PERSONNEL PSYCHOLOGY
2006, 59, 623–664

THE COMPARATIVE EFFECTIVENESS OF WEB-BASED AND CLASSROOM INSTRUCTION: A META-ANALYSIS

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Meta-analytic techniques were used to examine the effectiveness of Web-based instruction (WBI) relative to classroom instruction (CI) and to examine moderators of the comparative effectiveness of the 2 delivery media. The overall results indicated WBI was 6% more effective than CI for teaching declarative knowledge, the 2 delivery media were equally effective for teaching procedural knowledge, and trainees were equally satisfied with WBI and CI. However, WBI and CI were equally effective for teaching declarative knowledge when the same instructional methods were used to deliver both WBI and CI, suggesting media effects are spurious and supporting Clark's (1983, 1994) theory. Finally, WBI was 19% more effective than CI for teaching declarative knowledge when Web-based trainees were provided with control, in long courses, and when trainees practiced the training material and received feedback during training. Study limitations and directions for future research are discussed.

Web-based instruction (WBI) is becoming a favored training option in industry, government, and higher education. WBI is a "hypermedia-based instructional program, which utilizes the attributes and resources of the World Wide Web to create a meaningful learning environment where

The authors are indebted to Kenneth Brown, Kevin Ford, Richard Mayer, Ann Marie Ryan, and three anonymous reviewers for comments and suggestions on earlier versions of this manuscript.

This research was funded by the Department of Defense through contract number DASW01-03-C-0010. The views expressed here are those of the authors and do not necessarily reflect the views or policies of the Department of Defense.

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learning is fostered and supported" (Khan, 1997, p. 6). WBI is delivered via a computer using the Internet, enabling instant updating, distribution, and sharing of information (Rosenberg, 2001). In a survey of organizations in the American Society of Training and Development's benchmarking service, the percentage of companies using technology-delivered training increased from 8% in 1999 to 27% in 2004, and about 75% of the technology-delivered courses in 2004 were online (Sugrue & Rivera, 2005). In addition, over 1,100 institutions of higher education in the United States offer online courses (Newman & Scurry, 2001). Finally, the Army uses online instruction as a retention tool, with over 40,000 soldiers in 50 countries pursuing advanced degrees online (Symonds, 2003).

Given its growing popularity, it is important to understand whether or not this delivery medium is effective, whether WBI is more effective than other delivery media, and what contextual or methodological factors moderate its effectiveness. In this study, effectiveness is operationalized as both learning from and reactions to delivery media. We examine cumulative evidence of the effectiveness of WBI relative to classroom instruction (CI) and moderators of the comparative effectiveness of the two delivery media.

Effectiveness of WBI as an Applied Issue

The rush to implement WBI preceded empirical evidence of its benefits. Given the increasingly widespread implementation of WBI, it is important to determine whether or not WBI is effective for imparting useful knowledge and skills. WBI will have utility to organizations and institutions if it results in learning and retention, is well received by users, and is cost effective to the sponsoring organization or institution. There have been few studies of the cost effectiveness of WBI, but a sufficient number of primary studies have now been conducted to determine its effectiveness with respect to learning and user reactions. However, Arbaugh (2005) questioned whether single studies are useful for understanding the impact of technology and course characteristics on WBI effectiveness. By examining trends across studies, we can draw quantitative conclusions of WBI effectiveness only a decade after its introduction. Given evidence that WBI is effective, more organizations and institutions will be able to justify the expenditures necessary to adopt it. If evidence suggests that it is not as effective as existing delivery media, organizations and institutions may be more cautious about replacing traditional delivery media with WBI or seek to develop more effective online training methods. Finally, if WBI is effective under some conditions and not others, organizations and institutions that place training online can use the results of this study to identify optimal learning conditions.

Accordingly, this study is a meta-analysis of studies that compare the effectiveness of WBI and CI for delivering instruction on the same topic. CI will be used as a basis for comparison as it is the most common delivery medium (Sugrue & Rivera, 2005) and because there is still a paucity of studies comparing WBI to other delivery media.

Effectiveness of WBI as a Theoretical Issue

The question of whether or not WBI is more effective than other delivery media has theoretical importance. WBI has several advantages that may result in WBI being more effective than other delivery media. WBI represents a nonlinear instructional medium that may encourage deeper processing and cognitive flexibility in learners (Spiro & Jehng, 1990) by allowing trainees to more effectively integrate new information with existing knowledge (Salomon, 1988). WBI may also be a superior medium to the extent that it offers a cluster of instructional methods (e.g., text, audio, graphics, synchronous and asynchronous communication) that can be tailored to meet individual needs. Arbaugh (2005) detailed clusters of WBI features that may lead to greater instructional effectiveness including media variety, facilitation of Web exploration, learner ease, and flexibility of use. WBI can also provide beneficial features that are not easily replicable in CI, such as immediate feedback (Kulik & Kulik, 1988; Phye & Andre, 1989). To the extent that WBI incorporates these features, we might expect WBI to be more effective than other delivery media.

On the other hand, educational psychologist Richard Clark (1983, 1994) has been a long-time critic of studies and reviews that purport to show that newer, technologically based instructional media are superior to existing media (e.g., Fletcher, 1990; Kulik, 1994). Although media is often used to refer to the general method of delivering training, here media refers to *technological* devices used for the purpose of instruction (Clark & Sugrue, 1995). Clark has argued that delivery media, such as computers, video teleconferencing, and the Internet, are inconsequential in affecting learning outcomes, especially when compared with more powerful influences such as individual differences and instructional methods. Instructional methods refer to techniques used within a course to convey course content such as lecture, reading textbooks, assignments, or group discussions.

Clark (1983, 1994) criticized media effectiveness research on two grounds. First, most studies fail to institute experimental controls sufficient to rule out alternative explanations for group differences. Specifically, individuals may choose the delivery media with which they are most comfortable due to a lack of random assignment into WBI and CI. Second, Clark argued that most prior studies have failed to isolate instructional

attributes that are *unique* to a single medium. For example, WBI may provide more opportunities for learner customization than CI, but (a) CI can provide some customization in some situations and (b) opportunities for learner customization are not unique to WBI. Clark suggested that if studies fail to isolate attributes unique to the medium, results of those studies cannot be accepted as evidence of the superiority of the medium. In short, Clark concluded that there is nothing uniquely beneficial about any computer-aided instructional medium (including WBI).

Clark's position has received broad support (e.g., Bernard et al., 2004; Russell, 1999) but is not without its critics. Cobb (1997) argued that certain delivery media reduce the cognitive demands placed on learners, and media should be chosen to maximize cognitive efficiency, allowing learners to spend less time mastering the material. Kozma (1994) argued that although it may be difficult to isolate individual instructional attributes to any single medium, it is possible to identify clusters of attributes (e.g., customization and hyperlinking) that are more efficiently accomplished in one medium than others. For example, compared to CI, WBI is more likely to offer customization of instructional methods and content, as well as continual access.

In summary, there are two schools of thought with respect to the relative effectiveness of WBI and CI. Clark's position argues that no instructional medium is uniquely advantageous. On the other hand, pro-technology researchers believe that WBI provides greater flexibility and greater access to multiple instructional methods such that it may be superior to media that are grounded in a single instructional method (Dumont, 1996; Hiltz & Wellman, 1997; Sullivan, 2001).

We intend to apply meta-analytic methods to address the important theoretical question of whether instructional media matters. After Clark (1983, 1994), we will do so in three ways. First, we examine a subset of all studies in which a true experimental design is used. Clark has argued that past research supporting technology-assisted instruction has failed to execute proper experimental procedures that control for participant motivation or prior experience with the technology. Our report will support Clark's position if we find positive mean effect sizes for learning when analyzing all studies and no effects for media when analyzing only true experiments.

Second, we examine a subset of studies that equate instructional methods across delivery media. WBI and CI have similar instructional methods when all of the instructional methods included in WBI have a comparable instructional method in CI. For example, when lecture is provided in CI, a comparable instructional method in WBI is an online video of the lecture. WBI and CI have different instructional methods when an instructional method is present in WBI or CI, and there is not a comparable instructional method in the other delivery media. For example, CI may use role plays

but WBI does not. Clark has argued that media studies often confound delivery media with instructional methods, making it impossible to determine whether main effects are due to differences in media or instructional methods. In order to address the effect of delivery media when instructional methods are equivalent, we isolate studies that compare WBI to CI when identical instructional methods are used. Our research will support the pro-technology position if greater learning from WBI relative to CI occurs even when instructional methods do not differ across delivery media. In turn, our research will support Clark's position if no learning differences between WBI and CI are found when instructional methods are the same across delivery media.

