

Constant Comparative Analysis of Electronic Form of TTU for Handheld Interfaces

Design Guidelines for Handheld Interfaces	TTU
Enable Frequent Users to Use Shortcuts	x
Offer Informative Feedback	x
Design Dialogs to Yield Closure	x
Support Internal Locus of Control	x
Consistency	x
Reversal of actions	x
Error prevention and simple error handling	x
Reduce short-term memory load	x
Design for multiple and dynamic contexts	x
Design for small devices	x
Design for limited and split attention	x
Design for speed and recovery	x
Design for “top-down” interaction	
Allow for personalization	
Design for enjoyment	

When asked about their experience with synchronizing data, many participants focused on three issues that occurred while synchronizing data with the server wirelessly or via cable connected to their desktop computers: (1) the synching function in the programming, (2) the Internet connection in the schools, and (3) the university firewall. For example, one typical comment was, “Synching was a nightmare! It took a long time, [and] hardly ever worked. … sometimes [I] needed to leave school and it took forever.” Firewall problems were also mentioned: “[Synching] never worked because [of] wireless router or firewall. It took an hour sometimes and then gave an error message.” E-mail issues also were reported: “I get a failed to receive reply message when I try to login to the movian vpn.” Discussions with participants in the fall revealed that the main reasons for these synchronization problems were the heavy load on the schools’ Internet connection and low signal strength from wireless access points in the classrooms during the day. To illustrate, one participant reported, “I am in the oldest building in the district and it was taking 30-75 minutes to find a connection . . . ” Another participant commented, “[Synching] was frustrating because we did not have access to wireless and being out in the portables, I had to go into the building and wait on the synch . . .” In response, the research team improved the transmission protocols, which led to a marked increase in connection reliability and decreased transmission times during the winter. The difference between data synchronization in fall and winter is illustrated quantitatively in the “timeliness of the data” section above.

Another theme that emerged from the multiple data sources and the analysis was the “timer” that the researcher programmed into the data collection system. Participants’ problems with “timers” occurred mainly in the fall (because of the use of 15-minute intervals) and fell under two categories: alarm sound and timing. When the researcher conducted school visits for troubleshooting and e-mails, most of the participants requested that the sound of the alarm be changed: “The only invasive part about the PDA was the little alarm, but after [the researcher] changed the sound, no one [else] could really hear it.” However, the main difficulty that participants reported was the resetting of the time for the upcoming interval: “I am not getting any kind of alarm on my PDA. I signed in [successfully] but nothing is coming up to tell me to code. I am just coding every 15 min as soon as I remember.” A similar comment was, “This is my first day. I have yet to have an alarm go off. I must be doing something wrong.”

Availability

The interviews, evaluations and reports about the availability of Pocket PCs with an installed data collection system revealed that participants used these computers at different locations and at different times. Some participants reported using lanyards or clips for carrying the device outside: “We need to use lanyards so that we can keep the PDAs ready and available for use. It was hard to hear them when placed in a pocket or purse.” Another pointed out that “[We need] a better clip so that we can carry it with us and have our hands free.” Participants also expressed a desire for student awareness of the project: “[It would be] really cool if students could see how you are coding their behavior, and give them feedback on their desk from across the room.”

Safety

Battery life, the final theme, was identified across participants. Findings from the technical reports revealed only one incident of data loss because of a dead battery. Participants also stated that needing to recharge the Pocket PCs while coding was sometimes problematic: “When the PDA needed to [be charged] I couldn’t take it everywhere with me and I might forget to code or have to keep going back to my desk.” Another commenter noted,

> “The handheld [did] not come on. I have had it turned off since Friday afternoon. I plugged it in last night and tried to turn it on this morning. . . . I cannot get it turned on. When I plugged it in last night a screen came up saying to reboot. I did that but it went off and I didn’t try again until this morning when I got to school.”

In summary, results from five different data sources (teachers’ self-reports, observations of time use by the external data collectors, interviews with the teachers, technical reports, and self-report satisfactions), revealed that the data-collection system installed on the Pocket PC was reliable, maintainable, available, and safe when compared with traditional paper-and-pencil systems. However, dependability attributes were mainly satisfied in the winter because of the improvement in the scripting system based on teacher settings. Although data accuracy results were similar in the fall and winter, significant changes were observed in the other functions of the reliability attribute in the winter. Maintainability was the potential attribute that differentiated dependability of the handheld computers in both fall and winter. There were numerous technical help requests, e-mails and school visits during the fall, and very few in the winter. Teachers reported that the handheld computers appeared to be available whenever and wherever needed, especially in the fall, because of the shorter time intervals. Battery problems were the only threat to the safety attribute.

Conclusion

Researchers, who could benefit from the ability to record anywhere within short time periods or access data wherever operations are taking place, are looking for ways to simplify data collection, reduction, and analysis. As a result, various technologies, including desktop and laptop computers, as well as mobile handheld computers, have been tried. However, finding a dependable technology to maintain data integrity from collection to analysis and that can code more interactions and behaviors is a challenge. This study explored whether handheld computers are dependable for data collection and observation in special education settings.

One of the main concerns in research studies is to have a sufficient quantity and quality of data points to generalize the findings. The reliability of data collection methods is ensured only when data have integrity and quality, meaning that all data are complete, accurate, and timely (Malan, Haffner, Armstrong, & Satin, 2000; Sarkar et al., 2006). Overall rates of retrieved records in both fall (92.65%) and spring (98.61%) were satisfactory based on the assigned records. The numbers of assigned and submitted records in the fall were five times higher than the ones in winter since the participants self-reported their time use in 15-minute intervals. Regarding individual rates of retrieved records, most participants followed the schedule and coded for 10 or more days in the fall, but only five participants did so during the spring. Although many participants coded for more than 10 days in the fall, the retrieved rate was lower than that in the winter. One reason might be that participants missed some of the short-time intervals during the day. Many participants who missed an interval tried to code in another 15-minute interval to complete their assignments; however, some had schedules that did not allow them to code at other times. Another reason might be the participants' lower level of experience and comfort with activity codes and handheld computers during the fall.

Missingness also is a practically significant factor for data quality and integrity. The rate of missing records in both fall (9.33%) and winter (4.02%) underscores that data collection with handheld computers can be alternatively utilized to reduce the number of missed records. Two types of missing records were identified. The first occurred when there was no set beginning and ending time for the activity interval. These two time values were critical because inter-agreement and interpretations of findings were based solely on the time of the activities that participants reported. Participants tapped the start button to insert the beginning time of their activity interval and the stop button to declare the ending time. This type of missing record was not caused by a malfunction of the hardware or software, but by the participants' failure to record the time. Fletcher et al. (2003) and Johannes et al. (2000) reported similar findings, which suggest the need for a validation mechanism to ensure that participants send all necessary information. The second type of missing data was the recording of zero values for all activity codes within any specific time interval. The main reason for this type of missing data was the alarm system found in the electronic form on the Pocket PC. When the alarm pop-up window was displayed, participants were required to tap the defer button on the window to reset the alarm for the next interval. The screens of the Pocket PC computers were programmed to turn dark after a minute without use in order to conserve battery power. Participants would anywhere on the screen to reactivate the computer, but in doing so caused the pop-up window to be displayed behind the form screen. Therefore, in their attempts to deactivate the alarm or call up a new blank form screen, participants were sending zero code values with their start or stop time values. Once begun, a record could not be deleted. This problem mainly occurred in the fall because of the short time intervals required at that time. The fact that no first-type and less second-type data were missing during the winter was a result of longer intervals and a small fix in the programming that made the alarm system independent from the Pocket PC operating system.

The use of handheld computers meant that data were available for analysis as soon as data records were submitted and synchronized with the central database. Having timely data records also allowed the researchers to predict possible problems in data collection. When compared with the winter session, fall rates of timely data were significantly low. The only reason was the synchronization of handheld data with the server database. Participants were required to synchronize their daily records with the server database at the end of every coding day. This was problematic at times for three reasons. First, the school's Internet connection sometimes caused problems. An Internet connection was required on the Pocket PCs before participants could tap the synchronization button. Participants who attempted to connect wirelessly to the school's network or through their desktop computer sometimes encountered problems with the stability of the wireless connection (caused by long distances to the router) or with router maintenance. Second, when participants set their Internet connection, they were required to run a special application to remove the university firewall before tapping the synchronization button. Although this application was preset and required two taps to run, the university servers sometimes failed to remove the firewall. Third, the electronic form of the synchronization initially was not compatible with the school connection settings. Synchronization was occurring based on timestamp values in both Pocket PC and server database. When run, the system would visit all the records in the server database, and then update the database with the new records. This method took time because the school Internet connection was slow and the number of records increased in the server database. Accordingly, this forced participants to synchronize their daily data records on a different day than it was produced. This was addressed in the winter session by separating the new records in each Pocket PC computer's database first and inserting them directly to the server database without any timestamp comparison.

Accuracy and inter-observer agreement were approached as substitutes (Johnston & Pennypacker, 1993) in this study. Obtaining multiple agreement scores reduced the bias that agreement indicates nothing about accuracy because of the chance factor. The overall rate of point-by-point percent agreement between data collected with electronic and paper forms was high enough in the fall (85%) and winter (73%), and is consistent with previously reported results (Berthelsen & Stilley, 2000; Fletcher et al., 2003). Although the Kappa (*k*) indices between the participants and the data collectors or electronic and hard copy forms were fair (Suen & Ary, 1989) in both fall and winter, taking both agreement indices with the significant Pearson's *r* correlations (Cohen, 1960) into account, it appears that participants and data collectors were in agreement with respect to the definitions of on- and off-task, and how these behaviors were exhibited by participants in the classroom. Agreement between the participants and data collectors slightly decreased in the winter, an expected outcome because the time intervals were increased. Another factor that could affect the agreement indices was the difference in the interpretation of the activity codes by the participants and data collectors. When there was a major difference between two parties' scores, the data collectors met with the participants after the time intervals to discuss whether additional clarification was needed. The fact that this data collection method produced results similar to traditional techniques may mean that a significant advantage may emerge for computerized methodologies when they are improved.

