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A Meta-Analysis of Three Types of Interaction Treatments in Distance Education

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This meta-analysis of the experimental literature of distance education (DE) compares different types of interaction treatments (ITs) with other DE instructional treatments. ITs are the instructional and/or media conditions designed into DE courses, which are intended to facilitate student–student (SS), student–teacher (ST), or student–content (SC) interactions. Seventy-four DE versus DE studies that contained at least one IT are included in the meta-analysis, which yield 74 achievement effects. The effect size valences are structured so that the IT or the stronger IT (i.e., in the case of two ITs) serve as the experimental condition and the other treatment, the control condition. Effects are categorized as SS, ST, or SC. After adjustment for methodological quality, the overall weighted average effect size for achievement is 0.38 and is heterogeneous. Overall, the results support the importance of the three types of ITs and strength of ITs is found to be associated with increasing achievement outcomes. A strong association is found between strength and achievement for asynchronous DE courses compared to courses containing mediated synchronous or face-to-face interaction. The results are interpreted in terms of increased cognitive engagement that is presumed to be promoted by strengthening ITs in DE courses.

Keywords: distance education, meta-analysis, student interaction, interaction treatment.

Introduction

Review of DE Research

There have been many discussions of how distance education (DE) is similar to and different from face-to-face forms of educational experience. It is not surprising that the distance that separates the activities of teaching and learning, as well as the media that are required to bridge that gap, are among the most commonly cited. Before the dawn of the electronic and then the digital revolutions, it was the postal service that provided the mediating role. It is no wonder that DE (then called "correspondence education") was considered to be a slow and, by some, a second-rate way of educating and being educated (e.g., Thompson, 1990). This type of education started to change in the 1980s as access to digital media provided communication functionality, facilitating more immediate contact between students and instructors. In the 1990s, the Internet and high-speed access began to affect DE courses, bringing them closer to the mainstream of educational practice (Peters, 2003), so that today, applications of online and Web-based DE abound. Evidence of the widespread application of DE includes the rise in dedicated virtual high schools and level of choice between DE and classroom instruction (CI) that many universities now offer their students.

Much of the research from the 1980s onward focused on establishing the comparative equivalence of DE and face-to-face instruction. Bernard, Abrami, Lou, Borokhovski, Wade, et al. (2004) explained this phenomenon:

> It is arguably the case that these comparisons are necessary for policymakers, designers, researchers, and adopters to be certain of the relative value of innovation. Questions about relative effectiveness are important, both in the early stages of development and as a field matures, to summarize the nature and extent of the impact on important outcomes, giving credibility to change and helping to focus it. (pp. 379–380)

In 1999, Thomas L. Russell declared, based on a collection of 355 comparative studies, that DE and CI were not significantly different from one another in terms of achievement and satisfaction. Bernard, Abrami, Lou, Borokhovski, Wade, et al. (2004) criticized his nonsystematic vote count methodology, but he is not alone in the quest to determine the comparative effectiveness of DE and CI.

Since the year 2000, a small cottage industry has emerged in the DE research community, in which meta-analysis is used as an analytical tool to synthesize the comparative literature of CI and DE (otherwise referred to as online learning, Web-based learning, networked learning, etc.; Allen, Bourhis, Burrell, & Mabry, 2002; Allen et al., 2004; Bernard, Abrami, Lou, Borokhovski, Wade, et al., 2004; Cavanaugh, 2001; Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004; Jahng, Krug, & Zhang, 2007; Lou, Bernard, & Abrami, 2006; Machtmes & Asher, 2000; Shachar & Neumann, 2003; Sitzmann, Kraiger, Stewart, & Wisher, 2006; Williams, 2006; Ungerleider & Burns, 2003; Zhao, Lei, Yan, Lai, & Tan, 2005).

In previous meta-analysis, Bernard, Abrami, Lou, Borokhovski, Wade, et al. (2004) examined 232 studies (yielding 699 independent effect sizes) dated from 1985 to 2002, in which DE was compared to CI on measures of achievement, attitudes, and course completion. They separated studies into asynchronous (i.e., mostly correspondence and online courses) and synchronous DE (i.e., mostly teleconferencing and satellite-based delivery) and found different results for the two patterns across the three classes of measures, although asynchronous studies were not compared directly with synchronous studies. Table 1 is a summary of these results. Asynchronous DE courses were more positive than CI courses in terms of achievement and attitudes than synchronous DE courses versus CI courses but had a bigger problem with course completion.

So generally speaking, what have we learned from all of this synthesis activity and the primary research efforts that preceded it?

TABLE 1
Summary of average effect sizes for Bernard, Abrami, Lou, Borokhovski, Wade, et al. (2004)

Distance education pattern	Outcome measures		
	Achievement	Attitudes	Course completion rate
Asynchronous	$g+ = 0.05$ ($k = 174$)*	$g+ = -0.00$ ($k = 71$)	$g+ = -0.09$* ($k = 53$)
Synchronous	$g+ = -0.10$ ($k = 92$)*	$g+ = -0.19$ ($k = 83$)*	$g+ = 0.01$ ($k = 17$)

Note. All means were significantly heterogeneous except for Synchronous Course Completion.
*$p < .05$.

1. We have learned that DE can be much better and also much worse than CI (i.e., wide variability in effect sizes) based on measured educational outcomes and that some pedagogical features of DE design are related to increased student achievement.
2. We have learned from Phipps and Merisotis (1999) and Bernard, Abrami, Lou, and Borokhovski (2004) that the research methodologies typically used to assess this phenomenon are woefully inadequate and poorly reported. Fundamental confounds associated with different media, different pedagogies, different learning environments, and so forth, mean that causal inferences about the conditions of design, pedagogy, and technology use are nearly impossible to make with any certainty.
3. We have learned that the very nature of the question (How does DE compare to CI?) impedes our ability to discover what makes DE effective or ineffective, because the question is cast as a contrast between such starkly different forms for achieving the same end. For example, in DE versus CI studies, delivery method is often confounded with instructional design, in which the DE condition has instructional design features not present in the classroom control condition and vice versa. This does not mean that we know nothing about designing good DE; it is just that we have not learned it from classroom-comparison reviews.

Comparisons of DE versus DE should provide a better way of examining the effects of various instructional treatments. Ideally, a review of this type should include studies in which instructional and other treatments are administered on a roughly equal footing so that confounding problems, so easily identifiable in DE versus CI comparative studies, are reduced. Clark (2000) argued this point by saying, “All evaluations [of DE] should explicitly investigate the relative benefits of two different but compatible types of DE technologies found in every DE program” (p. 4).

Although timely and potentially revealing, technical aspects of a between-DE quantitative synthesis are not as straightforward as DE versus CI meta-analyses, in which the control condition (the CI group) can be identified unambiguously.

With a wide range of treatments being compared, there is often no obvious control condition; therefore, the +/0/– valence of the effect size is in doubt. When the control condition is clearly identifiable, positive (+) effects indicate that the treatment has outperformed the control and negative (–) effects indicate that the control has outperformed the treatment. Part of our work in completing the current meta-analysis has been to establish a rational and revealing way of determining the +/0/– valence of each calculated effect size. This meta-analysis is an examination of the literature of empirical studies in which different instructional treatments are contrasted. We hope that this review will further our understanding, not of whether DE is effective compared to its alternatives, but specifically how the design and implementation of DE can be optimized to improve student learning and satisfaction.

Interaction in DE

We searched the theoretical literature of DE for constructs that would, first, broadly encompass a large number of studies and, second, provide relevant contrasts to determine the valence of the effect sizes. Although there are many interesting perspectives, three emerged as potentially useful dimensions for enabling comparisons between treatment conditions: (a) student interaction in DE (e.g., Moore, 1989); (b) student autonomy (Daniel & Marquis, 1979; Moore, 1973; Moore & Kearsley, 2005); and (c) technological functionality (Moore & Kearsley, 2005).

Given its alleged importance in DE and previous findings by Lou et al. (2006) about its predictive qualities in connection with achievement, we chose student interaction as the basis for effect size coding and as the structure within which analyses would be conducted and results interpreted.

The DE literature is largely univocal about the importance of interaction (Anderson, 2003a, 2003b; Bates, 1990; Daniel & Marquis, 1979, 1988; Fulford & Zhang, 1993; Jaspers, 1991; Juler, 1990; Laurillard, 1997; Lou et al., 2006; Moore, 1989; Muirhead, 2001a, 2001b; Sims, 1999; Sutton, 2001; Wagner, 1994). This is because of the integral role that interaction between students, teachers, and content is presumed to play in all of formal education (e.g., Chickering & Gamson, 1987; Garrison & Shale, 1990) and because interaction was largely absent during so much of the early history of DE (Nipper, 1989).

Although interaction is not explicit in all definitions of DE (e.g., Keegan, 1996), it is an integral part of some. For example, The U.S. Distance Learning Association states, "distance education refers specifically to learning activities within a K–12, higher education, or professional continuing education environment where interaction is an integral component" (Holden & Westfall, 2006, p. 9).

Some of the original thinking about interaction in DE focused mainly on human–human interaction. Daniel and Marquis (1988) defined interaction "in a restrictive manner to cover only those activities where the student is in two-way contact with another person (or persons)" (p. 339). Later, Wagner's (1994) broader and somewhat more abstract and technical definition characterized interaction as "reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another" (p. 8). Thurmond and Wombach (2004) described the content-driven goal of interaction in DE as "the learner's engagement with the course content, other learners, the instructor, and the technological medium used in the course. . . . Ultimately, the goal of interaction is to increase understanding of the course content or mastery of the defined goals" (p. 4).

Some definitions of interaction (Beard & Harper, 2002; Crawford, 1999; Wagner, 1994) refer to the social purpose and processes of interaction, particularly in regard to student–student (SS) and student–teacher (ST) interaction. Gilbert and Moore (1989) distinguish between instructional interactivity and social interactivity, and Yacci (2000) acknowledges that the affective benefits of interactivity are less well understood than the content benefits but that there is evidence that interactions in an online classroom provide social presence and satisfaction. These social aspects probably would not register on measures of achievement but might on measures of attitude and course satisfaction.

Holden and Westfall (2006) and a number of other researchers make two additional points that are important in a discussion of interaction and DE. One is the difference that exists between asynchronous DE, mediated synchronous DE, and mixed DE (i.e., DE plus CI, also called blended and hybrid forms of DE). Mediated synchronous and blended DE contains natural conditions for interaction, especially between the student and teacher and often among students. Asynchronous DE may or may not contain capacities for text-based and/or voice-based and video-based synchronous communication (e.g., MSN, Skype), but these facilities must be built into the design of the technology applications available to students and teachers.

The second point made by Holden and Westfall (2006) distinguishes interaction that is asymmetrical from interaction that is symmetrical. Asymmetrical interaction, like reading a textbook or watching a videotaped lecture, is considered by Holden and Westfall to involve one-way communication. By contrast, symmetrical interaction is equally balanced between the parties involved, like having a telephone conversation, having an audio or video chat, or participating in an e-mail discussion forum. By this description, a face-to-face lecture and discussion is both synchronous and symmetrical, and listening to a taped lecture or discussion is asynchronous and asymmetrical. However, synchronous, asynchronous, and blended patterns often do contain elements of both symmetrical and asymmetrical interaction. Anderson (2003a) remarked that one-way mediated communication (e.g., instructor's recorded message) can sometimes supplant the need for two-way communication, often at lower cost, if information giving is the primary goal.

Types of Interaction

An interaction is commonly understood to describe actions among individuals but is extended here to include individual interactions with curricular content. Moore (1989) distinguished among three forms of interaction in DE: (a) SS interaction, (b) ST interaction, and (c) student–content (SC) interaction.

SS interaction refers to interaction among individual students or among students working in small groups (Moore, 1989). In correspondence courses, this interaction is often absent; in fact, correspondence students may not even be aware that other students are taking the same course. In later generations of DE, including two-way videoconferencing and Web-based courses, SS interaction can be synchronous, as in videoconferencing and chatting, or asynchronous, as in discussion boards or e-mail messaging. With DE becoming popular in mainstream education with on-campus students, SS interaction may also include face-to-face contact.

According to social theories of learning and distributed cognition (Salomon, 2000), SS interaction is desirable both for cognitive purposes and motivational support, and indeed, is at the heart of notions about constructivist learning environments in DE (e.g., Kanuka & Anderson, 1999).