Third, we will examine a subset of studies in which WBI is used as a supplement to CI (henceforth WBI-S). Although Clark has not addressed the additive effects of multiple delivery media, if media do not matter, we will find no difference in the relative effectiveness of CI and WBI-S (provided content is identical across groups). In contrast, the pro-technology position will be supported if there is greater learning or more positive reactions when course content is delivered via multiple media as in the case of WBI-S.

Comparisons of WBI-S to CI provide preliminary cumulative evidence of the relative effectiveness of blended learning programs. Blended learning programs are those that provide some combination of offline and online learning (Singh, 2003). Note that in practice, instructional methods might include face-to-face instruction, synchronous or asynchronous online chat rooms or discussions, posted lecture notes, assignments, and many other instructional methods. Although there have been several anecdotal accounts of the effectiveness of WBI-S, there has not yet been a thorough review of the delivery medium. Given the practical and theoretical issues previously outlined, we propose a number of hypotheses and research questions.

Main Effect Hypotheses

The first objective is to examine the effectiveness of WBI relative to CI for teaching declarative and procedural knowledge and for training reactions. Declarative knowledge refers to trainees' memory of the facts and principles taught in training and the relationship among knowledge elements (Kraiger, Ford, & Salas, 1993). Declarative learning outcomes include changes in verbal knowledge, how knowledge is organized, and in cognitive strategies for accessing and applying knowledge. Procedural knowledge refers to information about how to perform a task or action (Kraiger et al., 1993). Procedural learning outcomes include compilation (i.e., proceduralizing steps and mentally grouping the steps into a more complex production) and automaticity (i.e., accomplishing tasks without

conscious cognitive effort, which enables simultaneous performance of additional tasks).

Goldstein and Ford (2002) and Welsh, Wanberg, Brown, and Simmering (2003) identified four advantages of WBI: consistent world-wide training, training can be delivered just-in-time to meet the job requirements of employees, reduced information overload, and training can be tailored and refined to meet the needs, prior knowledge, and interests of individual learners. These advantages are both strategic (consistent world-wide training) and pedagogical (individually tailored). Other pedagogical advantages include greater flexibility and access to multiple learning modes (Dumont, 1996; Hiltz & Wellman, 1997; Sullivan, 2001). Welsh et al. also summarized a number of instructional disadvantages of WBI, including the potential for lack of interaction among peers (both during and following training) and the potential for static, noninteractive information processing replacing more dynamic forms of learning. In addition, learners may lack Internet access, sufficient bandwidth to optimize training delivery, or the technical skills needed to access instructional content or upgrade training software or hardware.

Zhao, Lei, Lai, and Tan (2005) conducted a meta-analysis to compare the effectiveness of distance education courses (i.e., courses where the instructor and students are physically separated) to face-to-face courses and found no difference in the overall effectiveness of the two delivery media. However, several previous meta-analyses have reported overall positive effect sizes for various forms of technology-delivered instruction compared to CI including videodiscs (Fletcher, 1990), computer-assisted training (Kulik, 1994; Kulik & Kulik, 1991; Yaakub, 1998), and hypermedia systems (Liao, 1999). In addition, earlier meta-analyses by Olson and Wisher (2002) and Paul (2001) suggested WBI is more effective than CI. Olson and Wisher reported a corrected mean effect size of .24 based on a meta-analysis of 15 studies, suggesting WBI is 9% more effective than CI for teaching declarative and procedural knowledge. Paul reported a corrected mean effect size of .17 ($k = 27$) for training reactions and .24 ($k = 47$) for learning criteria, suggesting trainees react 7% more favorably toward WBI than CI and WBI is 9% more effective than CI for learning criteria. However, both Olson and Wisher and Paul completed their literature searches before 2003 (precluding the inclusion of research reports written in the last 3 years) and averaged across declarative and procedural knowledge outcomes (precluding an understanding of whether the effectiveness of WBI varies across factual and skill-based knowledge). In addition, Olson and Wisher focused exclusively on university courses and Paul did not distinguish between training reactions and learning criteria when testing the effectiveness of WBI-S. This meta-analysis will overcome these limitations by examining 96 research reports from 1991

to 2005, including employee and college training courses, and clearly distinguishing between both WBI and WBI-S and among declarative knowledge, procedural knowledge, and training reactions. Based on the results of preliminary meta-analyses, we hypothesize:

Hypothesis 1: WBI will be more effective than CI for teaching declarative knowledge.

Hypothesis 2: WBI will be more effective than CI for teaching procedural knowledge.

Hypothesis 3: Trainees will react more favorably toward WBI than CI.

In addition to studying the relative effectiveness of WBI, we are also interested in the relative effectiveness of WBI-S compared to CI. According to media richness theory, richer media (i.e., providing the same content through multiple media) result in greater learning, particularly for equivocal or ambiguous tasks (Daft & Lengel, 1986). In other words, learners benefit from exposure to both CI and WBI.

In both higher education and corporate training, WBI-S is known as blended learning. Blended learning is perceived by many as a strong instructional approach that incorporates the benefits of both personal interaction and facilitated instruction with self-study between instructional meetings using the Web (Kerres & deWitt, 2003; Masie, 2002; Pratt, 2002). In particular, blended learning is seen as advantageous in that it fosters learning communities, extends the total length of training, offers follow-up resources in a community of practice, can provide access to guest experts, and offers timely mentoring or coaching via either face-to-face or online laboratory and simulation activities (Bonk, Kim, & Zeng, 2005). In addition to these hypothesized advantages, there is preliminary empirical support for blended learning. Paul (2001) reported a meta-analytic corrected effect size of .27 indicating WBI-S was 11% more effective than CI when averaging across reactions and learning criteria. Thus, we hypothesize:

Hypothesis 4: WBI-S will be more effective than CI for teaching declarative knowledge.

Hypothesis 5: WBI-S will be more effective than CI for teaching procedural knowledge.

Hypothesis 6: Trainees will react more favorably toward WBI-S than CI.

Research Design Moderators

Trainee population. A second objective of the study is to examine moderators of the effectiveness of WBI relative to CI. The overwhelming majority of the research on the effectiveness of WBI relative to CI has focused on declarative knowledge, precluding an analysis of the effect of

the moderator variables on the acquisition of procedural knowledge and training reactions. Thus, the moderator hypotheses and research questions focus exclusively on declarative knowledge.

The first moderator analysis examines differences in the effectiveness of WBI relative to CI for college student and employee populations, after controlling for the age of trainees. We control for the age of trainees because trainees tend to be older in corporate training than college courses (U.S. Bureau of the Census, 2006) and in WBI than CI (Bocchi, 2004; Schneider & Germann, 1999; Tallent-Runnels et al., 2006). Research also indicates trainees in their late 20s and 30s are more motivated, have more positive attitudes toward training, are less anxious, and focus more on achieving specific learning outcomes than younger trainees (Graham, 1991; Tallent-Runnels et al., 2006). Controlling for age effects allows us to assess if there are differences in the effectiveness of WBI relative to CI, after controlling for a demographic characteristic that is related to both the trainee population and learning.

We focus exclusively on research reports where trainees are acquiring knowledge to prepare them for their current or future employment opportunities in order to generalize to a sample of working adults. To accomplish this, we include both college and work-related training courses. There is no theoretical reason to believe online instruction is more or less effective in university versus work settings. Many corporations have established training partnerships with universities, outsourcing employee training to universities (e.g., Cisco, British Airways, and Merck outsource to Duke University and Cardinal Health and the New Jersey State Police outsource to The New Jersey Institute of Technology; Harris, 2005). Thus, a clear distinction between university and corporate training courses may no longer exist. However, we want to determine whether there is a difference in the relative effectiveness of WBI and CI for teaching declarative knowledge across populations to ensure the results are applicable to both university and corporate settings. Accordingly, the first research question is:

> *Question 1*: Will the population (student vs. employee) moderate the effectiveness of WBI relative to CI for teaching declarative knowledge, after controlling for the age of trainees?

Similarity in instructional methods. The second moderator analysis investigates the effectiveness of WBI relative to CI after eliminating differences in instructional methods. To reduce experimental biases previously discussed, we examine differences in the effectiveness of the two delivery media when the same instructional methods are used to deliver both WBI and CI. If Clark (1983; 1994) is correct, any observed effects of WBI

for teaching declarative knowledge should disappear when we control for instructional methods.

