This is the last version submitted for publication. Citation for the published article:

Lou, Y., Bernard, R.M., & Abrami, P.C. (2006). Media and pedagogy in undergraduate distance education: A theory-based meta-analysis of the empirical literature. *Educational Technology Research & Development, 54*(2), 141-176.

Media and Pedagogy in Undergraduate Distance Education: A Theory-Based Meta-Analysis of Empirical Literature

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Abstract

This meta-analysis employs a theoretical framework in quantitatively synthesizing empirical studies that investigate the effects of distance education (DE) versus classroom instruction on undergraduate student achievement. Analyses of 218 findings from 103 studies were conducted according to how media were used to support DE pedagogy. The results indicate that the effect sizes for synchronous instructor-directed DE were consistent and not significantly different from zero; in asynchronous DE, media only supporting independent learning was generally less effective than media supporting collaborative discussion among students, although both subsets were significantly heterogeneous. Follow-up analysis of asynchronous DE findings was framed in terms of three patterns of interaction — student-content, student-instructor and student-student.

Introduction

A longstanding debate in the educational technology literature is whether media or pedagogy makes technology-mediated learning more or less effective. Clark (1983, 1994) argues that pedagogical methods and the application of instructional design principles, rather than the medium used, are what impacts student learning. Others (e.g., Kozma, 1994; Ullmer, 1994; Cobb, 1997) argue that different media attributes make some types of learning easier with one medium than another. For example, television can present information in a dynamic and stimulating manner and therefore may be more appropriate for teaching concepts and skills such as learning a foreign language, where students may benefit most from vicarious experience. The media debate continues in the context of distance education (DE) research, where technology is required for content delivery and communication between students and instructors and among students. While Clark (2000, 2003) continues to argue that media do not influence learning, others (e.g., Smith & Dillon, 1999) claim that the media attributes do.

In an attempt to quantitatively synthesize empirical DE studies and identify moderating factors, we conducted a comprehensive meta-analysis of DE comparative studies published between 1985 and 2002 (Bernard et al. 2004). In total, 232 studies containing 688 independent achievement, attitude, and retention outcomes were analyzed. We coded and analyzed 51 study features in an attempt to identify moderating factors of DE effects. To estimate the relative importance of media, pedagogy, and methodological research quality, related study features were classified into the three respective blocks: 8 media features (e.g., use of two-way videoconferencing, use of the Web, and use of email), 10 pedagogy and course design features (e.g., systematic instructional design, problem-based learning, and instructor and student activities), and 13 methodology features (e.g., instructor equivalence, student equivalence, and class size equivalence). The three blocks of study features were entered in different orders and analyzed using weighted multiple regression (WMR).

The results of the WMRs revealed some interesting insights into the relative importance of these three sets of predictors. Methodological quality explained a significant amount of variance in both synchronous and asynchronous DE outcomes (49% and 12%, respectively, for achievement) when the block of 13 methodology study features was entered at step 1. Pedagogy explained a significant 10%-13% of variance whether entered at step 1 or after controlling for methodology quality. Media were only significant when entered at step 1. These results support Clark's (2000) view that research methodological quality often confounded studies on technology effects and that pedagogy features were more important than media in predicting student achievement. However, further examination of the individual predictors also showed that after controlling for methodology quality, a few media-related features significantly predicted DE student achievement. What is more puzzling is that while some media (e.g., use of one-way TV or video) predicted DE student achievement positively, some (e.g., use of telephone to contact the instructor) predicted DE student achievement negatively. These results suggest more intricate and complex relationships between media and pedagogy, calling for further analyses for better and more holistic understanding.

The purpose of this study is to extend the work in Bernard et al. (2004) to further explore the relationship between media and pedagogy in influencing DE student achievement using a theoretical framework. In particular, we attempt to identify how media were used to support different types of DE pedagogy, the relative effects of different types of media-supported DE pedagogy, how different types of interactions (Moore, 1989) were supported via media and pedagogy, and the relative impact of media and pedagogy on DE student achievement. In the following sections, we discuss the rationale for focusing on types of media-supported DE pedagogy and types of interaction as a framework in coding and analyzing the data in this study.

Types of DE Delivery Media and Pedagogy

DE delivery media have changed dramatically as technology has advanced. Nipper (1989) categorized them into three generations. First generation DE refers to the early days of print-based correspondence study. Characterized by the establishment of the Open University in 1969, second generation DE refers to the period when print materials were integrated with broadcast TV and radio, audio and video-cassettes, and increased student support. Third generation DE was heralded by the invention of Hypertext and the rise in the use of teleconferencing (i.e., audio and video). To this, Taylor (2001) adds the fourth generation, characterized by flexible learning (e.g., computer-mediated communication [CMC], Internet accessible courses) and the fifth generation (e.g., interactive multimedia online, Internet-based access to online resources). Generations three, four and five represent the potential for DE to move away from authoritarian and non-interactive courses to those involving a high degree of student control and two-way communication, as well as group-oriented processes and greater flexibility in learning.