Student–instructor interaction traditionally focused on classroom-based dialogue between students and the instructor. According to Moore (1989), during ST interaction, the instructor seeks "to stimulate or at least maintain the student's interest in what is to be taught, to motivate the student to learn, to enhance and maintain the learner's interest, including self-direction and self-motivation" (p. 2). In DE environments, student–instructor interaction may be synchronous through telephone calls, videoconferencing, and chats, or asynchronous through correspondence, e-mail, and discussion boards. Face-to-face interaction between student and instructors is also possible in some DE environments and when DE is blended with face-to-face classroom environments. According to Moore (1989; Moore & Kearsley, 2005) and several other DE theorists (e.g., Anderson, 2003b; Holmberg, 2003), ST interaction may be directed toward providing motivational and emotional support, activities that may register on attitude instruments more than measures of achievement.

SC interaction refers to students interacting with the subject matter under study to construct meaning, relate it to personal knowledge, and apply it to problem solving. Moore (1989) described SC interaction as "the process of intellectually interacting with the content that results in changes in the learner's understanding, the learner's perspective, or the cognitive structures of the learner's mind" (p. 2). Presumably, SC interaction also encompasses the development of mental and physical skills. SC interaction may include reading informational texts, using study guides, watching videos, interacting with computer-based multimedia, using simulations, or using cognitive support software (e.g., statistical software), as well as searching for information, completing assignments, and working on projects.

In discussing the continuing evolution and cross-fertilization of these seemingly distinct modes of interaction, Anderson (2003a) states, "due to increasing computational power . . . and storage capacity of computers . . . there is pressure and opportunity to transform ST and SS interaction into enhanced forms of student–content interaction" (p. 3). There is some question, though, as to how such progress would affect the traditional relationships and bonds that have come to be valued by students and teachers alike.

More recently, Anderson (2003a) expanded the three types of interaction in DE to include instructor–instructor interaction, instructor–content interaction, and content–content interaction. Although these interactions may be important in a larger DE context, they are not often reported in DE studies that focus on individual DE courses. Therefore, these interactions are beyond the scope of this research.

Strength of Interaction Treatments (ITs)

An important distinction lies between the actual behaviors constituting the three types of interaction, which for research purposes may be observed or measured, and the conditions or environments that are designed and arranged by teachers to encourage such behaviors. We refer to the latter as "interaction treatments" to distinguish them from the actual interaction behaviors that are intended to arise from them. The behaviors themselves are seldom described in research reports in sufficient depth or with sufficient precision to be studied in a systematic review. Because ITs represent the levels of the independent variable in most studies, they are usually described in detail and can be studied.

Moore (1989) encouraged distance educators to "organize programs to ensure maximum effectiveness of each type of interaction, and ensure they provide the type of interaction most suitable for various teaching tasks of different subject areas, and for learners at different stages of development" (p. 5). More recently, Anderson (2003a) has provided a slightly different and more nuanced take on the provision of interactivity in DE, referred to by him as an "equivalency theorem." Equivalency, he says, suggests that different combinations of ITs can be provided in different strengths and/or not at all to provide students with experiences that are essentially equivalent, resulting in similar educational outcomes. He argues that

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student–student; student–content) is at a high level. The other two may be offered at minimal levels, or even eliminated without degrading the educational experience. . . . High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these experiences may not be as cost or time effective as less interactive learning sequences. (p. 4)

Anderson (2003a) goes on to describe the combinations of instructional treatments and technologies that can promote each of the three forms of interaction, specifying among other things the levels (i.e., strength) of each type of interaction that can be expected to be present or developed in different DE patterns. We used his descriptions to validate our own procedures for rating the strength of interaction patterns present in each of the studies that we included in the meta-analysis.

Purpose of the Meta-Analysis

This meta-analysis examines evidence of the effects of three types of ITs in DE research studies in relation to achievement outcomes. Another purpose that evolved out of Anderson's (2003a) hypotheses is to investigate combinations of ITs to determine if there are differences in their potential to affect achievement. Finally, asynchronous forms of DE are examined independently. Not only were asynchronous DE studies the most common single pattern (compared to synchronous and mixed forms) but also asynchronous DE is judged to be the DE pattern most in need of special consideration for the provision of the three forms of interaction.

Research Questions

1. What are the effects of the three kinds of interaction (SS, ST, and SC) on achievement?
2. Does more overall IT strength promote better achievement?
3. Do increases in treatment strength of any of the three different forms of interaction result in better levels of achievement?
4. Which combinations of SS, ST, and SC interaction most affect achievement?
5. Are there differences among synchronous, asynchronous, and mixed forms of DE in terms of achievement?
6. What is the relationship between treatment strength and effect size for achievement outcomes in asynchronous only DE studies?

Method

Meta-Analysis

Unlike some systematic reviews that are purely exploratory, this meta-analysis is designed to examine specific questions related to the instructional conditions that affect student interaction in DE; students' interaction with other students, with teachers, and with the content they are studying. We are particularly interested in the strength of the treatments that have the potential to influence learning and to foster more positive student satisfaction with DE courses. To do this, we had to make a series of judgments about the types and strengths of the ITs we were examining. In this section, we describe the general procedures as well as how we made various judgments relating to the general purposes of the meta-analysis.

Inclusion and Exclusion Criteria

The following criteria were used to define the set of studies to be included in the meta-analysis:

1. A comparison between two DE conditions (i.e., where teaching and learning were separated through synchronous or asynchronous means), either on the basis of pedagogical differences (e.g., feedback and discussion vs. no feedback and discussion) or technological differences (e.g., satellite, TV, radio broadcast vs. telephone and e-mail), was required.
2. DE applications with some face-to-face meetings (less than 50%) were included. In these instances of "mixed or blended learning," the dependent measure (e.g., grades, test scores) had to encompass the entire course, not just the DE or face-to-face segments separately.
3. A reported measure of achievement outcomes was required in the experimental and the control condition.
4. Sufficient data for effect size calculation (e.g., means and standard deviations) or estimation (e.g., $p < .05$), the reporting of sample sizes so that a standard error of effect size could be calculated, and the explicit direction of the effect (i.e., +/–) was required.
5. Only whole courses were included. Programs composed of more than one course, in which data were aggregated over a collection of courses, were excluded. We included outcome measures that reflected individual courses rather than whole programs.
6. A report of the same or closely equivalent achievement measures for each condition (i.e., outcome measure compatibility) was required.
7. An identifiable grade or age level of learner was required. All levels of learners from young children in kindergarten to adults were included.
8. The studies could come from publicly available scholarly articles, book chapters, technical reports, dissertations, or presentations at scholarly meetings.
9. The inclusive dates of the studies were from January 1985 to December 2006. The start year (1985) was chosen because it marked the beginning of the "digital age," when the forerunners of the Internet were available and e-mail could be used to communicate, representing the first alternative to the postal service DE (Peters, 2003).

10. Courses that were not institutionally based (e.g., home study) were excluded.
11. Only interventions that lasted 15 or more hours were included. Shorter interventions were considered lacking in the external validity necessary to generalize the findings to typical DE courses.

Data Sources and Search Strategies

The studies used in this meta-analysis were located through a comprehensive search of publicly available literature from January of 1985 through December of 2006. The following retrieval tools were used:

1. Electronic searches were performed on the following databases: ABI/Inform Global (ProQuest), Academic Search Premier (EBSCO), CBCA Education (ProQuest), Communication Abstracts (CSA), Digital Dissertations and Theses (ProQuest), ED/ITlib, Education Abstracts (Wilson), ERIC (Webspirs), FRANCIS (CSA), Medline (Pubmed), PsycINFO (EBSCO), and Sociological Abstracts (CSA). Other databases included Australian Education Index, Australian Policy Online, British Education Index, Education-line, EdResearch Online, International Centre for Distance Learning Literature Database, and Intute: Social Sciences.
2. Web searches were performed using the Google search engine.
3. Manual searches were performed in relevant journals, including *American Journal of Distance Education*; *Canadian Journal of Learning and Technology*; *Distance Education*; *Educational Technology and Society*; *International Journal of Instructional Technology & Distance Learning*; *International Review of Research in Open and Distance Learning*; *Journal of Distance Education*; *Journal of Interactive Media in Education*; *Journal of Interactive Online Learning*; *Journal of Learning Design*; *Journal of Technology, Learning and Assessment*; *Language Learning and Technology*; *Open Learning*; and *Turkish Online Journal of Distance Education*.

The reference lists of several earlier reviews were consulted, including Moore (1989); Moore and Thompson (1990); Russell (1999); Machtmes and Asher (2000); Cavanaugh (2001); Allen, Bourhis, Burrell, and Mabry (2002); Olson and Wisher (2002); Shachar and Neumann (2003); Bernard, Abrami, Lou, Borokhovski, Wade, et al. (2004); and Cavanaugh et al. (2004).

Branching searches were performed from the reference lists of many of the studies located in earlier stages of the review.

Although search strategies varied depending on the retrieval tool used, generally search terms included “distance education,” “distance learning,” “open learning,” “virtual university,” “virtual classroom,” “online learning,” “Web-based learning,” “electronic learning,” “elearn*,” “blended,” “hybrid,” “Internet,” “computer-mediated communication,” “computer conferenc*,” “video conferenc*,” OR “computer-assisted instruction.” These terms were combined with (student* or learn* or teach* or classroom*) and in some cases, depending on the nature of the database (achievement OR attitude* OR outcome* OR satisfaction OR perception*). Please contact the first author to receive the original search strategies.

Study Selection

After judging the abstracts of more than 6,000 manuscripts that were found through searches, we retrieved 1,034 as full texts and examined them for inclusion. The interrater agreement (Cohen's kappa) for this step was 0.74 ($r = 0.70$, $p < .001$).

Each of the full-text manuscripts retrieved was read independently by two researchers and rated on a 1 to 5 scale for possible inclusion, using the inclusion and exclusion criteria previously described. The interrater correlation for this step was 0.61 ($p < .001$). The two ratings for each study were combined to form a sum. Studies with a sum of 5 out of 10 or more were given further consideration for inclusion. In all, 190 studies met all inclusion criteria except for the "duration of treatment" criterion.

We decided to exclude 116 short duration studies, because most were conducted as part of a larger course, in laboratory settings, or otherwise under conditions that could not be generalized to normal DE settings (i.e., Criterion 11). This left a total of 74 studies for analysis. We estimated the overall interrater agreement (Cohen's kappa) for all steps in the selection process to range from 0.70 to 0.81.

The 74 studies were sorted into one of three categories of interaction: SS interaction, ST interaction, and SC interaction. Then the levels of the independent variable in each study were examined and assigned as either treatment or control. This distinction determined the valence of the effect sizes that were extracted from each study. The categorization of studies is described more completely.

Categorization procedure. Once selected, studies were categorized by the most prevalent interaction type contained in the independent variable (i.e., SS, ST, or SC) and the type(s) of outcome measure(s) present. Studies appeared in only one interaction category so that the categories were orthogonal and could be compared. Two trained coders, working independently, categorized the studies and then resolved any conflicts through discussion. The initial interrater agreement (Cohen's kappa) was 0.71.

Effect sizes were extracted from the studies. The 74 studies yielded 74 effect sizes for achievement outcomes and 44 for attitude outcomes. Table 2 shows the number of effect sizes that were distributed across the three categories of ITs for achievement and attitude.

After studies (effect sizes) were categorized, the levels of the independent variable were scrutinized to determine which condition was experimental and which was control. This was done by independent coders who compared the conditions to determine which was the IT condition. This judgment had two elements: (a) which level of the independent variable possessed the greatest potential for active engagement by students and (b) which level of the independent variable encouraged more two-way interaction (i.e., symmetrical interaction). Examples of these decisions are presented in the next section. It should be noted that the magnitude of interaction was not considered in assigning conditions or in calculating effect sizes. Rather, instructional treatments were judged on their capacity to elicit or activate interactive behavior in students. The table in Appendix A presents the designation of treatment and control (pedagogy and media treatments) for all of the studies in the meta-analysis.

TABLE 2
Number and percentage of effect sizes at the categorization stage

Interaction treatment categories	Achievement		Attitude	
	k	Percentage	*k*	Percentage
Student–student IT effects	10	13.5	6	13.6
Student–teacher IT effects	44	59.5	30	68.2
Student–content IT effects	20	27.0	8	18.2
Total effects	74	100.0	44	100.0

Examples of categorization decisions

To illustrate how the studies were categorized according to their potential for interactivity, four examples have been included here. In each case, we describe the two conditions that were compared, how we determined which was the treatment and which was the control, and the direction of the effect size. In these examples, Group A is considered to be the most interactive treatment and Group B the least interactive control.