This study was also designed to explore how participants used a handheld data collection tool developed in accordance with the design guidelines for mobile applications. The study findings suggest that participants were successful in self-reporting their daily time use with the resulting handheld-based data collection tool. However, some participants who had minor vision problems reported difficulty tapping the buttons with their styli because of the small size of the fonts and buttons on the Pocket PC screen. The design of the electronic form had two interfaces in the fall: one for authentication and one for inputting data. The synchronization function was removed from the second interface and was created as a new interface in the winter. Despite this improvement, the interface for inputting data was still problematic for the same participants because the start, stop and submit buttons, and 12 activity codes with six radio buttons, were clustered together in this phase of the application. Based on the results of these findings, the load of data input interface can be reduced by requesting user input in multiple steps, as discussed in the study by Luchini et al. (2003). This design might help participants who have vision problems.

Although some data from only one participant was lost because of battery failure, some participants did not feel comfortable carrying the Pocket PCs out of the classroom. When in class, most participants kept their computers in the charging station to prevent loss of battery power. Some participants who coded for more than four hours charged their computers during their lunch break. The battery issue was brought up during the training session because any battery failure is equal to a hard reset, which means that the computer will reformat back to factory defaults. Therefore, additional memory might be a safer solution for saving data if battery failure occurs.

This research also may be expanded with participation of general education teachers in other settings. New design prototypes should be tested by considering universal design principles customized to participants' learning styles. In this study, educational psychology graduate assistants observed the participants. However, practitioners as observers may produce more reliable data because they may have more experience observing participants in the classroom (Reschly, 2000). Also, the novelty of handheld computers, and the limited software options for data collection when using them in schools, might have an important influence on the participants' experiences using technology. Future studies using handheld computers might benefit from including participants' level of technology use as a covariate.

The research on handheld computer use to date has focused on content delivery and information design. Applications have included clinical work (Fischer et al., 2003), news retrieval (Albers & Kim, 2000), and students' academic activities (Luchini et al., 2003). When new technologies are integrated into existing settings or processes, there is a risk that these resources may not be adequately utilized or that they may be misused. The handheld computer is a relatively new technology for field researchers and educators. This study showed both the challenges and possibilities of incorporating handheld computers data collection in general and for observations in particular. The lessons learned from this experience are that handheld computers are a dependable alternative and a promising mechanism for school-based data collection. It is believed that understanding the usability of handheld computer applications will have two benefits. First, studying their dependability can help schools and institutions make informed and reasonable decisions when purchasing new technology. Second, fully understanding the potential advantages and disadvantages of existing technology will lead to the development and use of more effective and more extensive technology applications in the future.

CHAPTER IV

AN EXAMINATION OF TEACHER ACCEPTANCE OF HANDHELD COMPUTERS

Overview

As governments have invested generously in integration of new technologies into education, the teacher's role as the user of such technologies in the classroom becomes more prominent. However, relevant prior research suggests that teacher resistance to new technologies remains high. This study explores teachers' acceptance of handheld computer use, and identifies key intention determinants of using this technology based on a modified version of the technology acceptance model. The new model was tested using the handheld computer acceptance survey responses from 45 special education teachers who had handheld computer and Web experiences or had neither. The results showed that intention to use handheld computer was statistically significant and directly affected by perceived usefulness and perceived ease of use of the devices. The issue of dependability, which was not included in any technology acceptance literature, had a direct and indirect statistically significant effect on perceived ease of use and usefulness, and intention to use a handheld computer, respectively. Groups of participants differed on only subjective norm. Theoretical and practical implications are also discussed.

Introduction

When new technologies are integrated into existing settings or processes there is a risk that these resources may be inadequately utilized or misused. Adaptation and adoption of such resources are dependent on factors such as willing acceptance by the users, familiarity with the technology components, availability of appropriate resources, and design of the user interface and data entry formats (Legris, Ingham & Collerette, 2003). Accordingly, users often resist an unplanned and inappropriately applied technology. Consequently, hardware, software and user satisfaction must be considered to help ensure the smooth implementation of any system.

Education stakeholders have invested significant time and financial resources introducing technology to schools and teachers. In their study, Booth, Wilkie, and Foster (1994) stated a common assumption that "if new technology is introduced, then it will be accepted and used" (p. 1). However, success is possible only when teachers agree to actually utilize the technology in instructional and administrative tasks (Ching, 1999). In their meta-analyses, Legris et al. (2003) concluded that teachers' attitudes toward technology and its perceived usefulness are significant determinants of behavior that may influence teachers' success in high-level use of technology in instruction. This idea originated in Davis' (1989) study that indicated the determinants of computer acceptance based on belief-attitude-intention-behavior relationship and resulted in the Technology Acceptance Model (TAM). However, TAM has been criticized, namely for being independent from the organizational context and having only two constructs. To address this constraint, many subsequent studies based on this model or extending it have been conducted related to educational contexts and have found that teacher acceptance is a key factor in the effective implementation of technology to support instruction (Kellenberger & Hendricks, 2003; Koohang, 1989; Lawton & Gerschner, 1982). Therefore, in order to increase the acceptance and use of handheld computers and to accelerate their integration in schools, it is necessary to focus on teachers' acceptance of this technology in school settings.

Theoretical Background

Technology acceptance is a complex construct, influenced not only by the type of technology and its purpose, but also by a cluster of variables that influence the adoption and application of technologies (Wolfe, Bjornstad, Russell, & Kerchner, 2002). Among these are the user's perceptions of social acceptability, confidence in his or her ability to use the device, and willingness to engage in training (Davis, Bagozzi, & Warshaw, 1989). Understanding what specific variables influence teachers' acceptance of technology and assessing the level of device acceptability among teachers can be measured by evaluating teachers' attitudes, intentions to use the device, perceived usefulness, and perceived ease of use (Davis et al., 1989).

In their study of teachers' acceptance and use of technology, Hu, Clark, and Ma (2003) determined that "teachers appear to consider a rich set of factors in initial acceptance [of technological device usage in the classroom] but concentrate on fundamental determinants (e.g., perceived usefulness and perceived ease of use) in their continued acceptance" (p. 227). Hu et al. also concluded that teachers want to know that their adoption and utilization of technology will not only help them meet their school's goals, but also of their own goals in the classroom. Thus, the ability of technological devices to help achieve both micro (classroom) and macro (school/district) level goals must be considered, and administrators and policy makers should determine how they can leverage existing empirical and anecdotal evidence to convince teachers that handheld computers are, in fact, useful for both types of goal achievement.

Handheld Computers

When compared to conventional desktop and laptop computers, handheld computers are generally perceived to offer greater portability at a more affordable cost ($100 to $400) (Bell, 2006). Handheld computers, which weigh on average less than half a pound, are smaller, lighter, and easier to maneuver than larger and heavier laptops, and offer portability that desktop computers cannot provide (Adiguzel, in press; Fletcher, Erickson, Toomey, & Wagenaar, 2003; Trapl et al., 2005).

One of the most common handheld computers used in educational settings is the Pocket PC. Pocket PC computers with wireless support are more expensive than their PalmOS rivals, which dominate the market and have many shareware applications (Ice, 2004; Suliburk, 2003). A Pocket PC uses the Microsoft® Windows CE operating system, which is a portable version of the desktop Windows operating system, and accommodates optimized versions of many popular Microsoft desktop software programs such as Word, Excel, and Outlook (Dixon, 2003). In addition, Pocket PC computers with advanced multimedia capabilities and networking features are ideal for schools that require operating systems that have more power, are easier to use, and are more flexible in a wireless network setting (Suliburk, 2003).

Perceptions Regarding Ease of Use

Ease of use is a particularly important construct with respect to technology adoption and continued use (Davis et al., 1989). The phrase “ease of use” refers to the extent to which a person believes that using a technology will not require excessive mental and physical effort (Davis et al.). In particular, ease of use is the potential technology user’s confidence that he or she will not be required to invest substantial amounts of time, energy, or effort learning to use the technology and maximize its functional capabilities. For example, teachers may feel compelled to learn about technology independently if they believe that its use will benefit teaching, classroom management, and student outcomes; however, expecting teachers to independently pursue learning opportunities in the field of technology use may be unrealistic on the part of administrators, because teachers are already overburdened and overextended with an array of responsibilities.

Perceptions regarding the ease of use of software and hardware technologies are influenced not only by concrete factors such as the teacher’s actual ability to manipulate a technological device and use it for an intended purpose, but also by psychological factors, including the teacher’ beliefs about the utility of a device and the role that it can play in classroom activities (Windschitl & Sahl, 2002). These authors point out that the degree to which school administrators believe in teachers’ abilities to use technology effectively and the value they place on the technology itself are significant variables that influence teachers’ perceptions regarding the devices’ ease of use. The tone that is established and conveyed by the institutional culture, then, is a significant predictor of the perception that technology is easy to use and that learning how to use it effectively is possible.

Ease of use is not limited, however, only to initial perceptions among teachers about whether a device could be managed with minimal difficulties. Many handheld computers that can be used in educational settings have scalable capabilities. This means that a handheld computer not only can perform basic data collection functions, but that it can, in many cases, also be used to perform data analysis functions, as well as related storage, sharing, and maintenance tasks (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004). The more functions that are introduced, however, the more technology users are likely to feel overwhelmed by the learning curve they will need to master in order to use the technology effectively. Furthermore, as the number of potential functions increases, anxiety and fear of failure or inability to master the technology increase in kind (Hackbarth, Grover, & Yi, 2002). In turn, as anxiety and fear of failure escalate, the perception of ease of use tends to decline.