Another way of categorizing DE is according to what pedagogy medium is used and its purpose. Is it used to support instructor-directed instruction, individualized learning, or collaborative discussion among the students? Traditionally, DE has been designed to support individualized self-directed learning (Keegan, 1996). This is true for the early correspondence model and the multimedia model that uses audio and videotapes. It is still true for some of the DE applications that use only Web-based resources. The individualized learning model affords the highest degree of flexibility for anytime, anywhere, and anyplace learning. However, because the individualized model is also low in interaction, successful completion requires a high degree of student autonomy and self-regulation (Moore, 1989). This model is mostly used in adult education, especially with students who are working full time, or otherwise would not have access to regular university instruction.

Instructor-directed two-way interactive satellite television and videoconferencing provide the closest resemblance to traditional classroom instruction (Simonson, Schlosser, & Hanson, 1999). In videoconferencing, the instructor usually teaches a class of students at the host site and one or more classes of students at the remote site or sites simultaneously. The advantage of this type of DE is that the instructor is able to observe immediately how students react to the instruction and to adjust if necessary, just as instructors regularly do in the classroom. This paradigm emerged on U.S. university campuses (e.g., Penn State) in the 1950s (i.e., closed-circuit television) and continues as a common pattern in higher education today.

The collaborative learning paradigm in DE is more recent. It is a result of both advances in CMC technology and a shift in education towards a more collaborative learning model. According to recent constructivist and cultural learning theories, learning occurs through interacting with others (Resnick, Levine, & Teasley, 1993). Greater effectiveness is achieved when students collaborate and learn from each other through discussions that challenge ideas and create multiple perspectives. The collaborative paradigm may use only CMC or CMC in combination with other delivery media such as Web-based resources or email.

The above categorization takes into account media attributes and the pedagogy they are used to support. This scheme may help explain the different effects across DE studies employing various media. It can also deal with the use of multiple media and overcomes the limitation of treating each medium as if it was used in exactly the same way. Depending on its use, broadcast television could facilitate asynchronous individualized instruction with repeatable tapes or streaming video, or synchronously in instructor-directed instruction with two-way audio. Similarly, Web-based DE could use Web-based resources alone for individualized learning or with CMC to facilitate collaborative discussion among students.

Types of Interaction in DE

Interaction is the defining component of all forms of education. Moore (1989) describes three types of interaction in DE that play important roles in student learning: student-content interaction, student-instructor interaction, and student-student interaction.

Student-content interaction refers to students interacting with the subject matter under study to construct meaning, relating it to personal knowledge, and applying it to solve problems. Student-content interaction may include reading informational texts, using study guides, watching videos, interacting with computer-based multimedia, and completing assignments and projects.

Student-instructor interaction traditionally focused on classroom-based dialogue between students and the instructor. In DE environments, student-instructor interaction may be synchronous through the telephone, videoconferencing, and chats, or asynchronous through correspondence, email, and discussion boards. Face-to-face interaction between students and instructors is also possible in some DE environments. According to Moore (1989; Moore &

Kearsley, 1996, 2005) and several other DE theorists (e.g., Anderson, 2003; Holmberg, 1989, 2003), student-instructor interaction facilitates student learning not only by providing cognitive guidance and feedback, but also motivational and emotional support.

Student-student interaction refers to interaction among individual students or among students working in small groups. In correspondence courses, this interaction is often absent. In later generations of DE, including two-way videoconferencing and Web-based courses, student-student interaction can be synchronous, as in videoconferencing and chatting, or asynchronous through discussion boards or email messaging. With DE becoming popular in mainstream education with on-campus students, student-student interaction may also include face-to-face contact. According to social theories of learning and distributed cognition (Salomon, 1993), student-student interaction is often desirable both for cognitive purposes and for motivational support.

Since Moore, some theorists have added several other types of interactions. For example, Hillman, Willis, and Gunawardena (1994) added learner-interface interaction. More recently, Anderson (2003) expanded the three types of interaction in DE to include instructor-instructor interaction, instructor-content interaction, and content-content interaction (e.g., automatic retrieval or updating of specific types of Web resources according to specific criteria). While 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.

Based on the framework just described, the research questions asked in this study are: 1) What are the major types of media-supported DE pedagogy studied in undergraduate DE and what is their relative effectiveness on student achievement? 2) How are the three key interactions (student-content, student-instructor, and student-student) supported by media and pedagogy in undergraduate DE studies and what is the relative impact of each on student achievement? and 3) In addition to interaction features, what other factors moderate undergraduate DE student achievement?