Example 1. Beyth-Marom and Saporta (2002) compared two DE methods. One group (Group A) of social science undergraduate students studying basic research methods experienced seven satellite TV tutorials (two-way audio and one-way video so that students could see and hear an instructor who could hear them), whereas a second set of students (Group B) attended three satellite TV tutorials and received four (asynchronous) videotape cassettes to be viewed at their convenience. The fully synchronous group (Group A) was designated as the experimental group for ST interaction.

Example 2. Gulikers, Bastiaens, and Martens (2005) tested "authentic learning environment" technology by comparing two types of simulation exercises provided to undergraduate students. These students were asked to conduct an analysis of a virtual bus company that was having problems with a high incidence of employees taking sick leave. The task was presented in two forms; one version (Group B) provided all the necessary data on a Web site without multimedia animation, whereas the "authentic" condition (Group A) required the students to approach animated employees, conduct simulated interviews, and receive advice from an electronic advisor. We considered Group A to be high in "interaction with content" and designated it the experimental condition and designated Group B as the control condition.

Example 3. Hansen (2000) compared two approaches to course orientation applied to an Introduction to Microcomputers course for undergraduate students. The entire course was conducted at a distance through Web-based delivery of materials and e-mail, supplemented by an orientation session, phone calls, and face-to-face meetings between students and the instructor. The independent variable was the extent of the orientation session; the extended orientation group (Group A) received additional information and handouts and had reminder postcards mailed to them during the first 3 weeks of the term. The second group (Group B) did not receive the extended orientation. We assigned the achievement effect size to ST interaction and designated the extended orientation students (Group A) as the experimental group.

Example 4. Bell, Hudson, and Heinan (2004) provided two methods of online learning to physician assistant students in a medical terminology course. Both versions of the course used the same materials, but some students worked independently on the Web (Group B), whereas others (Group A) received 12 case studies in an online conference setting, which they then discussed through the use of asynchronous messaging. We applied the comparative outcomes to SS interaction, counting the case-based discussion participants (Group A) as the experimental group.

Effect size extraction

Calculated effect sizes (i.e., Cohen's d) representing the standardized difference between the mean of the most interactive condition (treatment) and the mean of the least interactive condition (control) were converted to Hedges' g to correct for small sample bias. Independent effect sizes were extracted from each included study.

Interrater reliability (i.e., Cohen's kappa) of the effect size calculation was 0.93. Effect sizes, standard errors, and sample sizes were entered into Comprehensive Meta-Analysis™ 2.0 (Borenstein, Hedges, Higgins, & Rothstein, 2005) for the main analyses. The accuracy of the analysis was verified by several investigators.

Coding Interaction Strength

After studies were categorized, it was apparent that the relative strength of the treatment (i.e., the difference between the experimental and the control) was not the same across studies in each category. Furthermore, it was also recognized that many studies, even though they had been placed in a dominant category (e.g., student–student interaction), contained elements of either or both of the other two interaction categories. As a result, we decided to create a coding scheme that took into consideration both of these factors.

Procedure for coding the relative strength of each IT

We evaluated the level of the independent variable in each study and decided the relative strength of the treatment by comparing the quality and/or quantity of interaction in the experimental group to the quality and/or quantity of interaction in the control group. If the two treatments both had high levels of interaction on SS interaction, for instance, then relative strength was coded as 0 because the relative strength of the treatment, taking both conditions into account, was considered to be minimal. If, on the other hand, the experimental group had a high level of interaction and the control group had a low level of interaction, the relative strength was coded as 2 (high). If the groups were moderately different in terms of interaction, a relative strength of 1 (moderate) was assigned to that difference.

We wanted to validate the results of our procedure for estimating treatment strength, so we used Anderson's (2003a) descriptions of the predicted strengths of pedagogy and technology treatments for correspondence education, DE via audio and video conferencing, and Web-based courses to re-evaluate our original strength ratings. Because Anderson's category descriptions are more general than the specific details of pedagogy and technology provided in studies, some overestimations and underestimations resulted. However, many were exact matches. Three coders independently judged the strength of the interactions. SS, ST, and SC coding produced significant ($p < .05$) interrater agreements *R*s of .77, .83, and .71.

Procedure for coding the cumulative strength of the three ITs

After coding each interaction dimension separately, we needed to develop a scale that combined overall strength across the three interaction dimensions. We used the following coding scheme:

1 means "Minimal" (any combination of 0s and 1s);
2 means "Moderate" (any combination of 0s and 1s + one 2); and
3 means "High" (any combination with more than one 2).

Procedures for coding strengths of pairs of ITs.

We wanted to assess each of three combinations of the categories of interaction strength to answer the question, "Which combinations of the three ITs are related to increasing average effect size?" Again, we used the relative strength ratings, this time for each pair of ITs: SS + ST, SS + SC, and ST + SC. The combination ratings were constructed in the following way:

0 means "Equal" (0 and 0);
1 means "Low" (any combination of 0s and 1s);
2 means "Moderate" (a 2 with either a 0 or 1);
3 means "High" (both 2s).

Coding Other Study Features

The complete coding sheet is in Appendix B. Other study features were coded to reflect methodological quality, demographics (age and subject matter), and DE mode (synchronous, asynchronous, and mixed).

Methodological Quality

The methodological quality of the studies included in a meta-analysis is of great concern because the quality of the studies may affect the veracity of the conclusions that can be drawn regarding the phenomenon under consideration. Studies that contain design flaws, either because of inattention by the researcher or logistical or practical circumstances, reduce the attribution of causality by failing to control for alternative explanations to the research hypothesis. Because studies of educational phenomena are often conducted in field settings rather than in laboratories, they are often judged to be low in internal validity.

Four approaches to dealing with methodological quality are common in the literature of meta-analysis. The first alternative is to use methodological quality as an inclusion criterion so that only the highest quality studies are included in the review (What Works Clearinghouse, 2006). The second alternative is to treat methodological quality as a study feature, classify included studies by quality criteria, and report their findings separately (Lipsey & Wilson, 2001). The third alternative is to weigh studies by methodological quality, giving more weight to some studies and less to others (Lipsey & Wilson, 2001). And the fourth alternative is to treat methodological quality as a predictor of effect size by removing its influence from the collection of evidence (Hedges & Olkin, 1985). All of these approaches have their advantages and their disadvantages.

In the first two approaches, low-quality studies are eliminated from consideration entirely or segregated and interpreted separately. The biggest problem here is that in a field such as education in which there are few high-quality studies, the meta-analyst may be forced to conclude that there are too few studies for interpretation and suspend investigation until more are available. In the third and fourth approaches, the effects of lower quality studies are reduced but not eliminated. Also, it is not clear how these approaches would aid the analyst in estimating the average effect size after adjustment for methodological quality was applied. A fifth approach, favored by us (Abrami & Bernard, 2008), uses an adjustment procedure to bring the average effect size of lower quality studies up to that of the average effect size of the highest quality studies (see Results section for more description). The within-class variability is left intact so that subsequent moderator variable analysis (i.e., regression or ANOVA) can proceed in the normal fashion. One of the big advantages of this approach is that all studies for which an effect size can be calculated are left in the study, thus improving the power of subsequent tests to find differences. In the current review, we used five coded methodological quality study features to form a judgment about study quality on a scale from 6 to 18 (i.e., research design was double weighted and some items had more than two levels).

Results

Outlier Analysis and Publication Bias

One study with a sample size of over 32,000 was removed because of its dominating effect on the weighted average effect size. "One study removed" analysis revealed that all of the remaining average effects fell within the 95th confidence interval of the overall adjusted average effect size so that all were considered within a reasonable range around the average effect. In addition, removal of three high-influence effect sizes failed to improve the fit of the distribution, so based on these two factors, all 74 effect sizes for achievement were retained.

An examination of the funnel plot (standard error by effect size) for achievement effects revealed a nearly symmetrical distribution around the average effect. No imputed effects were required for symmetry. Classic Fail-Safe *N* revealed that 44 additional studies would be required to nullify the effect of the achievement data. Taken together, no obvious publication bias was revealed.

Adjusting for Methodological Quality

In this study, we coded five study features related to methodological quality: (a) research design quality, (b) instrument quality, (c) statistical quality, (d) teacher equivalence (same/different teacher), and (e) material equivalence (same/different materials).

Abrami and Bernard (2008) outlined four steps, expressed as questions, for dealing with the methodological quality of studies in a meta-analysis. The four steps that we followed in conducting this meta-analysis were related to the following questions:

TABLE 3
Methodological quality scale and categories for achievement outcomes

Scale	g+	Relative frequency	Category names	Frequency (relative %)	g+ (category)
6	–0.52	1	Low	$k = 11$ (14.86%)	–0.001
7	–0.60	3			
8	–0.79	7			
9	–0.04	14	Moderate	$k = 52$ (70.28%)	0.05
10	–0.08	18			
11	0.07	14			
12	–0.00	6			
13	0.54	6	High	$k = 11$ (14.86%)	0.39
14	0.39	5			
Total	0.10	74		100.00	0.10

Step 1: Are the effect sizes homogeneous?
Step 2: Does study quality explain the heterogeneity?
Step 3: Which qualities of studies matter?
Step 4: How do we deal with the differences?

We now describe how we implemented these steps to adjust achievement outcomes according to the methodological quality of the studies in the meta-analysis.

Achievement outcomes. We found that the overall unadjusted average effect size of 0.10 was significantly different from zero, $z(73) = 3.52$, $p < .001$, and significantly heterogeneous, $Q_T(73) = 209.86$, $p < .001$. We then looked to see whether the variability might be explained by methodological quality. The scores on the methodological quality scale for these achievement data ranged from 6 to 14 and produced the frequency distribution of scale categories shown in Table 3. The scale categories significantly explained effect size, $Q_B(8) = 30.30$, $p < .001$ and, treated as an ordinal scale in regression, significantly predicted effect size ($\beta_{Regression}[1, 73] = .08$, $p < .001$, $Q_{Regression} = 23.50$, $p < .001$). Based on this analysis, we decided to classify the scale into three larger categories of methodological quality.

In deciding how to classify the effect sizes, we took three factors into consideration: (a) approximately equal intervals of the scale; (b) similar average effect sizes within categories, resulting in homogeneous or nearly homogeneous categories; and, if possible, (c) roughly proportionate relative frequencies within categories. Based on these factors, we decided to create three intervals (categories): low methodological quality = 6 to 8 ($k = 11$), moderate methodological quality = 9 to 12 ($k = 52$), and high methodological quality = 13 to 15 ($k = 11$). The final split represents a compromise among the three criteria previously described.

Following our procedures, post hoc tests of homogeneity were conducted between the categories, and the low and moderate categories were found to be equal and both were significantly different from the high methodological quality category. The difference between the average of the low and moderate categories and the high category average was 0.35. This value was then added as a constant

TABLE 4

Categories of methodological quality for achievement and statistics for unadjusted and adjusted effect sizes

		Unadjusted effect sizes			Adjusted effect sizes		
Methodology	*k*	*g*+	*SE*	*Q*	*g*+(adj)	*SE*	*Q*
Low	11	–0.00	0.07	23.06	0.34	0.07	22.91
Moderate	52	0.05	0.03	133.86	0.39	0.03	129.56
High	11	0.39	0.07	30.18	0.39	0.07	30.13
Within-class				187.10			182.60
Between-class*				22.76**			0.36
Total	74	0.10	0.03	209.86	0.38	0.03	182.96

*χ^2crit(2) = 5.99. ***p* < .0001.

to each effect size in the low and moderate categories. The inverse variance weights were recalculated, based on the adjusted standard errors, and the three categories were again compared.

Table 4 shows the unadjusted and adjusted mean effect sizes for each of the three categories of methodological quality. The left side of the table shows the unadjusted weighted mean effect size for each category of methodological quality. The right side of Table 4 shows the outcomes of the adjustment procedure. Note that the weighted mean effect sizes for the low and high categories are only approximately equal to that of the high category, because a single constant was applied to studies in the two lower categories. Although the procedure resulted in roughly equal category means, the variability within categories was left nearly intact (Q = 187.10 vs. 182.60). This approach allowed us to estimate and then model the effects attributable to the best quality studies while exploring the variability of the entire distribution.