Perceptions Regarding the Usefulness of Handheld Computers

Establishing an organizational culture that embraces technology—and, more importantly, supplies compelling empirical and anecdotal evidence substantiating its value, ease of use, and usefulness—plays a significant role in shaping teachers' perceptions of the utility of handheld computers. According to Zhao and Cziko (2001), teachers' perceptions of the utility of handheld computers and other computer technologies for classroom use are influenced by three principal beliefs: (a) that technology "can more effectively meet a higher-level goal than what[ever other means have] been used;" (b) that the use of such a computer will not disrupt classroom instruction and other "higher-level goals that he or she thinks are more important than the one being maintained;" and (c) that teachers will receive the training and ongoing support necessary to make the computer a useful tool (p. 5).

Whether policy makers present empirical or anecdotal evidence to teachers or administrators—or ideally, both—they must take a broad approach to the definition of usefulness. While one stakeholder group may consider the usefulness of handheld computers to be related primarily to the devices' portability, multiple functionalities, and the storage, access, and transfer of data, the teacher stakeholder group is likely to want to know how handheld computers will help them fulfill their classroom tasks and responsibilities. In addition, teachers want to know if the technology will enhance their overall job performance, as they assess it themselves, and also as assessed by their school administrators (Davis et al., 1989; Ma, Andersson, & Streith, 2005). Such evidence can be provided by empirical studies, but often has a profound influence when provided via the anecdotes and recommendations of other technology users. Thus, as administrators and policy makers attempt to convince teachers that handheld computers and other electronic technologies are useful in facilitating data collection, they should also consider the value of obtaining recommendations from other teachers familiar with these technologies. First-person accounts and testimonials that convey the technology's usefulness in achieving micro- and macro-level goals will be more likely than empirical arguments to persuade teachers.

Subjective Norm

The term subjective norm refers to a broad category that includes a teacher's perceptions about, opinions regarding, or suggestions influencing his or her adoption and use of a handheld computer or other technology (Ajzen, 1988; Hu et al., 2003; Ma et al., 2005; Taylor & Todd, 1995). For the most part, as the term suggests, these norms are particular to each user, and are largely subjective, influenced not by empirical information about a technology's utility, ease of use, or functionality, but by anecdotal accounts of others' experiences with the technology and one's perceptions and projections about the technology based on one's own previous experiences (Marcinkiewicz & Regstad, 1996). The more negative experiences one has had with technology in the past, the more likely one is to be predisposed to resist, reject, or misuse the technology being introduced, even if it has been proven to have compelling benefits for both micro- and macro-level goals (Marcinkiewicz & Regstad).

Therefore, administrators who implement policies related to technology should consider the degree to which subjective norms influence technology adoption and use among teachers who have disparate experiences, beliefs, and needs regarding technology. Besides gender (Yuen & Ma, 2002), Kwon and Chidambaram (2000) identified age, race, level of education, and extent of professional experience as subjective norms that exert statistically significant spheres of influence on the adoption of certain technologies by adults. Although it is unlikely that administrators will be able to control for or mitigate all of the subjective norms that influence technology adoption and use, they should, at the very least, acknowledge the potential influence of each of these subjective norms.

Perceptions Regarding the Intention to Use Handheld Computers

A teacher's decision to use a handheld computer may over time exert less of an influence than it does at present, particularly as both informal and formal elements of American culture demand the integration of technology in the country's classrooms (Cradler & Cradler, 2002). The No Child Left Behind (NCLB) Act signed into law by

President George W. Bush in the beginning of this decade included provisions for the expanding role of technology in American schools (Cradler & Cradler). The NCLB Act emphasized the importance of technology's adoption and utilization in special education classrooms, making teachers in this area particularly compelled to address the question of whether and how they would incorporate technology into their classrooms, not only for instruction, but also for observation, monitoring, and evaluation purposes (NCLB, 2002).

As Hu, Chau, Liu Sheng, and Tam (1999) pointed out, however, mere adoption of a technology is not necessarily equivalent to a commitment to use the technology, much less to do so consistently and effectively. Teachers have varying beliefs not only about the value and utility of technology, but also about its ease of use. Teachers also have varying levels of confidence in their own ability to master technology for basic and advanced purposes. Therefore, the teacher's intention and commitment to use a handheld computer or other technological resource in the classroom are dependent on a number of factors. Administrators and policy makers who realize that a conceptual and pragmatic gap often exists between a teacher's intention to use technology—which, in many cases, is mandated by the district and school—and his or her commitment to use it, will be better able to address these issues. A teacher may intend to use the handheld computer, and may actually do so to comply with administrators' expectations and demands. Intention and use however, should not be mistaken for indicators or confirmation that the technology is being used appropriately or optimally.

For these reasons, stakeholders responsible for determining the extent to which handheld computers will be implemented in classrooms need to attach some observable outcome criteria and measurements to the use of such technologies. Without making oversight punitive, administrators should ensure that technologies are being used correctly for the appropriate reasons, and that they are being leveraged to support the teacher's and school's overall instructional and achievement goals. Otherwise, the technology's potential benefits may be either undermined or underexploited.

Dependability

Dependability refers to a technology's ability to perform consistently. It is also defined as "the system property that integrates [the] attributes [of] reliability, availability, safety, security, survivability, [and] maintainability" (Avizienis, Laprie, & Randell, 2005, p. 1). Dependability of both hardware and software is a "desirable property of all computer-based systems," whether desktop, laptop, or handheld (Sterritt & Bustard, 2003, p. 247). Dependability and reliability are critical variables that, when taken into consideration, can help users predict the device's useful lifespan (Fitzgerald, 2002).

Dependability is measured by tabulating the incidents of "threats, faults, errors, and failures" that prevent the end user from being able to use the technology to fulfill its intended purpose (Avizienis et al., 2005, p. 1). Although dependability has improved considerably as technology has become more sophisticated, it remains a critical variable that determines both a user's interest in a technology and his or her ability to utilize it consistently, particularly because the same evolutionary process that has improved dependability has simultaneously increased the number of potential threats to dependability (Avizienis et al.). While technical support ideally is available, the user also wants to know that the hardware and software are both dependable and reliable, with minimal intervention required from technical support staff or materials.

Method

Participants

Participants were two categories of special education teachers: those involved in the funded project and those not involved. The study focused on special education teachers involved in the funded project from two districts in a south-central U.S. state during 2005-06 who used handheld- and Web-based data collection systems for self-report (n = 46). Those in the comparison sample were selected based on demographics and their lack of previous experience using any type of data collection system (n = 91), and was limited to those not already involved in the funded project. Of 137 special education teachers, a total of 45 participated in the study (see Table 4.1) to test the acceptance of handheld computers (response rate = 33%).

Table 4.1

Participants in the Study

N	Participants
8	Special education teachers who used only the handheld-based data collection system for self-report (recruited by the project in fall 2005 and winter 2006).
8	Special education teachers who used both Web- and handheld-based data collection systems (recruited by the project in fall 2005, winter 2006, and spring 2006).
12	Special education teachers who used only the Web-based version of the handheld data collection system (recruited by the project in spring 2006).
17	Special education teachers who did not use any data collection system.

A summary of demographic data is displayed in Table 4.2. Gender distribution showed an approximate 15:1 ratio in favor of female teachers. Their ages ranged from 22 to 31 (24.4%), from 32 to 41 (31.2%), from 42 to 51 (24.4%), and over 51 (20%). More than half of the participants (55.6%) have owned a handheld computer. They also reported they have used basic functions such as calendar, address book, to do list, and notepad in handheld computers more often than other functions (see Table 4.3).

Table 4.2

Participant Demographics (*N* = 45)

Demographic	%
Gender	
Male	6.7
Female	93.3
Age	
22 – 31	24.4
32 – 41	31.2
42 – 51	24.4
Over 51	20
Ownership of a handheld computer	Sz
Yes	55.6
No	44.4

Table 4.3

Frequency of Participants' Handheld Computer Use ($N = 20$)

Task	Never	Once or Twice	Monthly	Weekly	Daily
Basic functions such as calendar, address book, to do list, and notepad	35	25	15	10	15
Word processing	70	15	5	10	
Multimedia presentations	90	5		5	
Spreadsheet or database	80	15		5	
Drawing	100				
Internet access	45	25	5	10	15
Email	70	5	5		20
Games	65	20	15		
Playing music	75	10		15	
Taking pictures	60	15	10	15	
Stand-alone application to assist your activities	50	25		20	5

Note. 1. Values given are percentages.
2. Blank cells represent zero percentages.

Model

As shown in Figure 4.1, the Technology Acceptance Model (TAM) was used as a theoretical basis, with its modified version (Ajzen, 1988; Hu et al., 2003; Ma et al., 2005) used in this study.

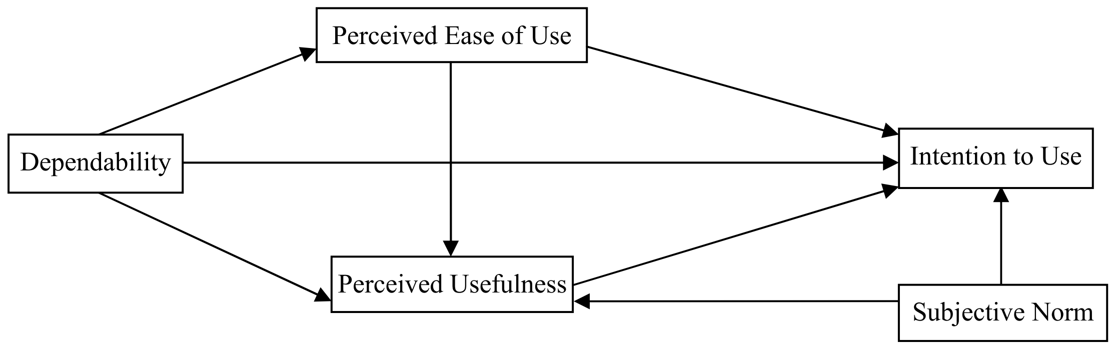

Figure 4.1. Theoretical model framework

In addition, a dependability construct was added to the model as a direct predictor of behavioral intention, ease of use, and usefulness. This was because teachers who experience difficulties regarding the dependability and reliability of their handheld computers are more likely than other users to use the device less frequently, to use it incorrectly, or even to abandon its use altogether (Edyburn, 2001). Teacher acceptance of handheld computers was measured using behavioral intention, which is theoretically and empirically supported in the TAM literature. Based on this expanded model, a teacher's intention to use handheld computer technology could be predicted and explained by his or her subjective perception of the technology's usefulness, ease of use, and dependability in conjunction with his or her subjective norm.