Method

Data Sources and Inclusion/Exclusion Criteria

This study is an extension of Bernard et al. (2004), which synthesized comparative DE studies on student achievement, attitudes, and retention at all levels of education, K-12, undergraduate, graduate, adult, military, and corporate training, from 1985 to 2002. The year 1985 was chosen as a cut-off since electronically mediated, interactive DE became widely available around that time. In this study, we focus on more intensive analyses of undergraduate achievement findings to further explore the complex relationship between media and pedagogy in moderating student achievement. There are two main reasons for selecting undergraduate achievement data only. First, this is one of the most common venues for DE/classroom comparisons. Second, there was a significant difference in the mean effect sizes for k-12 and undergraduate students (Bernard et al., 2004). It is expected that by analyzing a more focus set of data would allow us to better study the complex relationships between media and pedagogy in moderating student achievement. Our working definition of DE reads as follows:

- The semi-permanent separation (place and/or time) of student and instructor during planned learning events.
- The presence of planning and preparation of the learning materials, student support services, and the final recognition of course completion by an educational organization.

- The provision of two-way media to facilitate dialogue and interaction between the students and the instructor, and among students.

The studies included in this meta-analysis were a subset of those included in Bernard et al. (2004). The studies were located through a comprehensive search of publicly available literature from 1985 through December of 2002. Electronic searches were performed on the following databases: *ABI/Inform*, *Compendex*, *Cambridge Scientific Abstracts*, *Canadian Research Index*, *Communication Abstracts*, *Digital Dissertations on ProQuest*, *Dissertation Abstracts*, *Education Abstracts*, *ERIC*, *PsycInfo*, and *Social SciSearch*. Web searches were performed using Google, AlltheWeb, and Teoma search engines. A manual search was performed in *ComAbstracts*, *Educational Technology Abstracts;* in several distance learning journals, including *The American Journal of Distance Education, Distance Education, Journal of Distance Education, Open Learning,* and *Journal of Telemedicine and Telecare;* and in several conference proceedings, including *AECT, AACE, AERA, CADE*, *EdMedia*, *E-Learn*, *SITE*, and *WebNet.* In addition, the reference lists of several earlier reviews were examined for possible inclusions. Although search strategies varied depending on the tool used, generally, search terms included "distance education," "distance learning," "open learning" or "virtual university," AND ("traditional," "lecture," "face-to-face" or "comparison").

To be included in this meta-analysis, each study had to meet the following inclusion/exclusion criteria:

1. Each study had to have been conducted with undergraduate students.
2. Each study had to involve an empirical comparison of DE as defined in this meta-analysis (including satellite/TV/radio broadcast + telephone/e-mail, e-mail-based correspondence, text-based correspondence + telephone, Web/audio/video-based two-way telecommunication) with face-to-face classroom instruction (including lectures, seminars, tutorials, and laboratory sessions).
3. DE with some face-to-face meetings (less than 50%) was included. However, studies where electronic media were used to supplement regular face-to-face classes with the instructor physically present were excluded.
4. Each study had to report measured achievement outcomes for both experimental and control groups.
5. Studies with insufficient data for effect size calculations (e.*g*., with means but no standard deviations or no inferential statistics or no sample size) were excluded.
6. All studies had to be publicly available or archived.
7. The study had to be published or presented no earlier than 1985 and no later than 2002.
8. Studies comparing DE students' achievement results with national standards or norms rather than using experimental or quasi-experimental designs were excluded.
9. Outcome measures had to be the same or comparable. If the study explicitly stated that different exams were used for the experimental and control groups, the study was excluded.
10. The outcome measures had to reflect individual courses rather than whole programs. Thus, programs composed of many different courses, where no opportunity existed to analyze conditions and the corresponding outcomes for individual treatments, were excluded.
11. When data about a particular study were available from different sources (e.g., journal article and dissertation), although only the published source is referenced, additional data from the other source was used to make coding study features more detailed and accurate.

DE studies have been constantly criticized for their poor experimental control and research quality (e.g., Bernard, Abrami, Lou, & Borokhovski, 2004). One way to estimate best evidence in research synthesis is to use only randomized controlled experiments or rigorously controlled quasi-experimental studies (What Works Clearinghouse, 2002). Due to limited number of randomized studies in the DE comparative literature, however, this does not seem to be an optimal choice for our synthesis. Furthermore, we believe that there are a number of other methodological quality factors such as instructor equivalence or class size equivalence that may moderate DE study results. Another way to control for study quality is to code and analyze study quality as study features (Evidence for Policy and Practice Information and Coordinating Centre, 2004), and model variability under various research conditions (Gene Glass in his recent interview with Robinson, 2004). We chose the latter approach in this synthesis, as we did in Bernard et al. (2004). Specifically, we included all comparative studies that met the above inclusion and exclusion criteria. To control for study quality, we coded 13 methodology features, modeled variability, and controlled for quality differences via weighted multiple regression techniques, which are described in detail in Study Features Coding and Data Analysis.