Attitude outcomes. Attitude outcomes were analyzed using the same procedure based on methodological quality. The adjusted average ES of +0.09 was heterogeneous. Major results for the attitude data with respect to each research question are briefly summarized at the end of the Results section. For the purposes of this article, we concentrate on the achievement results, but detailed results of the attitude data are available by request.

Primary Analysis: Demographics

The publication demographics of the studies were examined through analysis of variance across categories of publication date. The achievement data did not differ across categories of publication date.

There is one positive outcome of this analysis, which we think bodes well for future research in DE. About 68% of achievement studies fell between 2000 and 2006. This does not necessarily suggest a shift away from CI/DE comparison studies, but it does indicate that more DE treatment comparisons are becoming available. The research-based study of DE may well benefit substantially from this apparent shift.

TABLE 5
Weighted average achievement effect sizes for categories of interaction

Interaction categories	k	$g+$(adj.)	SE
Student–student	10	0.49	0.08
Student–teacher	44	0.32	0.04
Student–content	20	0.46	0.05
Total	74	0.38	0.03
(Q) Between-class*		7.05**	

*$\chi^2_{crit}(2) = 5.99$. **$p < .05$.

TABLE 6
Categories of overall interaction strength for achievement outcomes

Interaction strength	k	$g+$(adj.)	SE
Low strength	31	0.25	0.04
Moderate strength	28	0.55	0.05
High strength	15	0.36	0.06
Total	74	0.38	0.03
(Q) Between-class*		23.80**	

*$\chi^2_{crit}(2) = 5.99$. **$p < .01$.

Educational level. There were only two prominent levels of education for the achievement data. For achievement outcomes, studies of undergraduate students (75.7%) predominated, followed by studies of graduate students (21.6%). The domination of postsecondary studies in this sample unfortunately reduces the generalizability of the results that follow. We hope that the future efforts of primary researchers will produce a sufficient corpus of studies for meta-analysis, at all levels of the educational spectrum.

Primary Results: Substantive Research Questions

1. What are the effects of the three kinds of interaction (SS, ST, and SC) on achievement?

The adjusted weighted means for each class of IT differed significantly ($Q_B = 7.05, p < .05$). Post hoc tests revealed that SS and SC means were both significantly larger than ST and that SS was not different from SC. All three categories were moderately and significantly variable (see Table 5).

These results suggest that ST ITs are less effective, possibly more difficult to implement consistently, or provide less added value than either SS or SC ITs.

2. Does more overall IT strength promote better achievement?

This question addresses Anderson's (2003a) hypotheses about the strength of treatments. The between-class comparison involving categories of treatment strength was significant (see Table 6), and post hoc comparisons revealed that both

TABLE 7
Weighted average effect sizes for categories of treatment strength

	Student–content interaction		
Interaction strength	*k*	*g*+(adj.)	*SE*
Low strength	35	0.32	0.04
Moderate strength	27	0.33	0.05
High strength	12	0.60	0.06
Total	74	0.39	0.03
(*Q*) Between-class*		17.36**	

*$\chi^2_{crit}(2) = 5.99$. **$p < .01$.

TABLE 8
Combinations of interaction categories for achievement outcomes

	SS + SC			ST + SC		
Levels of treatment strength	*k*	*g*+(adj.)	*SE*	*k*	*g*+(adj.)	*SE*
Equal (0)	11	0.17	0.09	4	0.40	0.15
Low (1)	34	0.33	0.04	32	0.28	0.04
Moderate (2)	29	0.48	0.04	38	0.49	0.04
Total	74	0.38	0.03	74	0.38	0.03
*(*Q*) Between-class		12.40**			13.94**	

*$\chi^2_{crit}(2) = 5.99$. **$p < .01$.

moderate and high-strength ITs outperformed low strength ITs and that high-strength ITs were not significantly different from moderate strength ITs. In addition, the linear association between treatment strength and effect size was significant ($\beta_{Regression}[1, 73] = .09$, $p = .01$, $Q_{Regression} = 6.66$, $p = .01$). This result seems to support Anderson's prediction.

These results suggest that increasing the strength of IT affects achievement.

3. Do increases in treatment strength of any of the three different forms of interaction result in better levels of achievement?

This is a more nuanced question about the strength of the three ITs. It examines the relative strength of each IT separately.

Only the SC category produced both significant between-class differences and a positive linear relationship with effect size. Table 7 shows the average effect size for each rating on the strength scale for each interaction category and the between-class *Q* statistics for achievement. Student–content produced a significant regression effect ($\beta_{Regression}[1, 73] = .13$, $p = .001$, $Q_{Regression} = 12.50$, $p = .001$). Post hoc analysis indicated that high-strength ITs outperformed both the low and moderate ITs. These results suggest that stronger SC ITs provide achievement advantages over weaker SC ITs.

TABLE 9
Comparisons among synchronous, asynchronous, and mixed patterns of DE.

DE Mode	*k*	g+(adj.)	SE
Synchronous DE	5	0.38	0.11
Asynchronous DE	37	0.39	0.04
Mixed DE	7	0.50	0.09
Total	49	0.41	0.03
(*Q*) Between-class*		1.40	

*χ^2_{crit} (2) = 5.99

4. Which combinations of SS, ST, and SC interaction most affect achievement outcomes?

This question asks whether certain combinations of SS, ST, and SC produce better achievement outcomes than others. The analyses produced significant results (see Table 8) for the combinations SS + SC ($\beta_{Regression}[1, 73] = .15$, $p < .001$, $Q_{Regression} = 12.39$, $p < .001$) and ST + SC ($\beta[1, 73] = .16$, $p = .001$, $Q_{Regression} = 10.24$, $p = .001$). The combination SS + ST was not significant.

5. Are there differences among synchronous, asynchronous, and mixed forms of DE in terms of achievement?

In this study, we found three distinct patterns: synchronous, asynchronous, and mixed DE studies. Mixed is also referred to in the literature as blended and hybrid and describes courses that are a combination of DE and face-to-face instruction. From the separate designations of the mode of the treatment and the mode of the control, we constructed three categories of direct or pure comparisons between like modes (i.e., synchronous vs. synchronous, asynchronous vs. asynchronous, mixed vs. mixed). Out of the 74 effect sizes for achievement, 49 remained in this analysis when unlike comparisons were removed.

On average, all experimental conditions were significantly better than their control conditions, but the between-class test of synchronous, asynchronous, and mixed studies was not significant (see Table 9). The "best of both worlds" prediction for mixed courses is not borne out statistically in these results (i.e., there is no advantage for mixed courses), but the low number of effect sizes suggests that this is an area of DE in need of research attention.

6. What is the relationship between treatment strength and effect size for achievement in asynchronous-only DE studies?

It is arguable that interaction is most crucial, and perhaps most difficult to achieve, in DE courses that are entirely asynchronous. These are DE courses that have no face-to-face or synchronous component and are most like the Internet and Web-based courses that have become so popular. We were interested in knowing if studies of this DE mode were different from studies containing synchronous or face-to-face components. Table 10 shows the weighted regression analysis of the asynchronous studies ($k = 37$) and other patterns (referred to as "not asynchronous")

TABLE 10
Weighted regression analysis between treatment strength and effect size for asynchronous and "not synchronous" distance education studies

	Asynchronous only		Not asynchronous	
Model	β	*SE*	β	*SE*
General treatment strength				
Slope	0.25*	0.06	0.02	0.05
(*Q*) Regression	16.36*		0.12	
Student–content treatment strength				
Slope	0.17*	0.07	0.15*	0.07
(*Q*) Regression	6.91*		3.88*	

Note. $k = 37$ ($df = 1, 35$).
*$p < .05$.

in which synchronous communication or face-to-face interaction was present ($k = 37$). The "not asynchronous" condition contains the same synchronous and mixed studies shown in Table 9, plus all other combinations where unlike modes were compared (e.g., asynchronous vs. synchronous). General treatment strength (i.e., overall strength without reference to particular interaction patterns) was a significant predictor of effect size for the "asynchronous only" studies but not for the other category. However, both categories of studies produced a significant linear relationship between SC strength and effect size.

When asynchronous studies were examined in terms of IT combinations, the same pattern emerged that was observed earlier for the entire collection. These are the 37 effect sizes shown in Table 9 that had a weighted average effect size of 0.39. The results of both regression analyses indicated strong relationships between combinations of ITs (i.e., SS + SC and ST + SC).

Summary of the Findings

The findings of this meta-analysis are summarized in Table 11.

Discussion

General Considerations

As an emerging educational practice matures—gaining its own raison d'être, its own clientele, its own methodologies, and its own infrastructures—the need diminishes for it to be justified through comparisons with its more established alternatives. This seemingly is the case for DE. It is arguable then, that the next form of progress to advance theory and practice will be made as researchers begin to examine how instructional and technological treatments differ between DE conditions, not between DE and CI. Only comparisons between DE treatments can provide direct evidence of "what works" in DE and only through research syntheses of this literature can we make broad statements that will hold up across many types of courses, learners, and curricula.

TABLE 11
Summary of the findings for achievement and attitude outcomes for each research question

Research questions	Findings: Achievement	Findings: Attitudes
Question 1: Categories of interaction (SS, ST, SC)	All categories > 0.25, SS and SC > ST	SS > ST and SC
Question 2: Overall strength of interaction categories	Increase in strength for moderate and high strength over low strength; regression is significant	Increase in strength for moderate over low strength; not enough data to evaluate high strength and regression is not significant
Question 3: Strength of individual categories	Increase in strength for high over low and moderate for student–content only	Increase in strength for moderate over low for student–content only
Question 4: Combinations of categories	Increasing relationship between strength and effect size for SS + SC and ST + SC	No finding
Question 5: Asynchronous vs. Synchronous vs. Mixed distance education	No difference among types of distance education.	Synchronous and asynchronous greater than mixed distance education
Question 6: Interaction in asynchronous distance education only (achievement outcomes)	Strength of SC affects outcomes in asynchronous settings more than in other settings	N/A

Note. SS = student–student interaction; ST = student–teacher interaction; SC = student–content interaction.

In this meta-analysis, we have attempted to synthesize the existing and somewhat scant literature of DE versus DE studies, within a commonly understood framework of ITs. We believe that in doing this, we have made a substantive contribution to progress in DE and successfully developed a prototype for future syntheses of the DE research literature. A range of researchable issues, including independence versus dependence and the role and function of technology, can also be investigated across competing and relatively comparable treatments.

In this meta-analysis, we have identified one of the critical challenges associated with comparing different instructional treatments rigorously—namely, determining the meaning of an effect size. If this meaning is unclear or inconsistent, nothing that makes sense can emerge from the exercise. Consider the following example. In some ways, student interaction and student autonomy are contradictory concepts (e.g., Daniel & Marquis, 1979), yet both are integral to the theoretical literature of DE. In certain instances, an effect size calculated on the basis of high versus low interaction would have the opposite sign of one calculated for high versus low independence. Both are correct, but their meaning is different, so studies of student interaction cannot be synthesized with studies of student autonomy. Therefore, maintaining a consistent distinction between the experimental and control conditions is of critical concern to the success of a meta-analysis of this type. Moreover, establishing mechanisms for verifying the reliability and conceptual validity of the many judgments that must be made may be even more important here than in a conventional meta-analysis.

Substantive Research Outcomes

The major conclusion from this review is that designing ITs into DE courses, whether to increase interaction with the material to be learned, with the course instructor, or with peers, positively affects student learning. The adjusted average effect of 0.38 represents a moderate and significant advantage for ITs over alternative instructional treatments, including less prominent ITs. We can only speculate on the internal mental processes that these ITs foster, but we believe that an increase in cognitive engagement and meaningfulness may be the result of different amounts and types of interactivity induced through the presence of ITs.

When divided according to Moore's (1989) categories of ITs, it appears that there is support for the importance of all three: SS, ST, and SC. However, we found a difference in effectiveness for SS and SC over ITs promoting ST interaction.

We did not code the studies for the quality or quantity of interactions that actually occurred in the experimental and control groups. Such information is typically not available in reports of research as measures of treatment fidelity, although occasionally they do appear as the dependent variable of a study. As a result, we know only about the relative differences in the affordances provided by ITs, not how students actually responded to them. Richard Clark (R. E. Clark, personal communication, October 12, 2007) made a point about the actual strength of the treatment being indeterminate in much of educational technology research.