Perceived usefulness was defined in this study as "a teacher's subjective probability that using [handheld computer technology would] increase his or her job performance within [the school] context" (Davis et al., 1989, p. 985), while perceived ease of use was defined as "the degree to which [a teacher expected handheld computer technology] to be free of effort" (p. 985). Subjective norm refers to a teacher's perceptions about, opinions regarding, or suggestions influencing his or her adoption and use of handheld computer technology (Ajzen, 1988). Dependability was defined as the degree to which the hardware and software of handheld computer were both dependable and reliable with minimal intervention from technical support staff or reference materials (Avizienis et al., 2005). Under this model, as informed by the reviewed literature, a teacher's perceptions of technology's usefulness and ease of use, as well as dependability and subjective norm, were investigated to test for significant effect on his or her decision to accept or reject handheld computer technology (see Appendix C).

Instrumentation

One instrument—a modified version of the original TAM instrument—was used in this study. The handheld computer acceptability survey (HCAS) (Hu et al., 2003; Ma et al., 2005; Venkatesh & Davis, 2000) includes questions dealing with teachers' demographics, experiences with handheld computers, and finally, the acceptability items. The central construct of acceptability is composed of sub-constructs. The HCAS was developed based on five sub-constructs regarding the handheld computer: dependability, usefulness, ease of use, teachers' intention to use, and subjective norm. TAM is a well-researched construct with historical precedent in the validity and reliability of scores obtained from previous administrations. The instrument was designed for and used with a similar population, thereby increasing its content validity (Salant & Dillman, 1994). HCAS includes items adapted from several variations of the TAM that were tailored to this study on handheld computer use in an education context. Specifically, HCAS included two items on intention to use (IU), six on perceived usefulness (PU), 10 on perceived ease of use (PEU), two on subjective norm (SN), and three on dependability (D) (see Appendix D).

All HCAS items were randomly arranged based on a Likert-type five-point scale scored using the following key: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. HCAS also included a demographic section that asked participants to state their sex, age, experience using handheld computers, and frequency of handheld computer use for daily tasks (such as word processing, Internet access, and e-mail).

Data Collection and Analysis

To measure participants' acceptance of handheld computers, data were gathered from HCAS responses. The online version was administered to four different groups of special education teachers in mid-spring 2008. All participants (N = 137) were sent an e-mail that included a secure link and password to HCAS. A participation incentive was provided. Two respondents were randomly selected to win $50 gift certificates to Amazon.com. Forty-five (33%) completed surveys were collected with an assurance of confidentiality.

The analyses used were linear regression, path analysis, and multivariate analysis of covariance (MANCOVA). Sub-construct scores were calculated for each participant to generate models for these analyses.

Model fit test. A five-variable path model was developed to examine causal relationships between three observed (measured) endogenous variables (PU, PEU, and IU) and two observed exogenous variables (D and SN). Three unobserved exogenous error terms representing residual variances within variables not accounted for by pathways were included and represented by “E’s” for measured variables in the model. The AMOS software (Arbuckle, 1995) with unweighted least squares estimation was used to fit the path model in Figure 4.1 to the HCAS data. The model’s overall fit with the HCAS data was evaluated using fit indexes different from Chi-square statistics, which are very sensitive to sample size ($N = 45$) (Kline, 1998). The goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), and Bentler-Bonett normed fit index (NFI) were considered to test the model fit (Hoyle, 1995). Each causal path was evaluated in terms of statistical significance (t statistics, $p = .05$) and strength using standardized path coefficient (standardized betas) that range from -1 to +1. In addition, R^2 was used as an indicator of the model’s overall predictive strength.

Group differences. Due to the nature of the data collected (survey data using Likert-scale items on five constructs measuring teacher acceptance of handheld computers), non-parametric inferential and descriptive statistics were also calculated on the scores of the dependent measures. To test differences among groups, a non-parametric MANCOVA (Stevens, 2002) with several planned contrasts was employed using SPSS 15.0 software. The five constructs of the HCAS served as dependent variables. Participants’ ages and genders were entered as covariates.

Results

Data from the HCAS instruments were analyzed to test the differences of four participant groups on five constructs (dependent variables) and the relations among observed and latent variables (constructs). With the exception of two items, the descriptive statistics of the HCAS items shown in Table 4.4 indicated that participants held generally positive (mean scores greater than three) perceptions towards handheld computer use. The mean scores ranged from 2.11 to 4.13, while the standard deviations ranged from .73 to 1.07. The internal consistency of the HCAS instrument was calculated using Cronbach's α-value. As shown in Table 4, three constructs exhibited an α-value greater than .7, a commonly accepted score for exploratory research (Nunnally & Bernstein, 1994). The α-value for subjective norm was lower than but close to 0.7, while it was .31 for dependability construct. However, item-total statistics results revealed that this value would increase to .79 if item D3 were deleted. Overall, the α-value for the HCAS instrument was .93, meaning that the internal consistency of the scores for this study was acceptable.

In terms of the descriptive statistics for four groups of the participants, Figure 4.2 presents percents of average total scores of the groups on five subscales (constructs). The overall group scores on each subscale show that all four groups had positive intentions toward handheld computer use, whereas the average scores on subjective norm and dependability were relatively low, ranging from 45% to 67.5%. The lower score (45%) on subjective norm from the first group of handheld-only users reveals that users of handheld computers do not consider the opinions or suggestions of others in their acceptance of handheld computers.

Table 4.4

Summary of Descriptive Statistics and Reliability of HCAS Instrument

	N	Mean	Std. Deviation	Construct Reliability
Intention to Use (IU)				.73
IU1	45	4.13	.726	
IU2	45	4.04	.976	
Perceived Usefulness (PU)				.86
PU1	45	3.87	.894	
PU2	45	3.58	.753	
PU3	45	3.78	.902	
PU4	45	3.87	.894	
PU5	45	3.58	.965	
PU6	45	3.69	.793	
Perceived Ease of Use (PEU)				.92
PEU1	45	3.09	.733	
PEU2	45	3.16	.999	
PEU3	45	3.38	.960	
PEU4	45	3.00	.905	
PEU5	45	3.67	.953	
PEU6	45	3.53	1.057	
PEU7	45	3.33	1.022	
PEU8	45	3.51	.757	
PEU9	45	3.51	.815	
PEU10	45	3.62	.936	
Subjective Norm (SN)				.62
SN1	45	2.84	.999	
SN2	45	3.02	1.011	
Dependability (D)				.31
D1	45	3.38	.834	
D2	45	3.80	.815	
D3	45	2.11	1.071	

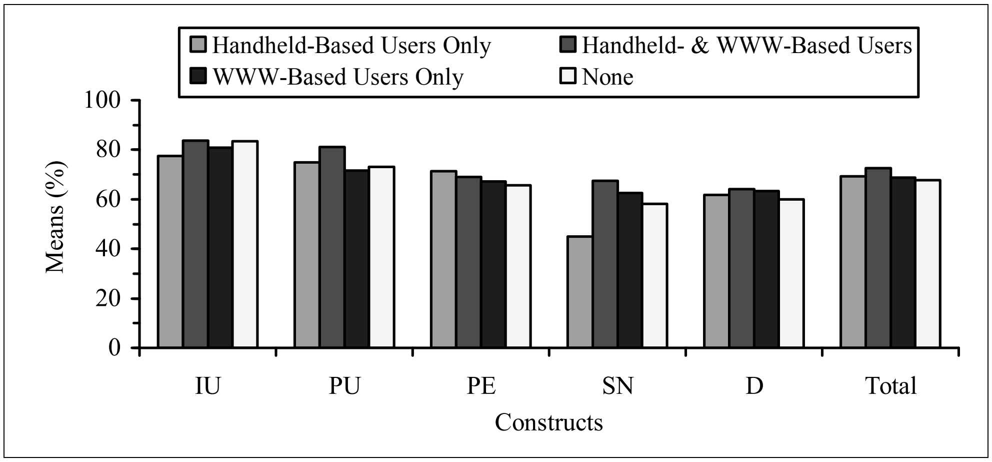

Figure 4.2. Means reported as percents of four groups of participants' scores across five constructs

A further examination of mean differences among the groups in total and on each subscale showed that the scores of the second group of participants, who were involved in the funded project and used both handheld- and Web-based data collection systems in fall 2005 and spring 2006, were higher than those of the other groups. Comparing scores on the five handheld computer acceptance subscales of participants who had access to handheld computers showed that experience using a handheld computer was barely associated with their acceptance of these computers (see Figure 4.3).

Model Fit Testing

Because the study's sample size was small ($N = 45$) and the chi-square test of absolute model fit is sensitive to sample size and non-normality in the underlying distribution of the input variables, unweighted least squares estimates and the other common fit indexes—GFI, AGFI and NFI—were considered in AMOS to analyze the survey data and to evaluate the model's overall fit (D'Agostino & Stephens, 1986; Schumacker & Lomax, 2004).