Second, we examine a subset of studies that use true experimental designs. This addresses Clark's concern that media comparison studies often confound instructional media with instructional quality, student motivation, and so forth. Random assignment of trainees to WBI and CI should reduce differences between test groups that may confound observed effects for learning. If Clark's position is correct, any observed effects for WBI relative to CI should disappear when we control for the experimental design. Consistent with Clark's position, we propose the following hypotheses:

> *Hypothesis 7*: Similarity of the instructional methods used in WBI and CI will moderate learning declarative knowledge from WBI relative to CI. That is, any effects observed for all studies will disappear when examining only studies where similar instructional methods are used in WBI and CI.

> *Hypothesis 8*: The research design will moderate learning declarative knowledge from WBI relative to CI. That is, any effects observed for all studies will disappear when examining only studies with true experimental designs.

Learner control. Learner control refers to the extent to which trainees have control over their learning experience by affecting the content, sequence, or pace of material (Friend & Cole, 1990). The absence of learner control is characterized by program control in which the instructional software controls most or all of the decisions in WBI.

A purported advantage of WBI is it typically provides trainees with more control than CI (Welsh et al., 2003). However, research also shows the effect of learner control on actual learning is negligible (Kraiger & Jerden, in press; Niemiec, Sikorski, & Walberg, 1996). As prior research has not consistently demonstrated an effect for learner control on learner achievement, we cannot develop a directional hypothesis regarding the moderating effect of learner control on the effectiveness of WBI. However, given the potential for individual customization in online courses, we are interested in the effect of learner control during WBI. Thus, we propose the following research question:

> *Question 2*: Will the level of learner control moderate learning of declarative knowledge from WBI relative to CI? Relative to CI, will participants learn more declarative knowledge with low or high levels of learner control in WBI?

Human interaction. Human interaction refers to the extent to which trainees interact with the instructor and other trainees throughout the course. Although prevalent in CI, human interaction can also be built into WBI through e-mails, chat rooms, group projects, and so forth. A number

of studies have found that higher levels of interaction between instructors and learners or among learners result in greater learner motivation, more positive attitudes toward learning or the instructional process, and improved learning outcomes (e.g., Entwistle & Entwistle, 1991; Hackman & Walker, 1990; Ritchie & Newbury, 1989; Wagner, 1994). In WBI, verbal behaviors (e.g., text messages) that establish immediacy are associated with greater participant learning (Freitas, Myers, & Avtgis, 1998; Rovai & Barnum, 2003). Human interaction decreases the likelihood that trainees will feel isolated in WBI and can help trainees remain motivated while learning the material (Brown & Ford, 2002). Consequently, we hypothesize:

Hypothesis 9: Human interaction will moderate the extent to which trainees learn declarative knowledge from WBI relative to CI. Relative to CI, trainees will learn more declarative knowledge from WBI with high levels of human interaction than with little human interaction.

Practice and feedback. Both the opportunity to practice and the provision of feedback were included in Kraiger's (2003) guidelines for designing effective training. Practice is essential for skill acquisition and feedback is needed for trainees to know whether they are effectively using their newly acquired knowledge and skills (Brown & Ford, 2002). Further, Azevedo and Bernard (1995) conducted a meta-analysis of 22 computer-based training studies and found students who were given feedback learned more than students who were not given feedback. Thus, the relative effectiveness of WBI and CI should be contingent upon whether one or both delivery media incorporated practice and feedback during training. We therefore hypothesize:

Hypothesis 10: Practice will moderate the extent to which trainees learn declarative knowledge from WBI relative to CI. Relative to CI, trainees will learn more declarative knowledge when they practice during WBI.

Hypothesis 11: Feedback will moderate the extent to which trainees learn declarative knowledge from WBI relative to CI. Relative to CI, trainees will learn more declarative knowledge when they receive feedback during WBI.

Length of training. We also explore the effects of the length of training on learning from WBI relative to CI. The training programs we reviewed varied tremendously in length, ranging from 1 to 120 days. Course length may differentially influence learning depending on whether trainees become more proficient at learning or whether early novelty effects wear off. We are curious as to whether the effectiveness of WBI relative to CI decreases, increases, or remains the same as the course length increases. We propose an additional research question:

Question 3: Will the length of training moderate learning declarative knowledge from WBI relative to CI? Relative to CI, will trainees learn more, less, or the same amount from WBI as course length increases?

Method

Literature Search

A computer-based literature search of PsycInfo and ERIC was used to locate studies in the training and education literature from 1996 to February 2005. The technology for online instruction is relatively new so we designated 1996 as a reasonable cutoff date for evaluations of WBI. We scanned references of the obtained studies for earlier citations and found only two relevant studies published prior to 1996.

In order to be included in the initial review of abstracts, each abstract had to contain a term relevant to the Internet and reactions or learning outcomes. To meet the search criteria, some combination of the keywords—*Web, online*, or *Internet* and *evaluate, learn, transfer, behavior, performance, knowledge, satisfaction, dissatisfaction, reaction, achieve,* or *outcome*—had to be present. The initial computer search resulted in a list of 3,461 possible reports. A review of titles and abstracts reduced the list to 249 reports potentially containing relevant information. Reading the reports identified 59 relevant studies. The electronic search was supplemented with manual searches of the reference lists from Allen, Bourhis, Burrell, and Mabry (2002), Bernard et al. (2004), Hsu (2003), Olson and Wisher (2002), and Paul (2001), as well as a manual search of the *Journal of Asynchronous Learning Networks* from 1996 to 2005. Manual searches contributed an additional 33 studies to this review.

We also searched for unpublished studies. First, a request was sent to the Advanced Distributed Learning listserv of over 8,000 people working in the area of training and development. Second, authors of annual review chapters on training (Campbell, 1971; Goldstein, 1980; Latham, 1988; Salas & Cannon-Bowers, 2001; Tannenbaum & Yukl, 1992; Wexley, 1984) and training textbooks (Blanchard & Thacker, 2004; Goldstein & Ford, 2002; Noe, 2005; Saks & Haccoun, 2004; Wexley & Latham, 2002) were asked to provide leads to unpublished work, as well as any manuscripts they may have. Third, consultants who listed training evaluation as an area of expertise on the Society of Industrial and Organizational Psychology (SIOP) Consultant Locator (http://www.siop.org/sioplocator) were contacted via e-mail. Fourth, the SIOP and Academy of Management conference programs from 1996 to 2005 were manually searched to locate relevant studies. These efforts identified an additional four studies, yielding a total of 96 studies that met the criteria for inclusion in this review.

Inclusion Criteria

The goal of the literature search was to identify all research reports where college students or employees were acquiring knowledge or skills to prepare them for current or future employment opportunities. Initially we also gathered research reports that reported gain scores from participating in WBI or that compared learning from or reactions following WBI or WBI-S to CI. However, due to the upward bias in effect sizes from gain score research (Lipsey & Wilson, 2001), this report focuses exclusively on studies that compared the effectiveness of WBI or WBI-S to CI. WBI was defined as a course where the material is delivered via the Internet. CI was defined as a course where the material is delivered face-to-face via an instructor. WBI-S was defined as a course that delivers material via the Internet and face-to-face via an instructor.

Studies had to meet five criteria to be included in the present review: (a) the study compared the effectiveness of WBI or WBI-S to CI for delivering material on the same topic; (b) the article was written in English; (c) the article reported results that allowed the calculation of a d statistic (e.g., group mean values and standard deviations, a t-test, or univariate F-test) or the author complied with a request to provide this information; (d) study participants were nondisabled adults ages 18 or older; and (e) training was conducted on a topic that provided job-related knowledge or skills. The last two criteria were used to support generalization to a population of adults participating in workplace training.

Data Set

Non-independence. Decisions about non-independent data points (i.e., multiple effect sizes from one sample) should take into account whether the effect sizes assess similar or different constructs (Arthur, Bennett, & Huffcutt, 2001). Effect sizes calculated for different criteria (i.e., training reactions, declarative knowledge, and procedural knowledge) were considered to be independent and retained as separate data points even if they were from the same sample. Occasionally a single study would report data from two Web-based training groups and/or two classroom groups. In these situations, an effect size was calculated for all possible Web-classroom pairs and averaged by weighting each of the effect sizes by the sum of the sample size of the independent training group and one half of the sample size of the non-independent group. Thus, the non-independent sample was weighted according to its sample size in the overall effect size. In addition, whenever a single study reported multiple effect sizes based on the same sample for a single criterion, the effect size

that was most similar to the other assessments of that particular relationship was used in the meta-analysis.