We are therefore left wondering what we would find if measures of student activity data were available, making it possible to connect induced student activity and interaction to measures of achievement. It may be that the presence of ITs functioned in exactly the way it was intended, by activating student interactivity, so that our estimates of the effects of interactivity are fairly accurate. But just because opportunities for interaction or collaboration were offered to students does not mean that students availed themselves of them, or if they did interact or collaborate, that they did so effectively. The latter case is the more likely event, so the achievement effects resulting from actual interactivity may be underestimated in our review. All we really know is that something in the nature of the distinction between treatments and controls affected achievement outcomes. Not understanding the underlying phenomenon is a problem that is encountered in research on interventions of all sorts in education and limits our ability to develop strong theories that can propel further development.

Larreamendy-Joerns and Leinhardt (2006) pointed out another possibility:

> Although online learning environments that allow for social interaction constitute a remarkable advance, they should not be construed as inevitably conducive to learning, solely because student–student and student–instructor exchanges take place. Nor should they be understood as obviously

> consistent with a vision of knowledge as practice or with efforts to nurture communities of practice. (p. 591)

According to this, activity itself may not be the active ingredient, particularly when it comes to SS interaction. To make things more complicated, Fulford and Zhang (1993) found that students' perception of interaction was a better predictor of course satisfaction than their actual measured interaction. Following this line of reasoning, providing the potential for interaction may be an important design consideration, even if students do not actually avail themselves of this potential. It seems unlikely, however, that perceived interaction would have any affect on achievement.

Some of the most interesting results from this meta-analysis involve Anderson's (2003a) notion of the strength of ITs. Implicit in his arguments about strength is that DE-learning environments should be designed with a consideration for the importance of the three forms of interaction (i.e., creating the conditions for them to occur) and that their strength is related to both effective learning and the satisfaction that students express. Anderson goes so far as to predict that bolstering the impact of at least one of the three interaction types, while the others can be at a minimal level (or eliminated altogether, he says), has an effect on "deep and meaningful formal learning" (p. 4).

Through our strength coding, we were able to investigate these claims. First, we found a significant linear relationship between IT strength and effect size for achievement outcomes. Furthermore, when the actual categories of strength were investigated through ANOVA, we found strong support for Anderson's (2003a) hypothesis about achievement. Both high and moderate levels of treatment strength were better than low levels.

When we looked at the strength of each category of IT separately, only strengthening SC interaction was related to increasing effect size. In essence, this suggests that when students are given stronger versus weaker course design features to help them engage in the content, it makes a substantial difference in terms of achievement. We also found SC ITs implicated when they were set in combinations with the other ITs. SS + SC and ST + SC produced significant linear effects as well as significant differences between levels of strength.

We went on to inquire about the nature of different patterns of DE—asynchronous, synchronous, and mixed—that had not been compared directly in previous work. In regard to their relationship to ITs, we found them to be about equal on measures of achievement.

In a final set of analyses, we found that the relationship between the strength of ITs and achievement held for asynchronous DE courses but did not hold for "not asynchronous" courses. It seems logical that courses lacking either mediated synchronous interaction or direct face-to-face interaction would benefit most from enhanced interactive capabilities.

The results of this meta-analysis do not provide recipes for improving the design of DE courses. Results are based on such a wide variety of instructional treatments that it would be difficult to argue for one over another. On the flip side, however, this variability means that the results generalize across many DE courses and course characteristics. As well, differences between treatments were, by necessity, judged in relative rather than absolute terms, making it difficult to rate with precision the expected outcomes associated with any given instructional or technology treatment. However, the results provide a blueprint for strategically examining individual courses in terms of the kinds of ITs that are made available to students. From these results, it seems that a designer's first consideration should be to provide strong associations with the content, unless content acquisition is not the primary goal of the instruction. Although we were not able to examine more refined questions regarding content ITs, it makes sense that those involving more overt student activity would be preferred over more passive forms. A second determination could be made as to the desirability of stronger SS or ST connections. Because technical capacities for facilitating human–human interaction seem to be constantly improving, it is likely that we can expect noticeable improvements in all forms of interaction that involve collaboration, discussion, and feedback. Strengthening all three forms of interaction seems ideal, but Anderson (2003a) points out that this may exceed the availability of human and technical resources needed for cost-effectiveness.

We can now conclude with some degree of confidence that the availability of ITs is related to increased learning in DE and that stronger treatments are more effective than weaker treatments. We cannot conclude from the available evidence in this research synthesis exactly how the interactivity that is presumed to underlie such treatments increases learning. We speculate that there are underlying cognitive and motivational mechanisms that are individually or collectively responsible for this link, but another generation of DE studies is needed to make these processes understood. We invite the community of DE theoreticians and primary researchers to think about and further explore the cognitive and attitudinal mechanisms that link ITs to better student performance and satisfaction. This includes developing, adapting, and testing emerging technologies and instructional approaches to enhance SS, ST, and SC interaction and suggesting how available resources can be used more effectively.

Ideas for future DE research and development. Increasing the quantity of interaction may lead to enhanced learning and satisfaction, but increasing the quality of such interactions, especially in terms of cognitive engagement and meaningfulness, may be of greater importance. This is an issue that we have been unable to address directly in this meta-analysis, so it seems appropriate to discuss it in terms of research and development work in progress. There appear to be at least two ways to foster increases in the quality of interactions: instructional design and software design.

Instructional designs that foster higher quality interactions focus on course features that promote high-quality learning activities. For example, cooperative learning structures may help ensure high-quality SS interactions by using positive interdependence among the learners as well as individual accountability to ensure cognitive engagement and meaningfulness. Similarly, designing effective course strategies for problem-based (Bernard, Rojo de Rubalcava, & St-Pierre, 2000) and guided discovery (Brown & Campione, 1994) forms of DE may promote the quality of SC interactions. Finally, the quality of ST interactions may be increased by ensuring that content interactions focus on comprehension and higher order thinking skills rather than activities that deal with lower level factual information, procedural details of a course, or assessment issues.

A range of knowledge tools may also be used to promote better quality DE interactivity. For example, Mayer (2001) and others have shown that interactive multimedia can lead to improved learner performance compared to text-only conditions. Multimodal representations and dynamic representations, especially in mathematics and sciences, may help make complex concepts more understandable; more efficiently learned; better retained; and more readily recalled, applied, and transferred.

It is arguable that the range of established tools currently available to educators, such as Learning Management Systems technologies, has yet to be developed sufficiently or examined systematically by the community of DE developers and researchers for their capacity to activate interactive behavior. We encourage more and better quality research along these lines, as well as increased research activity in elementary and secondary school applications of DE.

Research whose time is past. To reiterate, a subsidiary yet compelling message arising from this review is that little more can be gained through comparisons between DE and CI. Although in our previous review of 103 DE versus CI studies (Lou et al., 2006), we were able to detect the importance of the three kinds of interaction in DE, we could not have made sense out of the relationship among the three types or tested specific claims about interaction in the way that the current review has. If there is any further traction to be gained by conducting DE versus CI studies, it is through more refined investigations of how specific instructional methodologies that have proven effective in CI environments such as cooperative learning (Johnson, Johnson, & Stanne, 2000) can be adapted for DE. As well, classroom instructors may gain equally from understanding how proven DE practices can successfully be adapted for their use.

APPENDIX A

Treatment and control designations for studies in the meta-analysis

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
		Achievement data *Studies that contain both achievement and attitude data are marked with an asterisk.* Student–student interaction		
*Bell, Hudson, & Heinan (2004)	Collaborative case study discussions	Web-based tutorial	Blackboard learning content management system (LCMS)	Blackboard LCMS
Brewer & Klein (2004)	Role-plus-reward interdependent groups	No structured interdependence groups	Asynchronous Web-based: Outlook Express	Asynchronous Web-based: Outlook Express
*Britton (1992)	Student group attending common lecture broadcast	Individuals attending lecture broadcast at personal workstations	Two-way audio, one-way video with one screen	Two-way audio, one-way video with individual screens
*Cheng (1991)	Self-paced learning with computer-based interaction	Self-paced learning with print-based material	Asynchronous CMC (Computer Mediated Communication) with phone in option	Correspondence with phone in option
*Jung, Choi, Lim, & Leem (2002)	Collaborative interaction: instructor-initiated group discussions	Academic interaction: consultation with instructor when needed	Asynchronous Web-based instruction	Asynchronous Web-based instruction

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Romanov & Nevgi (2006)	Unrestricted WebCT use with discussion forums and student–student message system	Restricted WebCT with regular e-mail access to teacher	Unrestricted use of WebCT LCMS	Restricted use of WebCT LCMS with regular e-mail access
Ruksasuk (2000)	Social and instructional interaction	Instructional interaction	Web-based instruction with e-mail, chat groups, bulletin boards, hyperlinks, and FAQ	Web-based instruction with hyperlinks, FAQ, and e-mail with teacher
*Skylar (2004)	Online access to PowerPoint notes, lecture notes, digital videos, textbook and discussion board	CD-ROM–based PowerPoint notes, lecture notes, digital videos, and textbook	Online Class: WebCT LCMS	Class-in-a-box: CD-ROM
Tuckman (2007)	Scaffolded distance learning: collaboration and peer and instructor coaching	Traditional distance learning: with asynchronous teacher interaction when needed	Web-based instruction with study skills support groups and to-do checklists	Web-based instruction with asynchronous communication via the Internet
		Student–teacher interaction		
Annetta (2003)	Presentation and discussion with two-way audio video	Scheduled video presentations	Live: two-way audio-video conferencing	Video: Videotape-based instruction
*Banks (2004)	Blended using asynchronous Internet-based instruction with instructor-led live classroom instruction	Asynchronous Internet-based with asynchronous discussions	Asynchronous Internet-based instruction	Asynchronous Internet-based instruction

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Beare (1989)	Telelecture: presentation through two-way audio conference	Video-assisted independent study: Asynchronous video (and some face-to-face)	Synchronous two-way audio conference	Video-assisted independent study: videotape
*Benson (2005)	Hybrid learning environment: combination of online and face-to-face sessions	Online learning environment: online sessions only	Web-based instruction	Web-based instruction
Bernard & Lundgren-Cayrol (2001)	High moderator intervention: instructor led discussions and activities	Low moderator intervention: passive instructor participation	Online collaborative environment	Online collaborative environment
Bernard & Naidu (1992)	Correspondence with teacher feedback	Correspondence without teacher feedback	Correspondence	Correspondence
Beyth Marom & Saporta (2002)	All seven sessions offered via synchronous lecture presentation and discussion	Four sessions of synchronous lecture presentations and discussions and three video-taped sessions	Satellite-based synchronous video tutorials	Combination of satellite-based synchronous video tutorials with asynchronous videotapes
*Caldwell (2006)	Web-based instruction with instructor facilitated face-to-face lab sessions	Purely Web-based instruction	Blackboard 6.0 LCMS	Blackboard 6.0 LCMS
Callahan, Givens, & Bly (1998)	Live lecture presentation and discussion	Video-recorded lecture presentation	CU-SeeMe: synchronous Internet-based TV broadcast	Videotape-based delivery

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APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
Campbell, Gibson, Hall, Richards, & Callery (2008)	Web-based instruction with supplemental face-to-face discussion	Web-based instruction with supplemental online discussion	WebCT LCMS	WebCT LCMS
*Cargile Cook (2000)	Interactive Web-based delivery with chat rooms and bulletin board access	Presentational Web-based delivery (no bulletin board and chat room)	Unrestricted use of WebCT LCMS	Restricted use of WebCT LCMS
*Chen & Shaw (2006)	Deductive/inductive predominantly teacher-centered instruction	Deductive/inductive predominantly student-centered instruction	Synchronous Webcam-delivered instruction	Asynchronous scripted online instruction
Cifuentes & Hughey (2003)	Blended: computer-mediated and face-to-face discussions	Asynchronous computer mediated discussions	FirstClass: computer communication software	FirstClass: computer communication software
*Daig (2005)	12-week course	6-week course	Blackboard LCMS	Blackboard LCMS
Davis (1996)	Lecture presentation and discussion	Lecture presentation and discussion	Satellite live broadcast with an audio conferencing system	Audio-graphic teleconferencing system with still-frame graphics
*Frith & Kee (2003)	Mixed conversation: Collaborative online instructor supported communication	Internal conversation: Individual study with instructor support when needed	WebCT LCMS with access to online chats	WebCT LCMS
Gallie (2005)	Presentation and discussions	Presentation with instructor support when needed	Blackboard LCMS with access to discussion boards	WebCT LCMS with e-mail options only