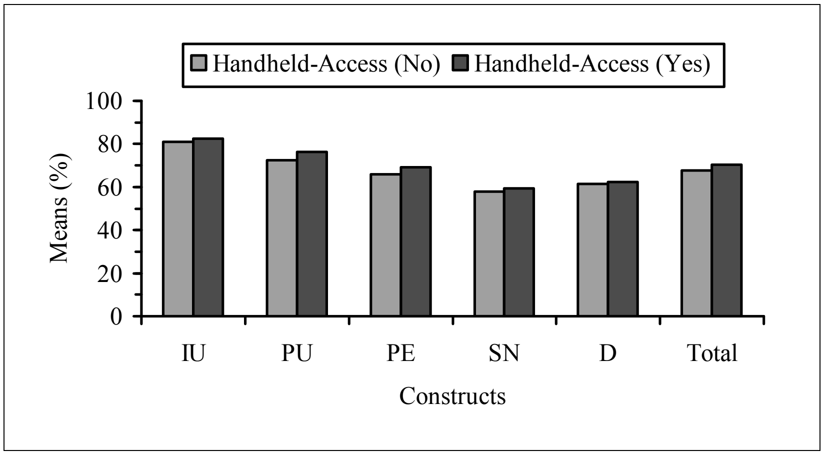

Figure 4.3. Means reported as percents of four groups of participants' scores based on handheld computer experience across five constructs

Overall, all implemented fit indexes indicated a good fit to the data based on the common acceptable values (see Table 4.5). Accordingly, the most common index of fit, GFI = .992 (Kline, 1998), AGFI = .937 (Segars & Grover, 1993), and NFI = .972 (Chin & Todd, 1995) exhibited an acceptable fit to the data, which meant the overall model resulted in a very good fit. The model was re-evaluated with a new dependability measure that was obtained after deleting the item D3 scores; however, the fit indexes stayed similar, as shown in Table 4.5.

Figure 4.4 shows the resulting path coefficients of the overall model. For the overall model, most of the standardized path coefficient represented a statistically significant relationship between the variables. Perceived usefulness and perceived ease of use had a statistically significant direct effect on participants' intention to use handheld computers, with standard path coefficients of .49 (p < .01) and .43 (p < .01) respectively.

Table 4.5

Model Fit Comparison

Model	GFI (> .90)*	AGFI (> .80)*	NFI (> .90)*
Default Model	.992	.937	.972
D3 Deleted Model	.992	.939	.974

* Recommended values

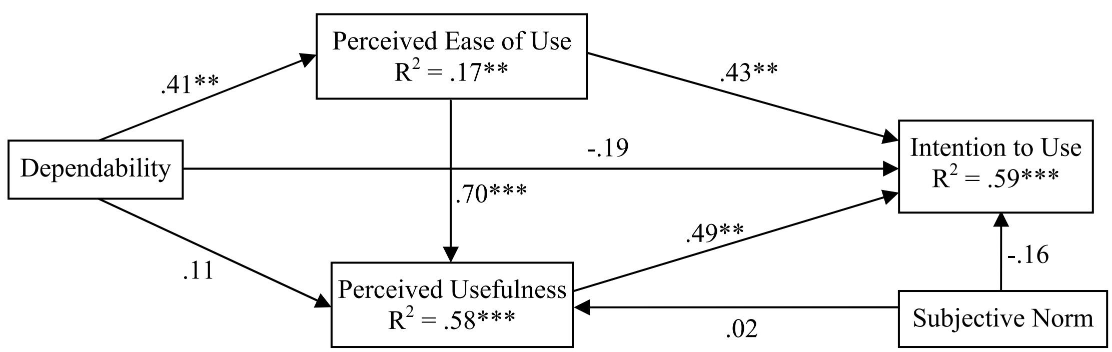

Figure 4.4. Theoretical model testing results for default

In other words, intention to use handheld computers would positively improve by .49 standard deviations, given a change in perceived usefulness of one full standard deviation, when the other variables in the model were controlled. Perceived ease of use had the strongest and statistically significant effect in the model, which was on perceived usefulness, with standard path coefficient 0.70 ($p < .001$). Direct effect of handheld computer dependability on perceived ease of use was statistically significant and .41 ($p < .01$). Although dependability had a statistically non-significant direct effect on perceived usefulness and intention to use handheld computers, it had a statistically significant indirect effect (.36), through the mediating perceived usefulness and perceived ease of use, on intention to handheld computer use. Subjective norm had neither a statistically significant direct nor indirect effect on perceived usefulness or intention to handheld computer use.

The proportions of explained variance across dependent variables—perceived ease of use, perceived usefulness, and intention to use handheld computers—ranged from 17% ($p < .01$) to 59% ($p < .001$). Overall, the model accounted for a statistically significant portion of variance (59%, $p < .001$) in participants' acceptance of handheld computers. Perceived ease of use was predicted by the direct effect of dependability resulting in an R^2 of .17 ($p < .01$), while perceived ease of use, dependability and subjective norm together explained 58% of the variance in perceived usefulness (see Table 4.6).

The model with D3 deleted (see Figure 4.5) revealed similar scores, except the path coefficients from dependability to perceived usefulness and perceived ease of use.

The direct effect of dependability on perceived ease of use remained statistically significant, but the path coefficient increased from .41 to .58, and explained variance increased from .17 to .34. The statistically significant change occurred in the direct effect of dependability on perceived usefulness. Statistically non-significant direct effect in the default model became statistically significant with the path coefficient, .29 ($p < .05$), in the new model. Based on the results from the two models, perceived usefulness remained the most important determinant of intention to use handheld computers, followed by ease of use, then dependability.

Table 4.6

Summary of Causal Path Testing Results

	Standardized Path Coefficients	
Causal Path	Default Model	D3 Deleted Model
D → PEU	.410 **	.580 ***
D → PU	.113	.290 *
SN → PU	.022	.062
PEU → PU	.697 ***	.562 ***
PEU → IU	.434 **	.416 *
D → IU	-.190	-.079
SN → IU	-.163	-.192
PU → IU	.491**	.486 **

Note. $R^2_{IU} = .59$ ***, $R^2_{PU} = .58$ ***, $R^2_{PE} = .17$ ** (Default)
$R^2_{IU} = .57$ ***, $R^2_{PU} = .62$ ***, $R^2_{PE} = .34$ *** (D3 Deleted)
* $p < .05$, ** $p < .01$, ***$p < .001$

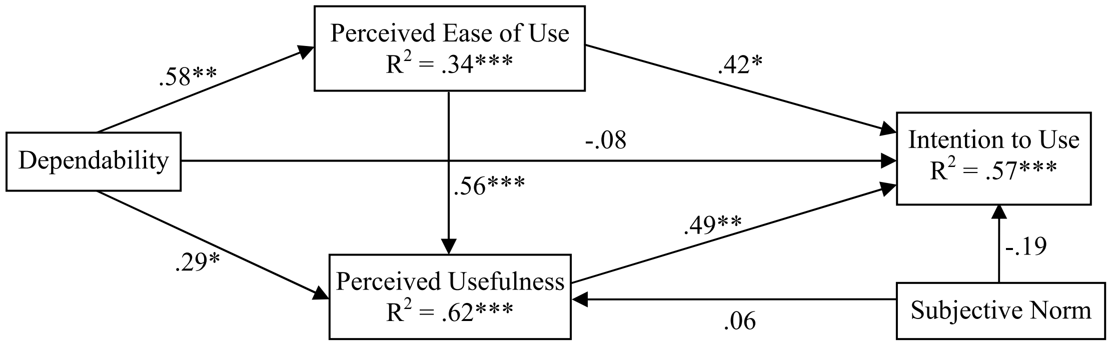

Figure 4.5. Theoretical model testing results for D3 deleted model

Group Differences Results

A MANCOVA was performed contrasting the groups on all five dependent variables. Levene's Test of Homogeneity of Variance and Box's M Test of Homogeneity of Covariance revealed no violation of assumptions. Bartlett's test was not considered because it is sensitive to departures from normality as well as heteroscedasticity, so Levene's test was used instead. Age and gender were tested separately within the overall MANCOVA to examine their relative contribution to any observed effects on the dependent variables.

Neither age (F (5, 35) = 1.7, $p > .05$) nor gender (F (5, 35) = .599, $p > .05$) accounted for a statistically significant proportion of the variance; therefore, they were not considered as covariates in the model. Overall group factor was statistically significant in the multivariate analysis (F (15, 102) = 1.809, $p < .05$), but examination of univariate ANOVAs yielded only one statistically significant dependent measure, subjective norm, among the four group levels (see Table 4.7).

Table 4.7

Univariate Analysis Results for Group on Dependable Measures

	MS	$F(3, 41)$	η^2	Power
Intention to Use	.801	.328	.023	.108
Perceived Usefulness	14.832	.908	.062	.231
Perceived Ease of Use	16.450	.327	.023	.108
Subjective Norm	7.660	2.957*	.178	.658
Dependability	.956	.288	.021	.100

*$p < .05$.

A summary of all planned contrasts is presented in Table 4.8. Of the eight planned contrasts within the MANOVA, only three—C1, C2, and C7—demonstrated statistically significant results, and these were on the same dependent measure of subjective norm. Specifically, contrasting group 1 against group 2 (C1) yielded that participants who used handheld- and Web-based data collection technology considered opinions or suggestions of others concerning their acceptance of handheld computers more than the ones who used only handheld computers ($p < .05$). A comparison of group 1 and group 3 (C2) revealed that participants who used only Web-based data collection technology cared more about the opinions or suggestions of others concerning their acceptance of handheld computers than those who used only a handheld-based version ($p < .05$). Contrasting group 1 with groups 2 and 3 (C7) showed that participants who used handheld- and Web-based data collection technology, and those who used only Web-based data collection technology, took into greater consideration the opinions or suggestions of others concerning their acceptance of handheld computer than those who used only a handheld-based version ($p < .05$). Based on participants' responses, the multivariate statistics with several contrasts demonstrated that four groups of participants differed only on subjective norm. Difference of the groups on the rest of the dependant measures was not statistically significant.