Coding and Interrater Agreement

In addition to recording all relevant effect sizes, sample sizes, and reliabilities, the following information was coded from each study: (a) reaction measures, (b) learning outcome criteria, (c) age, (d) population, (e) similarity of instructional methods in WBI and CI, (f) experimental design, (g) learner control, (h) human interaction, (i) practice, (j) feedback, and (k) length of training. Coding rules are described below. Scales for each moderator were drafted prior to coding and modified following initial attempts to code articles.

Training reactions. We initially sought to code and investigate the comparative effectiveness of WBI and CI on specific dimensions of training reactions (e.g., affect vs. utility). However, research reports often averaged across reaction dimensions when reporting the research results and too few studies were available within certain reaction dimensions. Accordingly, although separate dimensions of training reactions were coded whenever possible, specific dimensions were treated as indicators of an overall satisfaction construct by aggregating all studies that reported any reaction effect size in a single analysis. To avoid violating the assumption of independence, the effect sizes were averaged when multiple reactions were reported in a single study.

Learning outcomes. Declarative and procedural knowledge were coded based on the Kraiger et al.'s (1993) multidimensional framework of learning. Declarative outcomes were defined as cognitive and structural knowledge assessments designed to assess if trainees remembered concepts presented in training; they were always assessed with a written test. Procedural outcomes were defined as the ability to perform the skills taught in training. They were assessed by participating in an activity (e.g., simulation or role-play) or written test that required trainees to demonstrate memory of the steps required to complete the skills taught in training. For example, Browning (1999) taught an undergraduate course on educational technology and evaluated the course with both declarative and procedural knowledge assessments. The declarative knowledge assessment consisted of a multiple-choice and fill-in-the-blank examination designed to assess understanding of the concepts taught in the course. The procedural knowledge assessment required trainees to perform the software application skills taught in training.

Age. We coded the average age of trainees in WBI and CI.

Population. We coded whether trainees were college students or employees.

Similarity of instructional methods. Similarity of instructional methods across media was coded on a two-point scale. An instructional method is a technique used to deliver training content (e.g., lecture, online tutorials, video, and textbooks). WBI and CI had similar instructional methods when all of the methods present in WBI had comparable methods present in CI. An example is a management information systems course researched by Carey (2001). Both WBI and CI included a textbook, practice examinations, and assignments. CI received lecture and discussed with the instructor face-to-face, whereas WBI received a copy of the PowerPoint slides from the lecture online and e-mailed with the instructor. WBI and CI had different instructional methods when a method was present in WBI or CI and there was not a comparable method in the other delivery media. An example is an introductory psychology course studied by Taylor (2002). In this instance, CI was delivered via lecture, quizzes, and a textbook, whereas WBI was delivered via quizzes, a textbook, assignments, discussion board, and e-mail.

Experimental design. Research reports utilized an experimental design when trainees were randomly assigned to WBI and CI. Research reports utilized a quasi-experimental design when trainees self-selected into WBI or CI.

Learner control. Learner control was coded on a two-point scale separating low from high levels of control. Learner control can include control over the content, sequence, and pace of training (Friend & Cole, 1990). In this study, learner control was low if trainees had little or no control over the content, sequence, or pace. Examples of Web-based courses with a low level of control are noninteractive lecture-based classes or a computer-controlled sequence of activities completed in a set amount of time. Learner control was high when trainees had at least some control over two of the three dimensions (content, sequence, or pace) or a high level of control over one learner control dimension. Examples of courses with a high level of control are managerial courses where trainees can select material that is relevant to their jobs and courses where trainees have several months to review the online content. Initially we coded for pace, content, and sequence control separately, and we attempted to include three categories of control: high, medium, and low. However, because many of the articles provided little description of the training programs or did not provide information on all of the learner control dimensions, it was difficult to assess the degree to which training provided control over specific dimensions. Moreover, pace, content, and sequence control were highly correlated. Thus, overall control was coded as either high or low.

Human interaction. Human interaction was coded on a two-point scale where low indicated less than half of the course involved interacting with people (instructor or other trainees). An example of a Web-based

course with little human interaction is a course in which trainees participate in an online discussion once a week or less. Human interaction was coded as high when all or most of the course involved interacting with others. An example of a Web-based course with a high level of interaction is a course in which trainees frequently work on group projects and participate in online discussions.

Practice. Practice was coded on a dichotomous scale to indicate whether WBI and CI required trainees to practice the training material. Practice activities include completing assignments, participating in role-plays, taking practice exams, and writing papers.

Feedback. Feedback was coded on a dichotomous scale to indicate whether WBI and CI provided feedback to trainees on whether they were successfully learning the course material.[1]

Length of training. Length of training was coded as the number of days trainees spent in WBI and CI.

Coding agreement. All articles were coded independently by two trained raters. The initial mean level of agreement across all of the studies coded was 91%. The two coders then discussed discrepancies and reached a consensus. After discussing all discrepancies, 100% agreement was reached.

Calculating Effect Size Statistic (d) and Analyses

The Hedges and Olkin (1985) approach was used to analyze the data. The effect size calculated for each study was d, the difference between the Web and classroom training groups, divided by the pooled standard deviation. When means and standard deviations were not available, effect sizes were calculated from a t-test or univariate F-test based on the formulas reported in Glass, McGaw, and Smith (1981) and Hunter and Schmidt (1990).

Effect sizes were corrected for small sample bias using formulas provided by Hedges and Olkin (1985). We then corrected the reactions effect sizes for attenuation using the scale reliabilities reported in each study. When a study failed to provide a coefficient alpha reliability estimate, we used the average reliability for the variable across all samples from this study and from Sitzmann, Casper, Brown, Witzberger, and Polliard (2003). Although we aggregated all effect sizes for reaction measures, we corrected effect sizes at the study level based on the type of reaction measure. The average reliabilities were .83 for measures of affective, utility,

[1] We attempted to use more sophisticated coding schemes for human interaction, practice, and feedback, but lack of detail in primary studies prevented us from using more than a dichotomous scale.

and difficulty reactions, .87 for instructor reactions, .79 for delivery reactions, and .84 for reports that averaged across several reactions dimensions. We did not correct the declarative or procedural knowledge effect sizes for attenuation due to the lack of available test–retest or alternate forms reliability coefficients. Finally, 95% confidence intervals were calculated around the weighted mean *d*s. Confidence intervals assess the accuracy of the estimate of the mean effect size and provide an estimate of the extent to which sampling error remains in the weighted mean effect size (Whitener, 1990).

Outlier Analyses

We computed Huffcutt and Arthur's (1995) sample-adjusted meta-analytic deviancy (SAMD) statistic to identify outliers. This procedure identified one declarative knowledge outlier reported by Vessell (2000). Students in CI accessed course material that was intended to be exclusively utilized by students in WBI-S, providing students in CI with a competitive advantage and resulting in CI outperforming WBI-S. The associated SAMD value of 10.8 was more than twice the value of the next data point. In addition, one reaction outlier reported by Stadtlander (1998) was identified in which students in WBI encountered extensive technical difficulties, resulting in students being more satisfied with CI than WBI. The associated SAMD value of 10.8 was more than twice the value of the next data point. All of the analyses were run with and without the outliers. The results of the two sets of analyses were virtually identical. Thus, only the results with outliers removed are included in the present report.[2]

Moderator Analyses

Hedges and Olkin's (1985) homogeneity analysis was used to determine whether the effect sizes were consistent across studies. For main effect analyses, the set of effect sizes was tested for homogeneity with the Q_T statistic. Q_T has an approximate χ^2 distribution with $k - 1$ degrees of freedom, where k is the number of effect sizes. If Q_T exceeds the critical value, then the null hypothesis of homogeneity is rejected. Rejection indicates there is more variability in effect sizes than expected by chance fluctuations, identifying the potential for moderators.

The goal of the moderator analysis was to focus exclusively on studies that were consistent in their operationalization of WBI and CI. Oswald and McCloy (2003) recommended narrowing the set of studies included

[2]Results with outliers included in the analyses are available upon request from the first author.

in meta-analyses to a subset of studies that are theoretically and rationally similar to each other. We eliminated WBI-S studies, reducing the analysis sample but increasing the interpretability of the results. In addition, only a few studies examined the effectiveness of WBI relative to CI for teaching procedural knowledge and for training reactions. Thus, insufficient data were available to examine moderators of the relative effectiveness of the delivery media for these two criteria, and the moderator analyses will focus exclusively on the relative effectiveness of WBI and CI for teaching declarative knowledge.