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Grimes, Krehbiel, Nielson, & Niss (1989)	Lecture presentation supplemented with live interactive televised sessions with instructor	Lecture presentation with instructor support over the telephone when needed	Live broadcast with access to televised interactive sessions with instructor	Videotaped delivery and correspondence
Hansen (2000)	Self-learning with extended orientation session	Self-learning with short orientation session	Web-based instruction	Web-based instruction
Holmberg & Schuemer (1989)	Short assignments for every course unit	Short assignments for every 4-course units	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
Holmberg & Schuemer (1989)	Medium length assignments for every course unit	Medium length assignments for every 2-course units	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
Holmberg & Schuemer (1989)	Short assignments every 2-course units	Short assignments every 4-course units	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
*Huett (2006)	Computer simulations with confidence-building tactics and confidence-enhancing e-mails	Computer simulations	SAM 2003 (Skill Assessment Manager Software) and WebCT LCMS	SAM 2003 (Skill Assessment Manager Software)
Karr, Weck, Sunal, & Cook (2003)	Blended DE: online and face-to-face delivery modes combined at various stages of the course	Online course delivery with no face-to-face	Web-based with access to electronic discussion board	Web-based with access to electronic discussion board
*Katz (2000)	Live lecture presentation and discussion	Lecture presentation and asynchronous interaction with the teacher	Picture-Tel: synchronous interactive video system	Asynchronous interactive Internet-based

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
Kirschner, van den Brink, & Meester (1991)	Correspondence with feedback to students' essays	Correspondence with feedback to students' essays	Correspondence with audio-taped feedback	Correspondence with written feedback
Libler (1991)	Live lecture broadcast with certified teacher as facilitator on site	Live lecture broadcast with no facilitator	Indiana Higher Education Telecommunication System Interactive TV network	Indiana Higher Education Telecommunication System Interactive TV network
Lilja (2001)	Live lecture presentation and discussion	Online self-learning with accompanying study guide	University Industry Television for Education: Live interactive TV broadcast	Internet-based instruction
Lim, Morris, & Kupritz (2006)	Blended: Online self-learning with face-to-face classroom instruction	Online self-learning	Online learning environment	Online learning environment
Ostiguy & Haffer (2001)	Live lecture broadcast: Teacher-paced instruction	Self-paced asynchronous Web-based learning	Live interactive TV	Conferencing On the Web: Web-based asynchronous discussion software
Paulsen, Higgins, Miller, Strawser, & Boone (1998)	Live lecture broadcast and discussion	Asynchronous videotape-based small group learning	Live interactive TV	Videotape-based delivery
Rovai (2001)	Monthly face-to-face group meetings	Annual residencies face-to-face group meetings	Internet-based asynchronous learning network (ALN)	Internet-based ALN

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Stanley (2006)	Teacher-graded assignments	Automated quizzes	Online learning environment	Online learning environment
Walker & Donaldson (1989)	Two-way audio and graphics lecture presentation and discussion	Asynchronous videotape-based self-learning	AT&T Gemini 100 Electronic Blackboard LCMS	Videotape delivery
*Williams (2005)	Online self-learning with tutor available on demand	Online self-learning with no tutor available	Web-based computer mediated communication	Web-based computer-mediated communication
*Wise, Chang, Duffy, & Del Valle (2004)	High social presence learning environment	Low social presence learning environment	Web-based computer mediated communication	Web-based computer-mediated communication
*Worley (1991)	Live interactive instruction	Live interactive instruction	Two-way video and two-way audio	One-way video and two-way audio
*Yang (2002)	Structured discussion	Unstructured discussion	Web-based bulletin boards	Web-based bulletin boards
*Zhang (2004)	Teacher structures and moderated online collaboration	Peer controlled online collaboration	Cyberstats: comprehensive Web-based course ware	Cyberstats: comprehensive Web-based courseware
Zion, Michalsky, & Mevarech (2005)	Web-based instruction with meta-cognitive and motivational scaffolding	Web-based instruction with no scaffolding	Internet-based ALN	Internet-based ALN
		Student–content interaction		
*Alavi, Marakas, & Yoo (2002)	Distributed learning with advanced options for content manipulation	Distributed learning with limited options for content manipulation	Online learning environment with enhanced group support system technology	Online learning environment

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
Anderton (2005)	Online instruction with no goal planning and strategy monitoring and evaluation forms	Online instruction with the use of goal planning and strategy monitoring and evaluation forms	Online learning environment	Online learning environment
Bernard & Naidu (1992)	Correspondence instruction employing concept mapping	Correspondence instruction employing post-questioning	Correspondence	Correspondence
Cameron (2003)	Online self-learning	Online self-learning	Network simulation software	Static network diagramming software
Collins (2000)	Online self-study with access to a Web-based forum	Self-study with printed material	Web-based learning environment	Correspondence
Gulikers, Bastiaens, & Martens (2005)	Authentic learning environment: self-learning employing simulations	Nonauthentic learning environment: self-learning with no simulations	Buiten Dienst: Web-based learning environment	Web-based learning environment
Holmberg & Schuemer (1989)	Long assignments for every course unit	Medium length assignments for every course unit	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
Holmberg & Schuemer (1989)	Medium-length assignment every 2-course units	Short assignments every 2-course units	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
Holmberg & Schuemer (1989)	Long assignments for every course unit	Short assignments for every course unit	Correspondence: printed material with audiotapes	Correspondence: printed material with audiotapes
*Jordaan (1987)	Personalized instruction: Detailed study guide	Traditional: basic study guide	Correspondence	Correspondence

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Kohlmeier, McConathy, Cooksey Lindell, & Zeisel (2003)	Full-scale content: self-learning with completion of all lessons and case studies	Tailored content: self-learning with completion of selected lessons and case studies based on entry level	Computer-based learning environment	Computer-based learning environment
Lei, Winn, Scott, & Farr (2005)	Self-learning with two course CDs	Self-learning with one course CD	Computer-assisted instruction: CD-ROM	Computer-assisted instruction: CD-ROM
McKethan, Kernodle, Brantz, & Fischer (2003)	Video presentation supplemented with text description	Video presentation	Computer-assisted instruction	Computer-assisted instruction
*Miller & Pilcher (2002)	Self-learning with the supplement of videotaped study guide	Self-learning without the study guide supplement	Variety of DE learning environments	Variety of DE learning environments
Moshinskie (1997)	Live lecture presentation with content manipulation	Live lecture presentation and discussion	Two-way audio/graphics instruction	Two-way audio/video instruction
Schroeder (2006)	Multimedia enhanced instruction	Text-book-based self-learning	DE with printed and multimedia materials	DE with printed materials
Smith (1993)	Interactive self-learning	Passive self-learning	Computer-assisted instruction: interactive videodisc	Computer-assisted instruction: noninteractive videodisc
*Wallace, Grinnell, Carey, & Carey (2006)	High structure, high dialogue, low transactional distance learning condition	Low structure, low dialogue, high transactional distance learning condition	Web-based instruction	Web-based instruction

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
*Warrick (2005)	Facilitated group: small group online instruction with one facilitator per group	Mentored group: Online instruction with individualized mentor's support	Blackboard LCMS	Web-based learning environment
		Attitude data Student–teacher interaction		
Allen (1995)	Live interactive TV instruction	Self-study with video-taped instruction	Intercampus Interactive Telecommunication System (IITS): Interactive TV	Quality University Extended Site Telecourses: Video-taped instruction
Benbunan-Fich & Hiltz (2003)	Collaborative online learning with face-to-face communication	Collaborative online learning without face-to-face communication	Computer Mediated Communication collaborative learning environment	Computer Mediated Communication collaborative learning environment
Benke (2001)	Online instruction with high teacher immediacy	Online instruction with low teacher immediacy	Compressed Video Distance Education: telecommunication system with two-way audio and compressed two-way video	Compressed Video Distance Education: telecommunication system with two-way audio and compressed two-way video
Bore (2005)	Live video conferencing	Asynchronous Web-based instruction	Two-way videoconferencing	Web-based instruction
Boverie et al. (1997)	Live interactive TV instruction	In-class video-taped instruction	Interactive TV, one-way video, two-way audio	Video-taped instruction
Kuo (2005)	Video conferencing	Web-based instruction	Video conference–based delivery	Web-based course management courseware

(continued)

APPENDIX A (continued)

Study	Pedagogy (Experimental)	Pedagogy (Control)	Technology (Experimental)	Technology (Control)
Kurtz, Sagee, & Getz-Lengerman (2003)	Web-based interactive instruction with face-to-face communication	Web-based interactive instruction without face-to-face communication	Web-based learning environment	Web-based learning environment
		Student–content interaction		
Boucher & Barron (1986)	Computer marked course with elaborate prescriptive feedback	Computer marked course with minimal feedback	Computer-assisted correspondence course	Computer-assisted correspondence course
Little, Passmore, & Schullo (2006)	Additional Elluminate Live! (synchronous software) orientation session	No additional Elluminate Live! (synchronous software) orientation session	Blackboard Learning System: synchronous Web-based (Voice over Internet protocol) learning environment	Blackboard Learning System: synchronous (Voice over Internet protocol) learning environment
Murdock (2000)	Mastery study: computer-based instruction with extra remediation tasks	No treatment (control): computer-based instruction without extra remediation tasks	Computer-based and printed tutorial with e-mail correspondence	Computer-based and printed tutorial with e-mail correspondence
Suh (2004)	Synchronous interactive TV instruction	Asynchronous self-paced, Web-based instruction	Iowa Communication Network: interactive video system	Web course: Internet-based instruction
Sweeney-Dillon (2003)	Synchronous live interaction	Asynchronous Web-based instruction with online discussion forum	Synchronous two-way audio-visual instruction	Asynchronous Web-based instruction

APPENDIX B

Codebook of study features

1. Age
   a) Elementary (K–6)
   b) Secondary (7–12)
   c) Postsecondary
2. Subject matter
   a) Math (including statistics and algebra)
   b) Language (including language arts and second language learning)
   c) Physical and natural science (including biology, physics, chemistry, geology)
   d) Social sciences (including history, sociology, geography)
   e) Psychology
   f) Philosophy
   g) Computer science (information technology)
   h) Education
   i) Health sciences (including medicine, environmental health, and nursing)
   j) Business (including economics and management)
   k) Engineering
   l) Others (specify)
   m) Missing 999
3. Research Design
   a) Pre-experimental
   b) Quasi-experimental
   c) True experimental
4. Student–student interaction
   a) Experimental > Control
   b) Experimental = Control
   c) Experimental < Control
   d) Can't specify 999
5. Student–teacher interaction
   a) Experimental > Control
   b) Experimental = Control
   c) Experimental < Control
   d) Can't specify 999
6. Student–content interaction
   a) Experimental > Control
   b) Experimental = Control
   c) Experimental < Control
   d) Can't specify 999
7. Distance education mode experimental
   a) Synchronous
   b) Asynchronous
   c) Mixed

(continued)

APPENDIX B (continued)

8. Distance education mode control
   a) Synchronous
   b) Asynchronous
   c) Mixed
9. Technology use in two groups
   a) Same technology
   b) Different technology
10. Pedagogy use in two groups
    a) Same pedagogy
    b) Different pedagogy
11. Technology used in experimental (descriptive)
12. Technology used in control (descriptive)
13. Pedagogy used in experimental (descriptive)
14. Pedagogy used in control (descriptive)

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References

References marked with an asterisk are studies in the meta-analysis.

Abrami, P. C., & Bernard, R. M. (2008). *Statistical control vs. classification of study quality in meta-analysis*. Unpublished manuscript, Concordia University.

*Alavi, M., Marakas, G. M., & Yoo, Y. (2002). A comparative study of distributed learning environments on learning outcomes. *Information Systems Research*, *13*(4), 404–415.

*Allen, B. A. (1995). *Measurement of factors related to student and faculty satisfaction with video based and interactive television courses in distance learning (distance education).* Unpublished doctoral dissertation, the University of Alabama.

Allen, M., Bourhis, J., Burrell, N., & Mabry, E. (2002). Comparing student satisfaction with distance education to traditional classrooms in higher education: A meta-analysis. *American Journal of Distance Education*, *16*(2), 83–97.

Allen, M., Mabry, E., Mattrey, M., Bourhis, J., Titsworth, S., & Burrell, N. (2004). Evaluating the effectiveness of distance learning: A comparison using meta-analysis. *Journal of Communication*, *54*, 402–420.