Table 4.8

Contrasts of Group Means by Hypothesis

Contrasts	Group 1	Group 2	Group 3	Group 4
C1	1	-1	0	0
C2	1	0	-1	0
C3	1	0	0	-1
C4	1	1	-1	-1
C5	1	1	-2	0
C6	1	1	1	-3
C7	2	-1	-1	0

Note. Simple contrasts were used.

Discussion

This study was conducted to (1) investigate special education teachers' acceptance of handheld computers, (2) determine the key factors that influence special education teachers' intention to use handheld computers, and (3) test the differences between groups of participants who had varying levels of handheld computer use on five constructs: IU, PU, PEU, SN, and D. The model structured with these constructs, consistent with the Technology Acceptance Model (TAM) literature, including the new dependability construct, was also tested. It was found that the special education teachers' overall average scores for each construct were all positive. Perceived usefulness and perceived ease of use were two direct determinants of special education teachers' intention to use handheld computers. Dependability was statistically confirmed to be an essential contributor for special education teachers' intention to use handheld computers, through perceived usefulness and perceived ease of use. Subjective norm was the only construct on which the four groups of special education teachers differed significantly.

Perceived usefulness was one of the most significant factors in determining the special education teachers' acceptance of handheld computers, a finding similar to previous studies such as those by Ma et al. (2005) and Legris et al. (2003). Accordingly, special education teachers perceive that handheld computers are useful because such computers improve their instructional performance, productivity and effectiveness. The usefulness of technology was also associated with its ease of use and dependability in the study either directly or indirectly. Therefore, having handheld computers that are not easy to use and dependable may cause special education teachers to perceive such computers in general as not useful. Special education teachers also considered handheld computers as useful regardless of the others' positive suggestions and opinions.

Perceived ease of use had both significant direct and indirect effects on handheld computer acceptance, as mediated by perceived usefulness, just as Yuen and Ma (2002) found. In other words, special education teachers would adopt handheld computers when they are confident that using such computers would not require substantial investments of time, energy, or effort to learn and to maximize functional capabilities. A significant indirect effect of perceived ease of use on intention to use handheld computers (through perceived usefulness) also indicates that special education teachers' acceptance of handheld computers can be stronger and significant if they perceive handheld computers as easy to use and perceive that their use will benefit their teaching, classroom management, and student outcomes.

It was found that the average scores of subjective norm were low when compared with the other constructs. The model test results also showed that the effect of subjective norm on perceived usefulness and intention to use was not statistically significant. From a practical standpoint, special education teachers might not consider their colleagues' opinions or suggestions when making their initial decision to accept or reject the use of a handheld computer. This result is consistent with some previous studies (e.g., Davis, 1986; Ma et al., 2005), even though other studies (e.g., Ajzen, 1988; Mathieson, 1991; Taylor & Todd, 1995; Venkatesh & Davis, 2000) found either direct or indirect significance for these relationships. One reason for this discrepancy could be that the special education teachers in this study decided independently to accept handheld technology. On the other hand, more than half of the special education teachers in the study were required to use the handheld computers provided by the funded project. This argument was not consistent with the research study (Venkatesh & Davis, 2000) that found significant effect on intention to use in a mandatory-use context. Furthermore, the direct effect of subjective norm on intention to use handheld computers was adverse. The reason for this might be associated with special education teachers' own perspectives for accepting or rejecting handheld computers before they were informed of their colleagues' opinions.

The groups of special education teachers were significantly separated on only subjective norm. A primary reason for this significant difference was the scores of the first group of special education teachers, who used only handheld computers in the funded research study. This difference resulted from the fact that these special education teachers did not need any norms from the other subjects as they become confident and experienced using handheld computers. Similarly, Hu et al. (2002) found that the effect of subjective norm on technology acceptance was not supported at the end of the training session, though this effect was supported at the beginning of the session. Therefore, this study contributes to the findings in the technology acceptance literature that one who has experience using this technology may resist the norms provided by other subjects.

This study is unique because it added dependability as a new construct. The overall average scores of dependability were greater than three, meaning that special education teachers found handheld computers dependable for use in their school settings. Also, the model that tested results both before and after deleting one problematic item from the dependability domain showed that the direct effect of dependability on intention to use handheld computers was not supported. However, dependability had a statistically significant direct effect on perceived ease of use in both models, but on perceived usefulness only in the second model. One interpretation of this finding could be that as long as the handheld computer hardware and software are both dependable and reliable with minimal technical support, special education teachers consistently perceive handheld computers as easy to use and useful for school-based tasks (Avizienis et al., 2005). In addition to direct effect, the indirect effect of dependability on intention to use handheld computers remained significant in both models. This result is also plausible given that the dependability of handheld computers might not directly explain their acceptance by special education teachers who do not know that these computers are easy to use and useful. However, having dependable and useful, or dependable and easily used, technology makes a difference in special education teachers' acceptance of handheld computers.

Regarding the contrast results, all constructs except subjective norm did not differentiate the groups of special education teachers. One reason is associated with participants' differing levels of use and experience with handheld computers. Even if the 19 special education teachers experienced handheld computers in the funded project, there were still six more teachers not associated with the project who also used or owned handheld computers. It might be said that although the average scores of these 19 teachers showed positive intention to use handheld computers, this positivity was not sufficient to obtain significance among groups based on handheld computer experience.

Another possible reason is that special education teachers in all four groups from the onset might have been disposed to be open to new technology and believe that technology is an indispensably assistive tool for their daily tasks (Adiguzel & Vannest, 2007).

Implications

Although technology is evolving rapidly and has become increasingly common and accepted in school settings, just as it has in society at large, McDonald (2002) pointed out that "studies of score equivalence have largely ignored individual differences such as computer experience, computer anxiety and computer attitudes," all of which have been substantiated by the literature as potential obstacles inhibiting the adoption and application of handheld computers (p. 299). Although teachers may rightly be viewed as likely to be open to learning new skills, technology adoption is a complicated area of learning, the success of which is often influenced by existing beliefs and perceptions. Those responsible for implementing and overseeing handheld computer use may not be able to effectively manage the wide range of beliefs and perceptions pertaining to technology, but knowing that they exist could be a minimum expectation.

The findings of the study support the influence of dependability on perceived ease of use and perceived usefulness as an asset that accelerates the process through which teachers come to accept handheld computers. Accordingly, it is crucial that school administrators and policy makers regularly check with teachers to ensure that they are not experiencing difficulties vis-à-vis dependability and reliability, in addition to ensuring that teachers are trained to use the computer appropriately, that they are satisfied with its performance, and that they believe it to be both simple to use and meaningful for the realization of their own and the school's goals (Edyburn, 2001).

While developing awareness and providing training are important strategies that administrators planning the introduction of handheld computers in the classroom should use to prepare teachers for optimal leveraging of technology (Schulenberg & Yutrzenka, 2004), they are by no means the only, or even the most important, variables. The five areas discussed in this study must all be addressed to successfully and dependably prepare, plan, and implement the use of handheld computers into school- and classroom-based settings.

Limitations and Further Research

This study has several limitations. First, the sampling was not random. Cluster sampling was used. Only special education teachers were included in the study. Second, the sample size of the study was small in order to test the model and group differences, because small samples in testing models may yield unreliable results if alternative analyses are not implemented (Chou & Bentler, 1995; Kline, 1998). Thus, sampling and sample size must be considered a prerequisite factor when generalizing the findings. In this case, testing the model with a higher number of both special education and general education teachers might give more reliable results that could be generalized to other disciplines and contexts.

Third, the special education teachers in this study worked in different organizational contexts. Some were required to use handheld computers in the funded project in which they were involved. This participation brings the issue of context (Legris et al., 2003) into discussion and requires further research to test the models in mandatory and voluntary settings to bring different perspectives to the acceptance research. Fourth, the dependability factor on technology acceptance was tested and supported only with regard to handheld computers. The value of dependability should also be tested with other technologies to contribute a new model with several variations to the field. Finally, having lower reliability for dependability constructs when compared with satisfactory values may be a potential limitation, though this was improved by deleting the problematic item in the study. Therefore, caution should be taken regarding the reliability of each item in the instrument before conducting the main study. Specifically, having more than three items, as well as having alternately presented or negatively worded items, may alleviate the need for these caveats in further research (Selwyn, 1997).

Conclusion

Overall, the study tested the model to explain the technology acceptance decision process and the differences between the groups of special education teachers on five constructs of this model. Testing found that all the causal relationships among the constructs' latent variables (except the ones directed from subjective norm) were statistically significant; namely, special education teachers' intention to use handheld computers was successfully explained by their perceptions on the handheld computers' ease of use, usefulness, and dependability. Subjective norm was only factor for which the groups of special education teachers differed.

These findings are clearly an important addition to the literature pertaining to technology adoption in educational settings. A new tested dependability factor, blended with the factor of computer experience, will provide a new asset for technology acceptance models to be tested in diverse contexts and with different technology applications.

CHAPTER V

SUMMARY AND CONCLUSIONS

Handheld computers, as an emerging technology, are an increasingly significant tool in the field of education. This technology has rapidly advanced to the point that these computers can perform a wide range of functions, from note taking, to data collection and recording, to educational gaming. This study began with an overview of the recent literature examining the use of handheld computers as data collection tools, followed by a discussion of the dependability of handheld computers in special education settings. The dependability factor then was tested with four additional factors—perceived usefulness, perceived ease of use, subjective norm, and intention to use—to determine the potential influence of dependability on special education teachers' acceptance of handheld computers.