For investigations of learner control and human interaction, we held characteristics of CI constant. We focused our learner control moderator analysis on classroom courses low in learner control. Only four reports were based on CI that was high in learner control, and we eliminated these studies from the learner control analysis to increase the interpretability of the results. This allowed us to compare effect sizes between WBI low in learner control to WBI high in learner control. All of the classroom courses were high in human interaction, allowing us to compare effect sizes between WBI low and high in human interaction.

In the training length moderator analyses, we focused on studies where the number of days spent in training was the same for WBI and CI (eliminating four studies). This allowed us to examine the effect of varying course length on the relative effectiveness of WBI and CI. For practice and feedback, we utilized information from WBI and CI in the moderator analyses. Thus, we will report results for four moderator categories: WBI high and low by CI high and low for these two moderator variables.

The moderating effects of categorical variables were tested by classifying studies according to the moderator categories and testing for homogeneity between and within categories (Lipsey & Wilson, 2001). For each categorical moderator, a between-class goodness-of-fit statistic, Q_{B}, was calculated to test for homogeneity of effect sizes across moderator categories. It has an approximate χ^2 distribution with $p - 1$ degrees of freedom, where p is the number of moderator categories. If Q_{B} exceeds the critical value, it indicates there is a significant difference across moderator categories and is analogous to a significant main effect in analysis of variance. In addition, a within-class goodness-of-fit statistic, Q_{w}, was calculated to test for homogeneity of effect sizes within each moderator category. It has an approximate χ^2 distribution with $m - 1$ degrees of freedom, where m is the number of effect sizes across all of the moderator categories. If Q_{w} exceeds the critical value, it indicates the effect sizes within the moderator categories are heterogeneous.

The moderating effects of age and population were tested with a sample size weighted hierarchical regression analysis. The mean ages of the

Web and classroom training groups were entered in Step 1 and the population (student vs. employee) was entered in Step 2 in order to predict the declarative knowledge effect sizes across research reports. Finally, the moderating effect of length of training was tested with a sample size weighted correlation between the moderator variable and the effect sizes.

Results

Ninety-six research reports contributed data to this meta-analysis, including 65 published studies, 18 dissertations, and 13 unpublished studies. These studies reported data gathered from 19,331 trainees who took part in 168 courses. The topic of the training courses varied greatly and included psychology, engineering, computer programming, business, and technical writing courses. In 67% of research reports, the trainees were undergraduates, and trainees were graduate students (18% of courses) or employees (15% of courses) in the remaining studies. Across all studies providing demographic information, the average age of participants was 24 years and 41% of the participants were men.

Relative Effectiveness of WBI and WBI-S

The first and second hypotheses predicted WBI would be more effective than CI for teaching declarative and procedural knowledge. As shown in Table 1, across all studies, the declarative knowledge effect size was .15 indicating that, on an average, WBI was 6% more effective than CI for teaching declarative knowledge. Moreover, the confidence interval for declarative knowledge excluded zero, supporting Hypothesis 1. The WBI procedural knowledge effect size was near zero ($d = -.07$) and the confidence interval contained zero, suggesting WBI and CI were equally effective for teaching procedural knowledge and failing to support Hypothesis 2. Thus, across all studies, there is evidence that WBI was more effective than CI for teaching declarative knowledge but not for teaching procedural knowledge.

Hypothesis 3 predicted trainees would react more favorably toward WBI than CI. The mean corrected effect size was zero, suggesting trainees were equally satisfied with the two delivery media and failing to support Hypothesis 3.

The fourth and fifth hypotheses predicted WBI-S would be more effective than CI for teaching declarative and procedural knowledge. The WBI-S effect size was .34 for declarative knowledge and .52 for procedural knowledge, suggesting WBI-S was 13% more effective than CI for teaching declarative knowledge and 20% more effective than CI for teaching procedural knowledge. The 95% confidence intervals for both

TABLE 1

Meta-Analytic Results for Learning Outcomes and Reactions Comparing Web-Based Instruction and Web Supplements to Classroom Instruction

					95% Confidence Interval		
	d	Standard Error	*k*	*N*	Lower	Upper	Q_T
Declarative knowledge							
WBI vs. CI	.15	.02	71	10,910	.11	.19	267.49*
WBI-S vs. CI	.34	.03	33	6,799	.29	.39	135.26*
Procedural knowledge							
WBI vs. CI	−.07	.07	12	944	−.20	.06	61.15*
WBI-S vs. CI	.52	.09	6	507	.34	.70	23.33*
Reactions							
WBI vs. CI	.00	.05	22	2,580	−.09	.09	51.78*
WBI-S vs. CI	−.15	.06	11	1,769	−.26	−.05	119.67*

Notes. WBI = Web-based instruction; CI = classroom instruction; WBI-S = Web supplement to classroom instruction; *d* = inverse variance weighted mean effect size; *k* = number of effect sizes included in the analysis; *N* = sum of the sample sizes for each effect size included in the analysis; Q_T = homogeneity statistic.

*Indicates the Q_T value is statistically significant at the .05 level and the effect sizes are heterogeneous.

declarative and procedural knowledge excluded zero, supporting Hypotheses 4 and 5.

The sixth hypothesis predicted trainees would react more favorably toward WBI-S than CI. The mean corrected effect size for the WBI-S versus CI comparison was negative ($d = -.15$) and the 95% confidence interval excluded zero. Trainees reacted 6% more favorably toward CI than WBI-S, and the results were in the opposite direction of Hypothesis 6.

The Q_T statistic for all six effect sizes reported in Table 1 were statistically significant, suggesting there are potential moderators of the effectiveness of WBI and WBI-S relative to CI. Although we looked for main effects for each delivery media for reactions, declarative knowledge, and procedural knowledge, as stated above, the moderator analyses will focus exclusively on declarative knowledge comparing WBI to CI. Conducting focused analyses will allow us to draw stronger conclusions regarding moderators of the effectiveness of WBI relative to CI.

Moderator Analyses

The first research question addressed the moderating effect of the trainee population on declarative knowledge, after controlling for the age

of trainees. Sample size weighted hierarchical regression analysis was used to run the analysis. The mean ages of the Web and classroom training groups were entered in Step 1 and the population (student vs. employee) was entered in Step 2 to predict the declarative knowledge effect sizes across research reports. The mean ages of the WBI and CI groups accounted for a significant 44.2% of the variance. In addition, both beta-weights were significant, and the WBI beta-weight was positive and the CI beta-weight was negative (beta-weights = .47 and −.58, respectively; $p < .05$). Thus, the extent to which Web-based trainees learned more than classroom trainees increased as the age of the Web-based trainees increased and the age of the classroom trainees decreased. It is important to note that the average age was 29 years for WBI and 24 years for CI, and ages ranged from 20 to 46 years for both groups. Finally, trainee population accounted for a nonsignificant .5% of the variance in declarative knowledge effect sizes after controlling for the age of trainees. Thus, the effectiveness of WBI relative to CI did not differ for student and employee samples, after controlling for the age of trainees.[3]

Table 2 shows mean effect sizes and estimates of homogeneity within moderator subgroups (Q_B) for the subgroup moderator analyses. A significant Q_B indicates the mean effect sizes across categories of the moderator variable differ by more than sampling error, indicating the moderator variable is having an effect (Lipsey & Wilson, 2001). The Q_B statistic was significant for all of the categorical moderators (i.e., similarity of instructional methods, experimental design, learner control, practice, and feedback) except human interaction.

Experimental characteristics. The seventh hypothesis predicted WBI and CI would be equally effective for teaching declarative knowledge when the instructional methods were the same across delivery media. The declarative knowledge effect size was near zero when the same instructional methods were used to deliver WBI and CI ($d = .04$), supporting Hypothesis 7. However, WBI was 11% more effective than CI for teaching declarative knowledge when different instructional methods were used to deliver the two courses ($d = .29$). This pattern of results supported Clark's (1983, 1994) theory that instructional methods rather than delivery media determine whether students learn during training.