Anderson, T. (2003a). Getting the mix right again: An updated and theoretical rationale for interaction. *International Review of Research in Open and Distance Learning*, *4*(2), 9–14.

Anderson, T. (2003b). Modes of interaction in distance education: Recent developments and research questions. In M. Moore (Ed.) *Handbook of Distance Education* (pp. 129–144). Mahwah, NJ: Lawrence Erlbaum.

*Anderton, E. K. (2005). *An evaluation of strategies to promote self-regulated learning in pre-service teachers in an online class.* Unpublished doctoral dissertation, University of South Alabama.

*Annetta, L. A. (2003). *A comparative study of three distance education strategies on the learning and attitudes of elementary school teachers participating in a professional development project.* Unpublished doctoral dissertation, University of Missouri–Saint Louis.

*Banks, L. V. (2004). *Brick, click, or brick and click: A comparative study on the effectiveness of content delivery modalities for working adults.* Unpublished doctoral dissertation, Touro University International.

Bates, A. (1990, September). *Interactivity as a criterion for media selection in distance education.* Paper presented at the Annual Conference of the Asian Association of Open Universities, Jakarta, Indonesia.

Beard, L. A., & Harper, C. (2002). Student perceptions of online versus on campus instruction. *Education*, *122*, 658–663.

*Beare, P. L. (1989). The comparative effectiveness of videotape, audiotape, and telelecture in delivering continuing teacher education. *American Journal of Distance Education*, *3*(2), 57–66.

*Bell, P. D., Hudson, S., & Heinan, M. (2004). Effect of teaching/learning methodology on effectiveness of a Web based medical terminology course? *International Journal of Instructional Technology & Distance Learning*, *1*(4). Retrieved July 24, 2007, from http://www.itdl.org/Journal/Apr_04/article06.htm

*Benbunan-Fich, R., & Hiltz, S. R. (2003). Mediators of the effectiveness of online courses. *IEEE Transactions on Professional Communication*, *46*(4), 298–312.

*Benke, D. A. (2001). *The relationship between teacher immediacy behaviors and student continued enrollment and satisfaction in a compressed-video distance education classroom.* Unpublished doctoral dissertation, University of Northern Colorado.

*Benson, D. S. (2005). *Comparison of learning style and other characteristics of site-based, hybrid and online students.* Unpublished doctoral dissertation, Arizona State University.

*Bernard, R. M., & Lundgren-Cayrol, K. (2001). Computer conferencing: An environment for collaborative project-based learning in distance education. *Educational Research and Evaluation*, *7*(2), 241–261.

*Bernard, R. M., & Naidu, S. (1992). Post-questioning, concept mapping and feedback: A distance education field experiment. *British Journal of Educational Technology*, *23*(1), 48–60.

Bernard, R. M., Abrami, P. C., Lou, Y., & Borokhovski, E. (2004). A methodological morass? How we can improve the quality of quantitative research in distance education. *Distance Education*, *25*(2), 176–198.

Bernard, R. M., Abrami, P.C., Lou, Y., Borokhovski, E., Wade, A., Wozney, L., et al. (2004). How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research*, *3*(74), 379–439.

Bernard, R. M., Rojo de Rubalcava, B., & St-Pierre, D. (2000). Collaborative online distance learning: Issues for future practice and research. *Distance Education*, *21*(2), 260–277.

*Beyth Marom, R., & Saporta, K. (2002). *Satellite based synchronous tutorials vs. satellite based asynchronous videocassettes: Factors affecting students' attitudes and choices.* Norfolk, VA: Association for the Advancement of Computing in Education.

*Bore, J. C. (2005). *Distance education in the preparation of special education personnel: An examination of videoconferencing and Web-based instruction.* Unpublished doctoral dissertation, University of North Texas.

Borenstein, M., Hedges, L. V., Higgins, J., & Rothstein, H. (2005). *Comprehensive meta-analysis* (Version 2). Englewood, NJ: Biostat.

*Boucher, T. A., & Barron, M. H. (1986). The effects of computer-based marking on completion rates and student achievement for students taking a secondary-level distance education course. *Distance Education*, *7*(2), 275–280.

*Boverie, P., Murrell, W. G., Lowe, C. A., Zittle, R. H., Zittle, F., & Gunawardena, C. N. (1997). *Live vs. taped: New perspectives in satellite-based programming for primary grades*. Albuquerque: University of New Mexico, College of Education, Organizational Learning and Instructional Technologies (ERIC Document No. ED407939).

*Brewer, S. A., & Klein, J. D. (2004, October). *Small group learning in an online asynchronous environment.* Paper presented at the 27th meeting of the Association for Educational Communications and Technology, Chicago.

*Britton, O. L. (1992). *Interactive distance education in higher education and the impact of delivery styles on student perceptions.* Unpublished doctoral dissertation, Wayne State University.

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge, MA: MIT Press.

*Caldwell, E. R. (2006). *A comparative study of three instructional modalities in a computer programming course: Traditional instruction, Web-based instruction, and online instruction.* Unpublished doctoral dissertation, University of North Carolina at Greensboro.

*Callahan, A., L., Givens, P., E., & Bly, R. (1998, June). *Distance education moves into the 21st century: A comparison of delivery methods*. Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Seattle, WA.

*Cameron, B. H. (2003). Effectiveness of simulation in a hybrid and online networking course. *Quarterly Review of Distance Education*, *4*(1), 51–55.

*Campbell, M., Gibson, W., Hall, A., Richards, D., & Callery, P. (2008). Online vs. face-to-face discussion in a Web-based research methods course for postgraduate nursing students: A quasi-experimental study. *International Journal of Nursing Studies*, *45*(5), 750–759.

*Cargile Cook, K. (2000). *Online technical communication: Pedagogy, instructional design, and student satisfaction in Internet-based distance education.* Unpublished doctoral dissertation, Texas Tech University.

Cavanaugh, C. S. (2001). The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis. *International Journal of Educational Telecommunications*, *7*, 73–88.

Cavanaugh, C. S., Gillan, K. J., Kromrey, J., Hess, M., & Blomeyer, R. (2004). *The effects of distance education on K-12 student outcomes: A meta-analysis*. Naperville, IL: Learning Point Associates.
*Chen, C. C., & Shaw, R. S. (2006). Online synchronous vs. asynchronous software training through the behavioral modeling approach: A longitudinal field experiment. *International Journal of Distance Education Technologies*, *4*(4), 88–102.
*Cheng, H. C. (1991). Comparison of performance and attitude in traditional and computer conferencing classes. *American Journal of Distance Education*, *5*(3), 51–64.
Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE Bulletin*, *39*(7), 3–6.
*Cifuentes, L., & Hughey, J. (2003). The interactive effects of computer conferencing and multiple intelligences on expository writing. *The Quarterly Review of Distance Education*, *4*(1), 15–30.
Clark, R. E. (2000). Evaluating distance education: Strategies and cautions. *Quarterly Review of Distance Education, 1*, 3–16.
*Collins, M. (2000). Comparing Web, correspondence and lecture versions of a second-year non-major biology course. *British Journal of Educational Technology*, *31*(1), 21–27.
Crawford, M. W. (1999). Students' perceptions of the interpersonal communication courses offered through distance education (Doctoral dissertation, Ohio University, 1999). *Dissertation Abstracts International*, *60*(05), 1469 (UMI No. 9929303).
*Daig, B. (2005). *Student performance in e-learning courses: The impact of course duration on learning outcomes.* Unpublished doctoral dissertation, Touro University International.
Daniel, J., & Marquis, C. (1979). Interaction and independence: Getting the mixture right. *Teaching at a Distance*, *15*, 25–44.
Daniel, J., & Marquis, C. (1988). Interaction and independence: Getting the mix right. In D. Sewart, D. Keegan, & B. Holmberg (Eds.), *Distance education: International perspectives* (pp. 339–359). London: Routledge.
*Davis, J. L. (1996). Computer-assisted distance learning, part II: Examination performance of students on & off campus. *Journal of Engineering Education*, *85*(1), 77–82.
*Frith, K. H., & Kee, C. C. (2003). The effect of communication on nursing student outcomes in a Web-based course. *Journal of Nursing Education*, *42*(8), 350–358.
Fulford, C. P., & Zhang, S. (1993). Perceptions of interaction: The critical predictor in distance education. *American Journal of Distance Education*, *7*(3), 8–21.
*Gallie, K. (2005). Student perceptions as distance learners in internet-based courses. *Studies in Learning, Evaluation, Innovation and Development*, *2*(3), 69–76.
Garrison, D. R., & Shale, D. (1990). A new framework and perspective. In D. R. Garrison & D. Shale (Eds.), *Education at a distance: From issues to practice* (pp. 123–133). Malabar, FL: Krieger.
Gilbert, L., & Moore, D. R. (1989). Building interactivity in Web-courses: Tools for social and instructional interaction. *Educational Technology*, *38*(3), 29–35.
*Grimes, P. W., Krehbiel, T. L., Nielson, J. E., & Niss, J. F. (1989). The effectiveness of "economics U$A" on learning and attitudes. *Journal of Economic Education*, *20*(2), 139–152.
*Gulikers, J. T. M., Bastiaens, T. J., & Martens, R. L. (2005). The surplus value of an authentic learning environment. *Computers in Human Behavior*, *21*(3), 509–521.

*Hansen, B. A. (2000). *Increasing person-environment fit as a function to increase adult learner success rates in distance education.* Unpublished doctoral dissertation, University of Wyoming.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Orlando, FL: Academic Press.

Holden, J. T., & Westfall, P. J.-L. (2006). *An instructional media selection guide for distance learning.* Boston: United States Distance Learning Association.

Holmberg, B. (2003). A theory of distance education based on empathy. In M. G. Moore (Ed.), *Handbook of distance education* (pp. 79–86). Mahwah, NJ: Lawrence Erlbaum.

*Holmberg, B., & Schuemer, R. (1989). Tutoring frequency in distance education: An empirical study of the impact of various frequencies of assignment submission. In B. Holmberg (Ed.), *Mediated communication as a component of distance education* (pp. 45–80). FernUniversität–Gesamthoschule, Hagen, West Germany: Zentrales Institut für Fernstudienforschung.

*Huett, J. B. (2006). *The effects of ARCS-based confidence strategies on learner confidence and performance in distance education.* Unpublished doctoral dissertation, University of North Texas.

Jahng, N., Krug, D., & Zhang, Z. (2007). Student achievement in online education compared to face-to-face education. *European Journal of Open, Distance and E-Learning.* Retrieved February 21, 2007, from http://www.eurodl.org/materials/contrib/2007/Jahng_Krug_Zhang.htm

Jaspers, F. (1991). Interactivity or instruction? A reaction to Merrill. *Educational Technology*, *31*(3), 21–24.

Johnson, D. W., Johnson, R. T., & Stanne, M. E. (2000). *Cooperative learning methods: A meta-analysis*. Minneapolis: University of Minnesota Press.

*Jordaan, W. (1987). *The effectiveness of personalised instruction in distance education: An empirical study*. Pretoria: University of South Africa. (ERIC Document No. ED293398)

Juler, P. (1990). Promoting interaction, maintaining independence: Swallowing the mixture. *Open Learning*, *5*(2), 24–33.

*Jung, I., Choi, S., Lim, C., & Leem, J. (2002). Effects of different types of interaction on learning achievement, satisfaction and participation in web-based instruction. *Innovations in Education and Teaching International*, *39*(2), 153–162.

Kanuka, H., & Anderson, T. (1999). Using constructivism in technology-mediated learning: Constructing order out of the chaos in the literature, *Radical Pedagogy*, *1*(2). Retrieved May 27, 2007, from http://radicalpedagogy.icaap.org/content/issue1_2/02kanuka1_2.html

*Karr, C. L., Weck, B., Sunal, D. W., & Cook, T. M. (2003). Analysis of the effectiveness of online learning in a graduate engineering math course. *Journal of Online Interactive Learning*, *1*(3). Retrieved July 24, 2007, from www.ncolr.org/jiol/archieves/2003/winter/3/ms02023_Karr

*Katz, Y. J. (2000). The comparative suitability of three ICT distance learning methodologies for college level instruction. *Educational Media International*, *37*(1), 25–30.

Keegan, D. (1996). *Foundations of distance education* (3rd ed.). London: Routledge.

*Kirschner, P. A., van den Brink, H., & Meester, M. (1991). Audiotape feedback for essays in distance education. *Innovative Higher Education*, *15*(2), 185–195.

