The Use and Efficacy of Handheld Computers for School-Based Data Collection: A Literature Review

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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 consider alternative tools, and apply them effectively. One of these alternatives, 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 review examines the willingness of teachers to adopt handheld data collection systems by focusing on 5 main features: (a) ease of use, (b) usefulness, (c) subjective norms, (d) intention to use, and (e) dependability.

KEYWORDS handheld computers, acceptability, dependability, mobile computing, data collection

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 such improvements (Kahng & Iwata, 1998). There is a common perception that people have become familiar with the vast array of new technologies and adopted them in their everyday lives. However, the scholarly literature indicates that a considerable gap exists between the awareness of such technologies and their actual implementation (Spiegler, 2003). This article addresses such gaps in relation to 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 as an integral part of their practice. This often involves the collection of field-based data that requires multiple functions; specifically, it provides single-point or longitudinal raw data that allow evaluation of the performance of individuals, groups, policies, practices, or programs. Once the researcher has collected the desired data, he or she conducts quantitative and/or qualitative analyses and produces a summary of findings that provides guidance for recommendations regarding improvements of existing circumstances or conditions.

For educators, data collection and evaluation have become increasingly important components in the areas of job expectation and teacher accountability (Linn, Baker, & Dunbar, 1991; Mahoney & Zigler, 2006; Worthen & Sanders, 1991). The No Child Left Behind (NCLB) 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 NCLB 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 NCLB 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., 2002).

Although standardized achievement and performance tests are used by most schools as a means of tracking student 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 student 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 instru-
m ents 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” (1992, 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 col-
lecting data regarding their students’ academic and behavioral performance
(Airasian, 2001; Bell & Beedle, 1993; Dona’t, 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 num-
ber of problems associated with their use, thus turning administrators’ and
researchers’ attention to the use of electronic devices as data-collection in-
struments. Several problems have been identified in using 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 retriev-
ing data over a long period of time (Emmelkamp, 2005); and the frequent
lack of clarity that prevents accurate coding of written responses, leading 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 educa-
tion, medicine (Palermo, Valenzuela, & Stork, 2004), and psychology (Pettit,
1999).

In addition to potentially preventing or remedying the problems of using
paper-and-pencil assessments, the increasing availability and affordability of
both software and hardware make data collection via technological devices
a compelling alternative. The early literature on using computer-based tools
for data collection in the educational environment suggested that these tools
offer teachers and administrators, as well as other stakeholders, an array
of benefits over the traditional paper-and-pencil method. 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,
interresponse 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 provide portability and standardization of equipment across all the studies reviewed, they also require sufficient electrical outlets that 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 shorter battery life than handheld computers.

Handheld computers have emerged as one of the most promising new technologies by 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 (e.g., $100 to $400), portability, ease of use (minimum computer skills required), flexibility (ready availability), and battery life (typically 6 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, Chowdhury, & 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 they are observed or at some later time (Hoppe, Joiner, Milrad, & Sharples, 2003). As Davis (2002) 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 high-technology classrooms; and the ability to share data among teacher groups and, in some cases, with parents and other stakeholders. 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” (Davis, 2002, 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. (1994) explained, the portability of handheld computers and the increasing diversity of the number and types of software programs that permit teachers to collect 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. (1994), 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. Mini-Mooses™ (Multi-Option Observation System for Experimental Studies) and INTMAN™ (Interval Manager) are also two other applications developed on handheld computers by Tapp (2008a, 2008b) for collecting real-time observational data.

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 have discussed, “The primary, and most powerful uses of handheld computers, have not been for organizational purposes” (2002, p. 23). In order to understand the dynamics that have influenced 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.