The evaluation of handheld computers as data-collection tools in research settings and summary of the current understanding of handheld computer use from different perspectives in the existing research yielded five characteristics. These characteristics were then emphasized in the discussion of dependability's influence on teachers' willingness to adopt handheld data-collection systems: (1) ease of use, (2) usefulness, (3) intention to use, (4) dependability/reliability, and (5) subjective norms. Individual traits, such as participants' experience with computers, anxiety regarding computers, and attitudes toward computers, were substantiated by the literature as potential obstacles inhibiting the adoption and application of handheld computers

(McDonald, 2002). The five factors demonstrated evidence for determinants on teachers' acceptance of handheld computers. The results of the comprehensive literature review indicated that hardware, software, and user satisfaction should all be considered and coordinated to successfully adopt handheld computers.

Next, the dependability of handheld computers used for data collection in special education settings was investigated. Participants were 19 special education teachers who used Pocket PC computers (a brand of handheld computer) to self-report their daily time use in fall 2005 and winter 2006. Data on dependability were collected from five different sources (teachers' self-reports of time use, observations of time use by external data collectors, interviews with the teachers, technical reports, and self-reported satisfaction levels) to test four dependability attributes (reliability, maintainability, availability, and safety). Results indicated that Pocket PC computers were reliable, maintainable, available, and safe when used for data collection purposes, as compared with traditional paper-and-pencil systems. Data synchronization and reminder for recording data were the only major concerns in the fall, but these were alleviated prior to the winter session through improvements to the coding system. Overall, comparative results from these five sources showed that data collection via handheld computers was easy and accurate, especially for the short-time interval coding. However, the equipment through which a handheld computer interacts with a remote server and database needs improvement to be compatible with this emerging technology.

Finally, the third study explored teachers' acceptance of handheld computer use, and tested relationships among the five factors that influence intention to use this technology based on a modified version of the technology acceptance model. Participants were 45 special education teachers who were categorized into four groups based on their involvement in the dependability study: those who collected data using only a handheld computer; those who used both a handheld computer and a Web application; those who used a Web application only; and those who used neither a handheld computer nor a Web application. The new model was tested using the survey responses regarding handheld computer acceptance. The results paralleled those of previous studies (Legris et al., 2003; Ma et al., 2005; Yuen & Ma, 2002), showing that intention to use a handheld computer was statistically significant and directly affected by the device's perceived usefulness and perceived ease of use. Dependability, which was not included in the previous literature on technology acceptance, had direct and indirect statistically significant effects on perceived ease of use and usefulness, and on intention to use a handheld computer, respectively. Overall, all of the causal relationships indicated that special education teachers' intention to use handheld computers was successfully explained by their perceptions of the device's ease of use, usefulness, and dependability.

In conclusion, three studies showed that it is possible to use handheld computers in the direct observation of behavior in a school environment, without requirement of any settings. When the dependability of handheld computers is improved, the studies also demonstrated a marked improvement in data handling, and preference of handheld computers over paper entry. Comparative results from these studies also indicated that handheld method of recording and transferring data improved adherence to reporting requirements and results in data being submitted in a timely manner.

Synthesis of the Research

A growing number of studies have investigated the equivalence of data collected using electronic devices including handheld computers and data gathered using traditional paper and pencil methods. This is the only research study that investigated the use of handheld computers as an alternative to the other data collection methodologies by considering hardware, software and user satisfaction concurrently within the framework of dependability and acceptability attributes.

Many of the existing studies addressed the incidence of missing values, error rates and accuracy (in terms of reading and logging responses as raw data) in the comparisons of these data collection methodologies. The results of this research study were in alignment with previous studies (Fouladi et al., 2002; Lal et al., 2000; Ployhart et al., 2003; Stanton, 1998) for three addressed reliability issues, however, this research improved such comparisons by adding new factors such as maintainability, availability and safety attributes, and universal design principles. To illustrate, the overall rate of agreement between data collected with electronic and paper forms was high enough in this research, and is consistent with previously reported results (Berthelsen & Stilley, 2000; Fletcher et al., 2003). The missing records in this research were less and not caused by a malfunction of the hardware or software, but by the participants' failure. Fletcher et al. and Johannes et al. (2000) reported similar findings, which suggest the need for a validation mechanism to ensure that participants send all necessary information. This research study also evaluated the use of handheld computers by investigating hardware and software considerations, and user perceptions and concluded that handheld computers, when the interface is appropriately designed and the computers are maintained well, facilitated the data collection process and minimized missing data and inter-observer error, which was also found in the study by Gravlee et al. (2006).

When handheld computers are integrated into existing settings or processes, there is a risk that they may not be adequately utilized or that they may be misused. Adoption and utilization of such computers are dependent on factors such as acceptance by the individuals required to use them and their familiarity with the technology components, the availability of appropriate resources, and the design of the user interface and data entry formats. Therefore, dependability was added as a new construct to existing technology acceptance model to evaluate the acceptability of handheld computers in data collection. Ma et al. (2005) and Legris et al. (2003) showed that perceived usefulness was one of the most significant factors in determining the acceptance of new technology, which was obtained in this research for determining the special education teachers' acceptance of handheld computers. The significant effect of perceived ease of use on intention to use new technologies in the study of Yuen and Ma (2002) was repeated for handheld computer use in this research. In other words, special education teachers would adopt handheld computers when they are confident that using such computers would not require substantial investments of time, energy, or effort to learn and to maximize functional capabilities. Obtaining non-significant effect of subjective norm on intention to use handheld computers is consistent with some previous studies (e.g., Davis, 1986;

Ma et al.), even though other studies (e.g., Ajzen, 1988; Mathieson, 1991; Taylor & Todd, 1995; Venkatesh & Davis, 2000) found either direct or indirect significance for these relationships. On the other hand, the dependability construct with significant direct effects on perceived ease of use and usefulness was contributed to the existing literature as a new determinant of intention to use handheld computers. As long as the handheld computer hardware and software are both dependable and reliable with minimal technical support, special education teachers consistently perceive handheld computers as easy to use and useful for school-based tasks (Avizienis et al., 2005).

Implications for Education

Handheld computers are quickly replacing other technologies in many professions, and bringing the advantages of desktop and laptop computers to field-based researchers in support of learning and, particularly, data collection. As dependability and acceptability levels of these computers have increased, the implications of using these computers have become increasingly important in the field of education.

This study supported the hypothesis that handheld computers are dependable data-collection tools and can be used as an alternative to traditional data-collection methodologies. Using technology that is dependable for data collection is critical for educators, because dependability determines a teacher's interest in a technology, the technology's useful lifespan, and the accuracy, validity, and reliability of the data collected. Thus, handheld computers can be indispensable tools for teachers, enabling them to walk around, monitor, and track student behavior where the actions in question take place, and to access student information and organize the details of teaching in one small, portable device that can be used anywhere and at any time. In other words, handheld computers can improve a teacher's skills in recordkeeping and data assessing, thereby increasing his or her overall skills as an educator. Likewise, administrators benefit from having remote access to submitted data via handheld computers as they evaluate student performance at the school level.

The study also tested the factors that influence teachers' intentions to use handheld computers. It is particularly important to analyze how handheld computers are adopted and used in schools and how they fit into teachers' pre-existing perceptions. Handheld computers can be an asset within a curriculum by encouraging teachers to adopt a more student-centered approach in the classroom. Teachers who accept the handheld computer as an instructional tool can also help tailor the computer to address the learning needs of their specific students as well. For example, special education students who are equipped with handheld computers with specialized software can perform better in a regular classroom.

Overall, while handheld computers are not a direct replacement for many technologies, they can address specific problems and meet a variety of educational needs when used alongside desktop and laptop computers. Education stakeholders are in the early stages of discovering ways to use these devices to improve the efficiency and quality of the resources in the field of education. However, within the next few years, there will be an increasing awareness of the benefits that can be gained from the use of handheld computers and the handheld computer likely will become a necessity like the desktop or notebook computer. Therefore, planning and preparation on the part of administrators, policy makers and teachers are important to the successful acceptance and use of handheld computer technology for data-collection purposes in the school.

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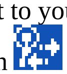
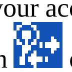
APPENDIX A

D2K DATA STEPS

1) STEPS TO RUN D2K APPLICATION
    a. TAP Windows **Start** button
    b. SELECT **D2K**
    c. SELECT **your ID**
    d. TAP **Enter**

2) STEPS TO SUBMIT DATA
    a. TAP D2K **Start** button (See date and time on the button)
    b. TAP **Cancel** (NO DEFER anymore) when you get Alarm sound and message. (During 15 minutes, since your PDA will sleep, its screen will be dark. When you hear the sound and alarm pops-up, be careful to touch the middle of the PDA screen namely **alarm message window**, otherwise alarm will not go off anymore.)
    c. TAP **Stop** button (See date and time on the button)
    d. SELECT your **Time Categories**
    e. TAP **Submit** button
    f. Do steps **a-e** for next 15 minute-interval.