*Kohlmeier, M., McConathy, W. J., Cooksey Lindell, K., & Zeisel, S. H. (2003). Adapting the contents of computer-based instruction based on knowledge tests maintains effectiveness of nutrition education. *The American Journal of Clinical Nutrition*, *77*(Suppl. 4), 1025–1027.

*Kuo, M. M. (2005). *A comparison of traditional videoconference-based, and Web-based learning environments* (ERIC Document Reproduction Service No. ED492707).

*Kurtz, G., Sagee, R., & Getz-Lengerman, R. (2003). Alternative online pedagogical models with identical contents: A comparison of two university-level courses. *Journal of Online Interactive Learning*, *2*(1). Retrieved July 24, 2007, from http://www.ncolr.org/jiol/archives/2003/summer/2/index.asp

Larreamendy-Joerns, J., & Leinhardt, G. (2006). Going the distance with online education. *Review of Educational Research*, *76*(4), 567–605.

Laurillard, D. (1997). *Rethinking university teaching: A framework for the effective use of educational technology.* London: Routledge.

*Lei, L. W., Winn, W., Scott, C., & Farr, A. (2005). Evaluation of computer-assisted instruction in histology: Effect of interaction on learning outcome. *Anatomical Record Part B, New Anatomist*, *284*(1), 28–34.

*Libler, R. W. (1991). *A study of the effectiveness of interactive television as the primary mode of instruction in selected high school physics classes.* Unpublished doctoral dissertation, Ball State University.

*Lilja, D. J. (2001). Comparing instructional delivery methods for teaching computer systems performance analysis. *IEEE Transactions on Education*, *44*(1), 35–40.

*Lim, D. H., Morris, M. L., & Kupritz, V. W. (2006, February). *Online vs. blended learning: Differences in instructional outcomes and learner satisfaction*. Paper presented at the Academy of Human Resource Development International Conference, Columbus, OH.

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis.* Thousand Oaks, CA: Sage.

*Little, B. B., Passmore, D., & Schullo, S. (2006). Using synchronous software in Web-based nursing courses. *Computers, Informatics, Nursing*, *24*(6), 317–325.

Lou, Y., Bernard, R. M., & Abrami, P. C. (2006). Media and pedagogy in undergraduate distance education: A theory-based meta-analysis of empirical literature. *Educational Technology Research & Development*, *5*(2), 141–176.

Machtmes, K., & Asher, J. W. (2000). A meta-analysis of the effectiveness of telecourses in distance education. *American Journal of Distance Education*, *14*(1), 27–46.

Mayer, R. (2001). *Multi-media learning.* Cambridge, UK: Cambridge University Press.

*McKethan, R. N., Kernodle, M. W., Brantz, D., & Fischer, J. (2003). Qualitative analysis of the overhand throw by undergraduates in education using a distance learning computer program. *Perceptual and Motor Skills*, *97*(3), 979–989.

*Miller, G., & Pilcher, C. L. (2002). Can selected learning strategies influence the success of adult distance learners in agriculture? *Journal of Agricultural Education*, *43*(2), 34–43.

Moore, M. G. (1973). Towards a theory of independent learning and teaching. *Journal of Higher Education, 44*(9), 661–679.

Moore, M. G. (1989). Three types of interaction. *American Journal of Distance Education*, *3*(2), 1–6.

Moore, M. G., & Kearsley, G. (2005). *Distance education: A systems view* (2nd ed.). Belmont, CA: Thompson/Wadsworth.

Moore, M. G., & Thompson, M. M. (1990). *The effects of distance learning: A summary of the literature* (Research Monograph No. 2). University Park: Pennsylvania State University, American Center for the Study of Distance Education. (ERIC Document Reproduction No. ED330321)

*Moshinskie, J. F. (1997). The effects of using constructivist learning models when delivering electronic distance education (EDE) courses: A perspective study. *Journal of Instruction Delivery Systems*, *11*(1), 14–20.

Muirhead, B. (2001a). Enhancing social interaction in computer-mediated distance education. *USDLA Journal*, *15*(4). Retrieved October 4, 2005, from http://www.usdla.org/html/journal/APR01_Issue/article02.html

Muirhead, B. (2001b). Interactivity research studies. *Educational Technology & Society*, *4*(3). Retrieved October 4, 2005, from http://ifets.ieee.org/periodical/vol_3_2001/muirhead.html

*Murdock, K. (2000). *Management of procrastination in distance education courses using features of Keller's personalized system of instruction.* Unpublished doctoral dissertation, University of South Florida.

Nipper, S. (1989). Third generation distance learning and computer conferencing. In R. Mason & A. Kaye (Eds.), *Mindweave: Communication, computers and distance education* (pp. 63–73). Oxford, UK: Pergamon.

Olson, T. M., & Wisher, R. A. (2002). The effectiveness of Web-based instruction: An initial inquiry. *International Review of Research in Open and Distance Learning*, *3*(2). Retrieved October 8, 2006, from http://www.irrodl.org/index.php/irrodl/article/view/103/561

*Ostiguy, N., & Haffer, A. (2001). Assessing differences in instructional methods: Uncovering how students learn best. *Journal of College Science Teaching*, *30*(6), 370–374.

*Paulsen, K. J., Higgins, K., Miller, S. P., Strawser, S., & Boone, R. (1998). Delivering instruction via interactive television and videotape: Student achievement and satisfaction. *Journal of Special Education Technology*, *13*(4), 59–77.

Peters, O. (2003). Learning with new media in distance education. In M. G. Moore (Ed.), *Handbook of distance education* (pp. 87–112). Mahwah, NJ: Lawrence Erlbaum.

Phipps, R., & Merisotis, J. (1999). *What's the difference? A review of contemporary research on the effectiveness of distance learning in higher education.* Washington, DC: Institute for Higher Education Policy.

*Romanov, K., & Nevgi, A. (2006). Learning outcomes in medical informatics: Comparison of a WebCT course with ordinary web site learning material. *International Journal of Medical Informatics*, *75*(2), 156–162.

*Rovai, A. P. (2001). Classroom community at a distance: A comparative analysis of two ALN-based university programs. *Internet and Higher Education, 4*(2), 105–118.

*Ruksasuk, N. (2000). *Effects of learning styles and participatory interaction modes on achievement of Thai students involved in Web-based instruction in library and information science distance education.* Unpublished doctoral dissertation, University of Pittsburgh.

Russell, T. L. (1999). *The no significant difference phenomenon.* Chapel Hill: Office of Instructional Telecommunications, North Carolina State University.

Salomon, G. (2000). *E-moderating the key to teaching and learning online.* London: Kogan Page.

*Schroeder, B. A. (2006). *Multimedia-enhanced instruction in online learning environments.* Unpublished doctoral dissertation, Boise State University.

Shachar, M., & Neumann, Y. (2003). Differences between traditional and distance education academic performances: A meta-analytical approach. *International Review of Research in Open and Distance Education.* Retrieved May 5, 2005, from http://www.irrodl.org/content/v4.2/shacharneumann.html

Sims, R. (1999). Interactivity on stage: Strategies for learner-designer communication. *Australian Journal of Educational Technology*, *15*(3), 257–272. Retrieved May 5, 2005, from http://www.ascilite.org.au/ajet/ajet15/sims.html

Sitzmann, T., Kraiger, K., Stewart, D., & Wisher, R. (2006). The comparative effectiveness of Web-based and classroom instruction: A meta-analysis. *Personnel Psychology*, *59*(3), 623–664.

*Skylar, A. A. (2004). *Distance education: An exploration of alternative methods and types of instructional media in teacher education.* Unpublished doctoral dissertation, University of Nevada, Las Vegas.

*Smith, J. J. (1993). The SPICE project: Comparing passive to interactive approaches in a video-based course. *The Journal*, *21*(1), 62–66.

*Stanley, O. L. (2006). A comparison of learning outcomes by 'in-course' evaluation techniques for an on-line course in a controlled environment. *Journal of Educators Online*, *3*(2), 1–16.

*Suh, Y. M. (2004). *Factors related to student satisfaction with Web and interactive television courses.* Unpublished doctoral dissertation, University of Iowa.

Sutton, L. A. (2001). The principle of vicarious interaction in computer-mediated communications. *International Journal of Educational Telecommunications*, *7*(3), 223–242. Retrieved March 14, 2005, from http://www.aace.org/dl/files/IJET/IJET73223.pdf

*Sweeney-Dillon, M. T. (2003). *Participant experience of distance education: Critical success factors.* Unpublished doctoral dissertation, Indiana University.

Thompson, G. (1990). How can correspondence-based distance education be improved? A survey of attitudes of students who are not well disposed towards correspondence study. *Journal of Distance Education/Revue de l'Enseignement à Distance*, *5*(1). Retrieved April 20, 2007, from http://cade.athabascau.ca/vol5.1/11_thompson.html

Thurmond, V. A., & Wombach, K. (2004). Understanding interactions in distance education: A review of the literature. *International Journal of Instructional Technology and Distance Learning*, *1*(1). Retrieved April 20, 2007, from http://itdl.org/journal/Jan_04/article02.htm

*Tuckman, B. W. (2007). The effect of motivational scaffolding on procrastinators' distance learning outcomes. *Computers & Education*, *49*(2), 414–422.

Ungerleider, C., & Burns, T. (2003). *A systematic review of the effectiveness and efficiency of networked ICT in education: A state of the field report to the Council of Ministers of Education, Canada and Industry Canada*. Retrieved April 19, 2007, from http://www.cmec.ca/stats/SystematicReview2003.en.pdf

Wagner, E. D. (1994). In support of a functional definition of interaction. *The American Journal of Distance Education*, *8*(2), 6–29.

*Walker, B., M., & Donaldson, J. F. (1989). Continuing engineering education by electronic blackboard and videotape: A comparison of on-campus and off-campus student performance. *IEEE Transactions on Education*, *32*(4), 443–447.

*Wallace, T., Grinnell, L., Carey, L., & Carey, J. (2006). Maximizing learning from rehearsal activity in Web-based distance learning. *Journal of Interactive Learning Research*, *17*(3), 319–327.

*Warrick, W. R. (2005). *The learner and the expert mentor, learners and a facilitator, peer-facilitated learning: A comparison of three online learning designs.* Unpublished doctoral dissertation, George Mason University.

What Works Clearinghouse. (2006). *What works clearinghouse study design classification* (Technical Working Paper). Washington, DC: U.S. Department of Education. Retrieved May 2, 2008 from http://ies.ed.gov/ncee/wwc/twp.asp

*Williams, P. B. (2005). *On-demand tutoring in distance education: Intrinsically-motivated, scalable interpersonal interaction to improve achievement, completion, and satisfaction.* Unpublished doctoral dissertation, Brigham Young University.

Williams, S. L. (2006). The effectiveness of distance education in allied health science programs: A meta-analysis of outcomes. *American Journal of Distance Education*, *20*(3), 127–141.

*Wise, A., Chang, J., Duffy, T., & Del Valle, R. (2004). The effects of teacher social presence on student satisfaction, engagement, and learning. *Journal of Educational Computing Research*, *31*(3), 247–271.

*Worley, E. N. (1991). Compressed digital video instructional delivery: A study of student achievement, student attitude, and instructor attitude. *Dissertation Abstracts International*, *53*(3-A), 710.

Yacci, M. (2000). Interactivity demystified: A structural definition for online learning and intelligent CBT. *Educational Technology*. Retrieved May 2, 2008, from http://www.it.rit.edu/~may/interactiv8.pdf

*Yang, Y.-T. C. (2002). *Use of structured Web-based bulletin board discussions with Socratic questioning to enhance students' critical thinking skills in distance education.* West Lafayette, IN: Purdue University.

*Zhang, K. (2004). *Effects of peer-controlled or externally structured and moderated online collaboration on group problem solving processes and related individual attitudes in well-structured and ill-structured small group problem solving in a hybrid course.* Unpublished doctoral dissertation, Pennsylvania State University.

Zhao, Y., Lei, J., Yan, B, Lai, C., & Tan, S. (2005). A practical analysis of research on the effectiveness of distance education. *Teachers College Record*, *107*(8). Retrieved February 22, 2007, from http://www.blackwell-synergy.com/doi/abs/10.1111/j.1467-9620.2005.00544.x

*Zion, M., Michalsky, T., & Mevarech, Z. R. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. *International Journal of Science Education*, *27*(8), 957–983.

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