The eighth hypothesis predicted WBI and CI would be equally effective for teaching declarative knowledge when trainees were randomly assigned

[3]We also ran our age–population hierarchical moderator analysis with population entered in the equation first and age entered in the equation second. Population did not account for a significant portion of the variance in the effectiveness of WBI relative to CI, even when it was entered in the equation before age. Thus, we can be confident that age rather than population is moderating the effectiveness of WBI relative to CI.

TABLE 2

Meta-Analytic Moderator Results Comparing the Acquisition of Declarative Knowledge From Web-Based Instruction Relative to Classroom Instruction

					95% Confidence interval		Homogeneity of effect sizes	
	d	Standard error	k	N	Lower	Upper	Q_B	Q_w
Instructional methods								
Same	.04	.05	16	2,032	−.06	.13	17.43*	215.12*
Different	.29	.04	37	3,689	.22	.37		
Experimental design								
Experimental	−.26	.09	11	529	−.43	−.08	22.96*	244.53*
Quasi-experimental	.18	.02	60	10,381	.13	.22		
Learner control								
WBI low, CI low	.07	.04	31	2,721	−.01	.15	15.13*	227.07*
WBI high, CI low	.30	.04	25	3,304	.22	.38		
Human interaction								
WBI low, CI low	.19	.05	19	1,719	.09	.29	.00	242.33*
WBI high, CI low	.18	.03	38	4,508	.12	.25		
Practice								
WBI yes, CI yes	.16	.03	41	4,163	.10	.23	12.42*	173.47*
WBI yes, CI no	.31	.06	10	1,527	.20	.42		
WBI no, CI yes	−.27	.36	1	31	−.98	.44		
WBI no, CI no	−.25	.19	2	116	−.63	.12		
Feedback								
WBI yes, CI yes	.16	.04	33	3,333	.08	.24	10.80*	152.53*
WBI yes, CI no	.33	.06	11	1,540	.22	.44		
WBI no, CI yes	−.27	.36	1	31	−.98	.44		
WBI no, CI no	.08	.07	9	933	−.05	.22		

Notes. WBI = Web-based instruction; CI = classroom instruction; d = inverse variance weighted mean effect size; k = number of effect sizes included in the analysis; N = sum of the sample sizes for each effect size included in the analysis; Q_B = between-class goodness-of-fit statistic; Q_w = within-class goodness-of-fit statistic.

*Indicates the Q value is statistically significant at the .05 level.

to courses. Although we found a positive mean effect size for declarative knowledge in quasi-experimental studies (d = .18), CI was 10% more effective than WBI for teaching declarative knowledge when trainees were randomly assigned to courses (d = −.26), failing to support Hypothesis 8. More importantly, the positive effects for WBI were reversed when only experimental designs were considered.

Training design characteristics. The second research question addressed the effect of learner control on the acquisition of declarative knowledge from WBI relative to CI. Note that the level of learner control was low in all of the classroom courses, allowing us to examine the effect of varying levels of learner control in WBI on training outcomes.

The results indicated that the level of learner control moderated the acquisition of declarative knowledge from WBI relative to CI. The extent to which Web-based trainees learned more than classroom trainees was greater when they were afforded a high ($d = .30$) than a low level of control ($d = .07$) during WBI.

Hypothesis 9 predicted, relative to CI, trainees would learn more with a high than a low level of human interaction in WBI. The level of human interaction was high in all of the classroom courses, allowing us to examine the effect of varying levels of human interaction in WBI on declarative knowledge effect sizes. Relative to CI, trainees learned the same amount with a low ($d = .19$) and a high ($d = .18$) level of human interaction in WBI, failing to support Hypothesis 9.

The tenth hypothesis predicted classes that provided practice would be more effective than classes that failed to provide practice. The effect size was largest when WBI but not CI included practice ($d = .31$), indicating WBI was 12% more effective than CI for teaching declarative knowledge. WBI was also more effective than CI when both delivery media incorporated practice ($d = .16$) but was less effective than CI when WBI failed to incorporate practice during training ($d = -.27$ when CI included practice, and $-.25$ when CI did not include practice). It is important to note that only one or two effect sizes were included in the analyses where WBI did not include practice. Overall the results suggest practice is beneficial in both WBI and CI, supporting Hypothesis 10.

Hypothesis 11 predicted feedback would moderate the relative effectiveness of WBI and CI, and classes that provided feedback would be more effective than classes that failed to provide feedback during training. The effect size was largest when WBI but not CI included feedback ($d = .33$) followed by the effect size where both WBI and CI provided feedback ($d = .16$). In both of these instances, WBI was more effective than CI for teaching declarative knowledge. In addition, the effect size approached zero ($d = .08$) when neither WBI nor CI provided feedback to trainees. Thus, the results indicate feedback is beneficial during both WBI and CI, supporting Hypothesis 11.

The third research question addressed the effect of length of training on learning from WBI relative to CI. Note that in each research report included in the analysis, the number of instructional days was the same for WBI and CI. A sample size weighted correlation was used to assess the effect of the number of days of training on learning from WBI relative to CI. The number of days of training was positively and significantly correlated with the declarative knowledge effect sizes (weighted $r = .33$; $p < .05$), indicating Web-based trainees gained more declarative knowledge relative to CI as the length of the class increased.

TABLE 3
Correlation Among Web-Based Training Moderator Variables

		1	2	3	4	5	6	7
1	Experimental design							
2	Similarity of instructional methods	−.24						
3	Learner control	−.10	.17					
4	Practice	.08	.19	.22				
5	Feedback	.21	.17	.15	.48*			
6	Population	−.19	−.23	−.15	−.46*	−.07		
7	Age of Web-based trainees	−.37*	.07	−.14	−.07	.01	.39*	

Experimental design: *quasi-experimental* = 1, *experimental* = 0; Similarity of instructional methods: *different* = 1, *similar* = 0; Learner control: *high* = 1, *low* = 0; Practice: 1 = *yes*, 0 = *no*; Feedback: 1 = *yes*, 0 = *no*; Population: *employees* = 1, *college students* = 0. *indicates the correlation is statistically significant at the .05 level.

Overall the moderator results indicated that six of eight moderators had an effect on the acquisition of declarative knowledge from WBI relative to CI (the exceptions are human interaction and the population). However, for all of the declarative knowledge categorical moderator results, the Q_w was significant, indicating there was more variation within the moderator categories than would be expected by subject-level sampling error alone (Lipsey & Wilson, 2001). That is, none of the moderator variables independently accounted for all of the variability in declarative knowledge effect sizes across studies.

Correlation among moderator variables. A limitation of the subgroup approach for examining moderators is that it is restricted to testing individual hypotheses and does not control for possible confounds between correlated moderators (Hedges & Olkin, 1985; Miller, Glick, Wang, & Huber, 1991). To address this concern, we tested the correlation among the Web-based training moderator variables (see Table 3). This allowed us to asses the extent to which the moderator variables overlap in their effects on learning from WBI relative to CI. Seventeen of 21 correlations among the moderators were less than .25 and were not statistically significant, suggesting little overlap. However, four correlations were greater than .35 and statistically significant: courses that incorporated practice also tended to provide feedback to trainees ($r = .48$; $p < .05$), college students were more likely to receive the opportunity to practice during training than employees ($r = -.46$; $p < .05$), employees tended to be older than college students ($r = .39$; $p < .05$), and older Web-based trainees were more likely to participate in an experimental design and younger Web-based trainees were more likely to participate in a quasi-experimental design ($r = -.37$;

$p < .05$). Accordingly, it is possible that some observed moderating effects may have multiple determinants.

Discussion

Meta-analytic procedures were used to examine the training outcomes of WBI and WBI-S compared to CI. More specifically, we examined the relative effectiveness of these media for teaching declarative and procedural knowledge and for training reactions. Additional analyses examined experimental and training context variables that moderate the effects of WBI relative to CI on the acquisition of declarative knowledge. We will discuss both practical and theoretical implications of our results, as well as limitations of the study and directions for future research.

Across all studies, the results indicated WBI was 6% more effective than CI for teaching declarative knowledge. These results were based on 71 effect sizes and 10,910 learners. WBI and CI were equally effective for teaching procedural knowledge and trainees were equally satisfied with the two delivery media.