3) STEPS FOR THE END OF THE DAY
    a. TAP **Usermenu** on the bottom and SELECT **close** when you are on D2K
    b. Connect to the wireless network and internet
        i. Teachers who have wireless access point in their schools
            1. Teachers who use DELL PDA X50V
                a. Enable your wireless using the button on the left side and it will automatically connect to your access point.
                b. Wait until you see the icon  on the top which means you are connected to your access point.
            2. Teachers who use DELL PDA X50
                a. Insert your wireless socket into the socket and it will automatically connect to your access point.
                b. Wait until you see the icon  on the top which means you are connected to your access point.
        ii. Teachers who don't have wireless access point in their schools
            1. Connect your PDA to your PC via USB cable.
            2. Wait until your PC recognizes your PDA (ActiveSync program will pop-up and automatically recognize your PDA)
            3. You are connected to the internet since you have internet connection on your PC.
    c. Connecting to TAMU
        i. TAP Windows **Start** button
        ii. SELECT **MovianVPN**
        iii. TAP **Login**
        iv. When you see finished, TAP **Ok.**

v. TAP **Exit** (You will see this icon  on the bottom which means you are connected to TAMU)

d. Synchronizing your data with our server
    i. TAP Windows **Start** button
    ii. SELECT **D2K**
    iii. SELECT **your ID**
    iv. TAP **Enter**
    v. TAP **Synch.** Button on the left bottom
        1. You will see new window with text Synchronizing D2K
        2. DO NOT touch anything at this point since your PDA will communicate with our server.
        3. In your new window, you will see the number of records next to D2K in the parenthesis which means your data is being synchronized with our data.
        4. When the program completes synchronization, the window will go off itself.

e. Disconnecting
    i. TAP **Usermenu** on the bottom and SELECT **close**
    ii. TAP Windows **Start** button
    iii. SELECT **MovianVPN**
    iv. TAP **Logout**
    v. When you see logged-off, TAP **Ok.**
    vi. TAP **Exit**
    vii. Disabling your connection
        1. Teachers who have wireless access point in their schools
            a. Teachers who use DELL PDA X50V
                i. Disable your wireless using the button on the left side.
                ii. You are done and keep charging your PDA…
            b. Teachers who use DELL PDA X50
                i. Unplug your wireless card
                ii. You are done and keep charging your PDA…
        2. Teachers who don’t have wireless access point in their schools
            a. Disconnect your PDA from your PC.
            b. You are done and keep charging your PDA…

APPENDIX B

Time Interval Codes

	Codes
	Academic Instruction
Definition	Teaching TEKS-related Academic Skills. Can occur in your class or another setting.
Examples	a) Presenting academic material b) Guiding academic student activities
Non-examples	a) Supervising students b) Teaching social skills c) Teaching daily procedures that are non-academic d) Proctoring tests
	Non-Academic Instruction
Definition	Instruction not directly tied to Texas Essential Knowledge and Skills.
Examples	a) Teaching social skills b) Impromptu discussion of current events c) Teaching procedures for activities.
Non-examples	a) Instructional Support during non-academic instruction b) Monitoring students during independent work c) Teaching TEKS-related academic skills
	Instructional Support
Definition	Time providing support to students, with minimal/no direct teaching, during academic or nonacademic instruction.
Examples	a) Being present while another teacher leads the lesson b) Being available to provide additional support to students in need c) Monitoring students as they work independently on academic or nonacademic content d) Brief answers to student questions
Non-examples	a) Supervising students during free time on the playground b) Teaching TEKS-related content c) Administering a spelling test d) Providing sustained, one-on-one instruction e) Re-teaching academic content

	Discipline
Definition	Time you spend responding to students' problem behaviors. Includes any teacher actions that occur because of student's misbehavior.
Examples	a) Writing discipline referrals b) Pulling/changing a cards in response to problem behavior c) Reprimanding or redirecting students who misbehave d) Having the class go back and then line up again because they ran the first time e) Participating in a conference that occurred as a direct result of a student's problem behavior
Non-examples	a) Filling out a daily report that must be sent home regularly regardless of problem behavior b) Attending ARD meetings c) Writing behavioral goals for an ARD
	Supervision
Definition	Monitoring students during non-instructional times.
Examples	a) Bus duty b) Assembly c) Cafeteria duty d) Recess e) Between classes in the hallway f) Walking the class or a student somewhere not discipline related g) Fire drill
Non-examples	a) Making copies b) Administering a spelling test c) Monitoring student work
	Assessment
Definition	Evaluating any aspect (social *or* academic) of student performance.
Examples	a) Grading papers b) Proctoring exams c) Individual progress monitoring
Non-examples	a) Filling out report cards b) Calculating and Inputting grades c) Writing IEP goals
	ARD Meetings
Definition	Includes meetings that are required under IDEA.
Examples	a) Emergency ARDs b) Placement change meetings c) Initial ARDs, etc.
Non-examples	a) Casual conversations with other adults b) Staff meetings

	Paperwork
Definition	Attending to any educational paperwork as required by your school, district, state, or the federal government.
Examples	a) Filling out forms for an ARD b) Scheduling an ARD c) IEP progress reports d) Recording assessment data to be used for annual IEP review e) Recording quiz or homework grades f) Reading reports on student data
Non-examples	a) Evaluating your teaching assistant b) Completing mileage forms for reimbursement
	Consultation/ Collaboration
Definition	Time spent communicating about students' educational needs.
Examples	a) Chatting in the lunch room about a student b) Emails about students c) Phone calls to parents about a student d) Working with another teacher to plan instruction e) Communicating with paraprofessionals about students/ instruction f) Team meetings specifically about students
Non-examples	a) Talking with other professionals about anything other than students' education b) Faculty meetings
	Other Responsibilities
Definition	General meetings, duties, and tasks that do not fall within any other categories.
Examples	a) Grade level committee meetings b) Work-related email correspondence c) Turning in attendance reports d) School safety committee e) Planning PTO fundraising events f) Serving on the hospice committee g) Training/in-service activities h) Running to Wal-Mart to purchase supplies i) Cleaning up your room j) Rearranging your room k) Ordering lab equipment l) DFS calls m) Club Sponsor
Non-examples	a) Hanging out in the office b) Bus duty

	Personal Time
Definition	Time spent attending to non work-related issues.
Examples	a) Bathroom b) Lunch c) Personal phone calls d) Non work-related email e) Chatting with others archers about personal topics
Non-examples	a) Phone calls to students' parents b) Meeting with the principal to discuss your annual performance review

	Plan/Prepare
Definition	Time spent individually preparing for instruction or planning for instruction.
Examples	a) Writing lesson plans b) Choosing videos to show as part of a science unit c) Setting up the classroom for instruction

APPENDIX C

Handheld Computers Acceptability Survey Constructs and Model

Construct	Definition	Reference
Perceived usefulness (PU)	The extent to which a person believes that using the handheld computer will enhance his or her job performance within the school context.	Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989); Hu, P. J., Clark, T. H. K., & Ma, W. W. (2003); Ma, W. W., Andersson, R., & Streith, K. O. (2005)
Perceived ease of use (PE)	The extent to which a person believes that using the handheld computer will be free of mental and physical effort.	Davis, Bagozzi, & Warshaw (1989); Hu, Clark, & Ma (2003); Ma, Andersson, & Streith (2005).
Intention to use (IU)	The decision whether or not to become a user of handheld computer.	Hu, Clark, & Ma (2003); Ma, Andersson, & Streith (2005); Hu, P. J., Chau, P. Y. K., Liu Sheng, O. R., & Tam, K. Y. (1999).
Subjective norm (SN)	A subjective norm refers to a teacher's perception about opinions or suggestions of the significant referents concerning his or her acceptance of handheld computer.	Ajzen, I. (1988); Hu, Clark, & Ma (2003); Ma, Andersson, & Streith (2005); Taylor, S., & Todd, P. A. (1995).
Dependability (D)	The trustworthiness of a handheld computer which allows reliance to be justifiably placed on the service it delivers. Dependability includes reliability (not the statistical estimation of reliability), safety, security, availability, and maintainability.	Avizienis, A.M., Laprie, J.C., & Randell, B. (2005).

APPENDIX D

Handheld Computers Acceptability Survey

Part I:

Directions: Please answer the following questions by putting a check mark with the appropriate response or filling in the information requested.

1. Gender ___ Male ___ Female
2. Age: _____
3. Have you owned or had access to a handheld computer? ___ Yes ___ No
4. I have been using handheld computers for _____ years.
5. During the last year, how often have you used a handheld computer for the following tasks (Check one answer per task)?

Task	**Never**	**Once or Twice**	**Monthly**	**Weekly**	**Daily**
Basic functions such as calendar, address book, to do list, and note pad					
Word processing					
Multimedia presentations					
Spreadsheet or database					
Drawing					
Internet access					
Email					
Games					
Playing music					
Taking pictures					
Stand-alone application to assist your activities					

Part II:

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	I intend to use handheld computers when they become available in my school settings. (IU)					
2.	To the extent possible, I would use handheld computers to do various Special Education tasks. (IU)					
3.	Using handheld computers improves Special Education teachers' school performance. (PU)					
4.	Handheld computers enable Special Education teachers to accomplish tasks more quickly. (PU)					
5.	Using handheld computers will make it easier for Special Education teachers to perform their daily activities. (PU)					
6.	Using handheld computers enhance Special Education teachers' effectiveness on Special Education services. (PU)					
7.	I find handheld computers to be useful for Special Education teachers. (PU)					
8.	The quality of the output from handheld computers is high. (PU)					
9.	Frequent errors are not common when using handheld computers. (PE)					
10.	I rarely need help when using handheld computers. (PE)					
11.	It is easy to get handheld computers to do what I need them to do. (PE)					
12.	It is easy to become skillful in using handheld computers. (PE)					
13.	Learning to operate handheld computers is easy. (PE)					
14.	Interactions with handheld computers are clear and understandable. (PE)					
15.	Interacting with handheld computers does not require a lot of mental effort. (PE)					
16.	Handheld computers are easy to use. (PE)					
17.	I rarely become confused when using handheld computers. (PE)					
18.	The results of using handheld computers are apparent. (PE)					
19.	People who influence my behavior think that I should use handheld computers. (SN)					

20.	People who are important to me think that I should use handheld computers in my instruction. (SN)					
21.	Handheld computers are reliable and trouble free for data collection. (D)					
22.	Handheld computers are dependable computers for data collection. (D)					
23.	Handheld computers are available for Special Education teachers to use for data collection any time. (D)					

(PU) = Perceived Usefulness; (PE) = Perceived Ease of Use; (IU) = Intention to Use;

(SN) = Subjective Norm; (D) Dependability

VITA

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