Literature on the dependability of handheld data collection systems and users’ willingness to adopt these systems focus on five main topics: (a) the potential user’s perceptions regarding the ease of using the handheld computer; (b) the potential user’s perceptions regarding the usefulness of the handheld computer; (c) subjective norms; (d) the potential user’s level of commitment to using the handheld computer, also known as intention to use; and (e) the potential user’s perceptions of the handheld computer’s dependability. Each of these topics will be discussed in this article. The underlying assumption of this 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 it influences 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., 1989). 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., 1989), 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 use 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., 2002).

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 feel compelled to learn about technology independently if they believe that its use will benefit teaching, classroom management, and student outcomes; however, administrators’ expectations 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” (Windschitl & Sahl, 2002, 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, simply 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., 2002).

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 the technology be introduced? Will teachers be “forced” to adopt handheld data collection technologies, or will teachers participate in decisions about their use? Second, 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. These variables must also be considered, in relation to 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 initially be viewed as burdensome (Hargreaves, 2000).
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: (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 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., 2003, p. 227). Interestingly, Hu and his colleagues also determined that “teachers appear to consider a rich set of factors in initial acceptance [of using technological devices in the classroom] but concentrate on fundamental determinants (e.g., perceived usefulness and perceived ease of use) in their continued acceptance” (Hu et al., 2003, p. 227). Ultimately, Hu et al. (2003) 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 also is 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).

**SUBJECTIVE NORMS**

The term subjective norms refers to a broad category that includes one’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). 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. 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 macrolevel goals (Marcinkiewicz & Regstad, 1996).

In addition, the technology 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. (2002, 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, 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. 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 macrolevel goals will be more persuasive to teachers than other arguments.

POTENTIAL USER COMMITMENT TO THE HANDHELD COMPUTER

The NCLB 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 observing, monitoring, and evaluating purposes (NCLB, 2002). As Hu, Chau, Liu Sheng, and Tam (1999) explained, 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.

**PERCEPTIONS REGARDING DEPENDABILITY 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, 2001, 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 using the technology to fulfill its intended purpose (Avizienis, Laprie, & Randell, 2001, 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/her ability to use 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., 2001). While technical support ideally is available, the user also wants to know that the hardware and software are dependable, with minimal intervention from technical support staff or reference materials.

Dependability is a critical variable that helps predict a technology’s useful life span and the accuracy, validity, and reliability of the data for which 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. (2003) posited that some additional concerns about the reliability of data entered into handheld computers exist.
because the user of a handheld computer is more likely to be multitasking during data collection. The same portability that makes the computer so appealing may also compromise data quality, as well as the completeness of the data set and interagreement (Hutter et al., 2003).

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

In addition to preexisting obstacles to optimal use of technology used for data collection (i.e., teachers’ negative perceptions regarding its ease of use and utility and the extent of their commitment to 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 generate skewed data sets by using the computer less frequently, or using it incorrectly, and may even abandon its use altogether (Edyburn, 2001). Thus, in addition to ensuring that (a) teachers are trained to use the computer appropriately, (b) they are satisfied with its performance, and (c) 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 they are using the computers properly and 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 is not a direct technical support issue, 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 issues is particularly important.

**ELECTRONIC DEVICES VERSUS PAPER-AND-PENCIL DATA COLLECTION METHODOLOGIES**

One way to address the aforementioned obstacles that often prevent the successful adoption and use 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 acknowledged that “many of these studies ... have had methodological limitations such as using nonequivalent 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., 2001, p. 339). Several of these studies are reviewed in this article.

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” (1998, 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 parallel 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., 2003, 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” (Fouladi et al., 2002, p. 204).

Although these studies utilized a Web-based format rather than a handheld computer, 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 interpret a respondent’s answer.
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 the 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 (e.g., peers, siblings, neighbors) in 1-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 instruction (Crawford & Vahey, 2002). 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 3 groups: (a) students new to the United States who spoke English as a second language, (b) special education students, and (c) 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 compared to traditional alternatives. 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 article must be considered to successfully and dependably prepare, plan, and implement handheld computers for data collection.

REFERENCES