The results differed when we examined instances of blended learning—WBI used to supplement face-to-face instruction (WBI-S). Across all studies, the results indicated that WBI-S was more effective than stand-alone CI for teaching trainees job-relevant knowledge and skills. WBI-S was 13% more effective than CI for teaching declarative knowledge and 20% more effective than CI for teaching procedural knowledge. Similar meta-analytic findings were reported by Zhao et al. (2005), who found "mixed method" or blended distance courses result in better outcomes than distance education or face-to-face instruction alone. WBI-S optimizes the instructional advantages of both WBI and CI and meets the training requirements of individual learners by employing multiple delivery media (Dennis, 2002; Pratt, 2002). The instructional advantage of WBI-S may be due to incorporating both the benefits of personal interaction typically found in CI and self-study between instructional meetings using the Web (Kerres & deWitt, 2003; Masie, 2002). Note, however, that trainees reacted 6% more favorably towards stand-alone CI than WBI-S. Although converting to WBI-S from CI may improve learning, there may be a tradeoff in terms of trainee satisfaction. Additional research is needed to investigate the underlying course characteristics that are driving this effect. It is possible that blended learning courses are more demanding and require a greater time commitment than CI due to incorporating both WBI and CI components. The added time commitment may be frustrating for students, decreasing satisfaction but increasing the likelihood that trainees will master the material by the end of training. However, this is conjecture and should be tested empirically.

Theoretical Implications

Advocates of WBI or technology-assisted instruction cite numerous potential pedagogical benefits including the use of multimedia, learner customization, and opportunities for guided learning (Bailey & Cotlar, 1994; Dumont, 1996; Hiltz & Wellman, 1997; Liaw, 2001; Sullivan, 2001). However, other theorists argue that there is nothing uniquely advantageous to any delivery medium; hence, we should expect no effects in well-designed media comparison studies. This position is summarized by Clark (1983) who wrote that media are "mere vehicles used to deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes change in our nutrition" (p. 445). Thus, a secondary purpose of our study was to capitalize on the large number of studies analyzed and unique coding methods to investigate the veracity of Clark's frequently cited position.

Our results support Clark's position that media effects in single study research are largely spurious. We first note that across all studies, we found relatively small differences between WBI and CI on both measures of declarative and procedural knowledge (although confidence intervals for the former outcome excluded zero). More importantly, we were able to examine the effect of the research design on study outcomes for declarative knowledge. We found that when trainees were randomly assigned to delivery media, CI was more effective than WBI for teaching declarative knowledge ($d = -.26$). However, this result is in the opposite direction of the effect sizes for WBI relative to CI across all studies ($d = .15$) and across studies using a quasi-experimental design ($d = .18$). Thus, consistent with Clark's arguments (1983, 1994; Clark & Sugrue, 1995), studies are more likely to provide support for WBI when research participants are allowed to self-select into courses.

The similarity of instructional methods moderator results added additional support for Clark's position. Clark argued that media comparison studies have confounded delivery media with instructional methods, making it impossible to detect the true cause of differences in course effectiveness. In this meta-analysis, WBI and CI were equally effective for teaching declarative knowledge when similar instructional methods were used to deliver the two courses, supporting Clark's position. This suggests that unique instructional methods or learning conditions are driving observed differences in the effectiveness of WBI relative to CI. In addition, WBI was on average 11% more effective than CI for teaching declarative knowledge when different instructional methods were used to deliver the two courses.

A qualitative analysis of research reports identified two characteristics of research reports where different instructional methods were used and

trainees learned more from WBI than CI. First, the Internet courses tended to incorporate more instructional methods than CI. Thus, trainees who were having difficulty mastering the training content could utilize multiple instructional methods when reviewing the material to increase the likelihood of mastering the course content. Second, the Internet courses tended to require students to be more active than CI. This is consistent with Webster and Hackley's (1997) guidelines for teaching in distance learning, "learning is best accomplished through the active involvement of the students" (p. 1284). Spending time practicing the key task components of training should help trainees develop an understanding of the deeper, structural features of the task (Newell, Rosenbloom, & Laird, 1989). Frequent practice should also increase the likelihood that trainees will automate skills by the end of training, leading to better performance at the end of training (Rogers, Maurer, Salas, & Fisk, 1997). Thus, it is critical that CI requires trainees to be as active as they are in WBI and incorporates as many instructional methods as WBI in order to promote similar learning outcomes between the two delivery media.

Together, our findings and observations suggest that instructional methods are more important than delivery media for ensuring effective learning. Practical implications of study findings will be addressed in the following section.

Practical Implications

The present meta-analytic results have several direct implications for organizations and institutions considering implementing WBI. Advocates of WBI (e.g., Galagan, 2001; Goodridge, 2001; Hall, 1997) suggest that it can be a more cost-effective means of training than face-to-face instruction, although well-controlled studies documenting the cost effectiveness or utility of WBI are rare (Welsh et al., 2003). Assuming that over time WBI is less expensive than CI, even findings that show no mean differences between WBI and CI training outcomes provide support for implementing online instruction. The results we report can be used in conjunction with accurate estimates of the cost of implementing and maintaining online instructional programs to estimate the utility (see Mathieu & Leonard, 1987) of converting CI to WBI.

The results also indicate care should be taken whenever organizations and institutions consider implementing WBI as the relative effectiveness of training may depend on both the intended learning outcomes and the training conditions. Given that WBI is at least as effective as CI for teaching job-relevant knowledge and skills, the present results can be used

by organizations and universities to justify the expenditures necessary to develop online instruction. However, caution is warranted when considering completely replacing CI with WBI. Researchers are beginning to understand that CI and WBI create very different learning environments (Arbaugh, 2005; Dumont, 1996; LaRose & Whitten, 2000). Thus, care should be taken to prevent trainees from being forced into online courses, which could ultimately result in some trainees failing to master course material. Accordingly, the moderator analyses we conducted are helpful for understanding conditions that influence the effectiveness of WBI. Our results indicated that learners acquired relatively more declarative knowledge from WBI than CI when different instructional methods were used, courses were longer, learners were afforded more control during WBI, and when learners had the opportunity to practice and received feedback during WBI. We return to the issue of designing more effective Web-based courses below.

It is important to note that the positive effect size for declarative knowledge across all studies was reversed when trainees were randomly assigned to courses. There are several possible explanations for these findings. First, it is possible that trainees who are higher in motivation or cognitive ability are self-selecting into WBI when they are allowed to choose between Web and classroom versions of a course. Thus, preexisting differences between trainees who prefer WBI and trainees who prefer CI may result in the appearance that WBI is more effective than CI. Second, trainees who lack technical skills may be forced to participate in WBI when trainees are randomly assigned to courses. Providing technically inept trainees with a computer and Internet skills course prior to participating in WBI may result in the two delivery media being equally effective for teaching declarative knowledge. An experiment where half of the trainees are allowed to self-select into WBI and CI and the other half of trainees are randomly assigned to courses would allow researchers to disentangle differences in the effectiveness of the delivery media for teaching declarative knowledge.

Another important finding is the effectiveness of WBI relative to CI did not differ across student and employee samples, after controlling for the age of trainees. However, the age of trainees accounted for 44.2% of the variance in the relative effectiveness of the two delivery media. The extent to which Web-based trainees outperformed classroom trainees increased as the age of online trainees increased and the age of classroom trainees decreased. In addition, Web-based trainees, on an average, were 5 years older than classroom trainees. Research is needed to discover the underlying causal mechanism driving this effect. We will elaborate on this idea later in the Discussion section.

Designing More Effective Online Training Courses

This study investigated the effect of several course design characteristics on the effectiveness of WBI relative to CI. Across studies, the extent to which Web-based trainees learned more than classroom trainees was greatest when Web-based trainees were provided with control, when trainees practiced the training material, when trainees received feedback during training, and in long courses. Under these conditions, the declarative knowledge effect size was .49, suggesting WBI was 19% more effective than CI. In contrast, it is also possible to design Web-based courses in which learning levels will be inferior to CI. CI was 20% more effective than WBI for teaching declarative knowledge when WBI failed to provide control, practice, and feedback to learners and in short courses ($d = -.51$). Thus, attention to course design features is critical for maximizing learning outcomes.

As WBI may be a new experience for many trainees, longer training programs may give learners the opportunity to adapt to the technology and the control they are afforded in WBI (DeRouin, Fritzsche, & Salas, 2004). That is, trainees may adapt their learning strategies in these environments. One of the demonstrated advantages of WBI is the opportunity to develop collaborative learning communities (e.g., Alavi, Wheeler, & Valacich, 1995; Rovai, 2001), but it takes learners time to build and benefit from collaborative contexts (Duffy & Kirkley, 2004; Garrison, 2003). Accordingly, it would be interesting to test inexperienced participants at multiple occasions in a Web-based training course to determine whether they are using more adaptive learning strategies over time and how collaborative learning environments facilitate learning over time. In addition, more research is needed to understand the effects of cohort size, peer-to-peer interactions, and synchronous versus asynchronous communication on the effectiveness of WBI.

We also found a moderating effect for learner control on declarative knowledge effect sizes. Compared to classroom learners, participants in WBI learned more when given a high level of learner control. This outcome is consistent with a recent finding of Kraiger and Jerden (in press) who reported that positive effects for learner control are more likely to be found in recent studies than older studies. This trend toward more support for learner control manipulations in recent research (such as those reviewed here) suggests that there may be characteristics of the modern learning environment or modern learner that interact with the provision of learner control. More research is needed to isolate and understand these effects.

Learner control may be provided along a number of dimensions such as content, sequence, or pace, and research has suggested that various dimensions of learner control may differ in their effects on learning from

WBI (Lunts, 1997). Due to limited descriptions of training courses in many research reports, we were unable to distinguish among the learner control dimensions in our coding. Thus, future primary research should provide more detailed descriptions of training courses to allow more precise coding and evaluation of learner control in future meta-analyses. More research is also needed to understand which specific learner control options online learners prefer and which facilitate learning.

Contrary to our hypothesis, our meta-analysis found human interaction did not affect learning from WBI relative to CI. However, there were not sufficient studies to examine differences among various forms of communication typically found in WBI (e.g., discussion boards, chat rooms, and e-mail); hence, we were unable to determine whether various forms of communication differ in their effects on learning. Although we could not investigate the specific communication channel, we coded the percent of communication that was synchronous (i.e., 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, & 4 = 76–100%) in each research report. After controlling for the level of human interaction, synchronous communication accounted for an additional 3.5% of the variance in the declarative knowledge effect sizes, and the beta-weight was positive suggesting synchronous communication facilitates learning more than asynchronous communication in WBI. Additional primary research is needed to clarify whether specific forms of synchronous and asynchronous communication differ in their effects on learning outcomes.

Comparison to Previous Technology-Assisted Instruction Meta-analyses

It is worth noting that the overall positive effect size for WBI compared to CI is smaller than those reported in meta-analyses of other types of technology-assisted instruction (Fletcher, 1990; Kulik, 1994; Kulik & Kulik, 1991; Liao, 1999; Yaakub, 1998), although similar to those in a recent meta-analysis of distance education (Zhao et al., 2005). There are several possible explanations for this. In contrast to previous meta-analyses, ours used an adult population learning work-related knowledge and skills, whereas others incorporated a wider age range of subjects and had a heavier reliance on the acquisition of declarative knowledge. In addition, WBI is a relatively new training platform, and as such, its overall effectiveness may be compromised by several nonpermanent conditions. For example, in many studies, there may have been insufficient bandwidth to optimize training delivery, or trainees may have lacked the technical skills needed to access the instructional content (Welsh et al., 2003). Over time, instructional designers may make more informed decisions about how to structure Web-based environments to ensure greater learning. Accordingly, our

study results are valuable in that they identify variables that influence the effectiveness of WBI.

In addition, our meta-analysis contained more published and unpublished studies than prior meta-analyses of technology-assisted instruction. It is possible that previous meta-analytic results reflect a publication bias or other sampling problems not evident in the larger number of studies we were able to locate and code. Regardless, as WBI, blended learning, videodiscs, and single-work station computer-based training are each options for training delivery, other researchers may want to explore possible differences in the relative effectiveness of various types of technology-assisted instruction.

Study Limitations and Additional Directions for Future Research

Although we would have preferred to investigate the effectiveness of WBI relative to CI based on three categories of learning outcomes, we were able to identify only 12 studies that assessed procedural knowledge and even fewer studies that assessed affective learning. In the latter case, there was an insufficient number of studies to determine an overall effect size, and in the former case, there was an insufficient number of studies to examine potential moderators. Thus, we could not determine whether online learning is more or less effective for affective outcomes than the overall effect sizes reported for declarative and procedural knowledge. This is not merely an academic question; an increasing number of organizations are implementing WBI for diversity and sexual harassment training. Often times changing participants' attitudes toward groups of employees is the desired outcome of these programs. Yet, little is known about the effectiveness of WBI in this regard. It is also possible that the size or direction of the moderating effects we found for declarative knowledge might differ if the learning outcome was procedural knowledge. Additional primary research is needed to examine the effectiveness of WBI for conveying affective and procedural knowledge.

It is also important to note that (a) we found different results depending on whether we isolated quasi-experimental designs or true experimental designs, and (b) there were only 11 studies that used random assignment of subjects to conditions. Accordingly, there were too few experimental studies to replicate other moderator analyses within this set (e.g., does using similar instructional methods matter if all subjects are randomly assigned to training condition?). In future studies, it is important to examine the impact of moderators of WBI effectiveness when participants can and cannot self-select into courses.

Another limitation is only 25 courses were identified that examined the effectiveness of WBI relative to CI for employee training programs.

Although the population did not moderate the relative effectiveness of the two delivery media after controlling for age, additional research should be conducted on the utility of WBI for delivering training for working adults.

The present results also suggest there are moderators of the effectiveness of WBI that were not identified in this study. We believe that trainees' previous experience with computers and the Internet may be one of the best predictors of learning from the Web. In this study, we attempted to code for this, but there was often a lot of variability among trainees within a single course and few studies provided sufficient detail to code for this moderator. Despite this limitation, computer experience accounted for 3.3% of the variance in the declarative knowledge effect size. In addition, the beta-weight was positive, indicating more experienced trainees learned more from the Web. Another potential moderator may be the quality of the training course. We also attempted to code for course quality, but again, many of the articles lacked sufficient details. This is another area where more detailed descriptions of the training courses and participants would advance meta-analytic research. Additional research is needed to examine the impact of these moderator variables on the effectiveness of WBI.

Research is also needed to assess why trainees aged 23–45 tended to learn more declarative knowledge from WBI than CI but trainees ages 18–22 tended to learn more declarative knowledge from CI than WBI. It is possible that, in accordance with andragogical learning theories (Knowles, 1984), slightly older trainees are more adept at dealing with the autonomy and learner control provided by WBI but younger trainees are more successful in a structured classroom environment. Graham (1991) compared attitudes toward tasks related to school, motivation, and anxiety levels of traditional and nontraditional aged college students (mean ages 19 vs. 34). She found nontraditional students had more positive attitudes, were more motivated, and experienced less anxiety than traditional students. In addition, Tallent-Runnels et al. (2006) reviewed the literature on WBI and concluded older trainees in WBI are more focused on achieving specific learning outcomes than younger trainees. Additional research is needed to assess if training attitudes, motivation, anxiety, or other factors are the underlying causal mechanisms driving differences in the effectiveness of WBI and CI for older and younger trainees.

Finally, research is needed to better understand the effect of course design characteristics and process variables on the effectiveness of WBI and the cost effectiveness of WBI. Do the dimensions of learner control—content, sequence, and pace—differ in their effects on learning from WBI? Do various forms of synchronous and asynchronous communication have differential effects on learning from WBI? Is there an optimal group size for facilitating online peer-to-peer interaction in WBI? Do trainees acquire more adaptive learning strategies over time in Web-based training courses?

Research is also needed to determine why CI is more effective than WBI when trainees are randomly assigned to delivery media. Is the underlying mechanism driving this effect student motivation, cognitive ability, a lack of technical skills, or another causal mechanism? Empirical data are also needed to evaluate the cost effectiveness of WBI. Is WBI more or less cost effective than other delivery media? What learning effect sizes are necessary to offset the developmental costs of implementing WBI? How does the utility of WBI change over time as (a) costs move from implementation to maintenance, (b) training designers learn how to better delivery training online, and (c) learners adjust to learning in an online environment?

Conclusion

The current meta-analysis identified 96 studies reporting data from 19,331 trainees who took part in 168 training courses. Across all of these reports, CI was more effective than WBI for teaching declarative knowledge when trainees were randomly assigned to courses and trainees were equally satisfied with the two delivery media. However, trainees learned the same amount of declarative knowledge from WBI and CI when the same instructional methods were used to deliver training. Overall these results support Clark's (1983, 1994) argument that instructional methods rather than delivery media determine learning outcomes. In addition, designing long training courses and providing trainees with control, practice, and feedback during WBI will maximize learning declarative knowledge from WBI relative to CI.

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