Each of the retrieved studies was read by two researchers for possible inclusion using the above inclusion/exclusion criteria. Any study that was considered for exclusion by one researcher was cross-checked by the other researcher.

Effect Size Extraction

The basic index for the effect size calculation is the mean of the experimental group (DE) minus the mean of the control group (traditional face-to-face instruction) divided by the pooled standard deviation:

$$d_i = \frac{\overline{Y}_{Experimental} - \overline{Y}_{Control}}{S_{pooled}} \qquad (1)$$

Cohen's *d* was converted to Hedges' *g* (i.e., unbiased estimate) using Equation 2 (Hedges & Olkin, p. 81):

$$g_i \cong (1 - \frac{3}{4N-9})d_i \qquad (2)$$

When sample sizes in a study are small, removing of sampling bias via Equation 2 tends to result in a slightly smaller sample effect size. For example, according to Hedges and Olkin (1985), suppose a study with $n^E = n^C = 10$ yields a sample effect size value of 0.60. Using Equation 2, the unbiased estimate would be 0.57. The difference between *d* and *g* tends to be smaller as N gets larger and they are essentially the same estimator in large samples.

Effect sizes extracted from data in forms such as *t*-tests, *F*-tests, *p*-levels and frequencies were computed via conversion formulas provided by Glass, McGaw and Smith (1981) and Hedges, Shymansky and Woodworth (1989). These effect sizes as well as those calculated from descriptive statistics were referred to in coding as "calculated effect sizes."

In the case of studies reporting only a significance level, effect sizes were estimated (e.g., $t = 1.96$ for $\alpha = .05$). In the case of studies reporting no significant difference without information on direction of effects, we used an estimated effect size of zero; when the direction was reported for no significant difference, a "midpoint" approach was taken to estimate a representative *t*-value (i.e., midpoint between 0 and the critical *t*-value for the sample size to be significant) (Sedlmeier & Gigerenzer, 1989) (e.g., the midpoint for $t = 1.96$ for $\alpha = .05$ would be 0.98). The rationale for estimating effect sizes from no-significant-difference results was to avoid bias toward more positive results in reporting.

The unit of analysis was the independent study finding. Only one achievement finding was extracted from each study unless they represented different participants (e.g., results from two courses for different groups of students). For repeated measures for the same group of participants and other situations such as more than one control condition, the following rules governed the extraction of findings to resolve dependency problems:

- When multiple achievement data were reported (e.g., assignments, midterm and final examinations, GPAs, grade distributions), final examination scores were used in calculating effect sizes.
- When there was more than one control group and groups did not differ considerably, the weighted average of the two conditions was used.
- If only one of the control groups could be considered “purely” control (i.e., classical face-to-face instructional mode), while others involved some elements of DE treatment (e.g., originating studio site), the former was used as the control group.
- In studies in which there were two DE conditions and one control condition, the weighted average of the two DE conditions was used.
- In studies in which instruction was simultaneously delivered to an originating site and remote sites (e.g. two-way videoconferencing), the originating site was considered to be the control condition and the remote site(s) the DE condition.

Outcomes and effect sizes from each study were extracted by two researchers independently and then compared for reliability. The inter-coder agreement rate was 91% for the number of effect sizes extracted within a study and 95% for effect size calculation.

Study Features Coding

Initial Coding

A comprehensive codebook was initially developed based on several prior reviews (e.g., Phipps & Merisotis, 1999), meta-analyses (e.g., Cavanaugh, 2001), conceptual papers (e.g., Smith & Dillon, 1999), and critiques (e.g., Saba, 2000). A sample of studies was then nomologically coded to identify salient study features present in the literature in order to avoid researcher bias (Abrami, Cohen, & d'Apollonia, 1988). The codebook was revised as a result of sample coding and a better understanding of the literature and the issues drawn from it (for the detailed codebook, see Bernard et al., 2004). The final codebook included:

- Thirteen research methodology quality study features: (a) type of publication, (b) type of measure, (c) effect size (i.e., calculated or estimated), (d) treatment duration, (e) treatment time proximity, (f) instructor equivalence, (g) selection bias, (h) time-on-task equivalence, (i) material equivalence, (j) learner ability equivalence, (k) mortality, (l) class size equivalence, and (m) gender equivalence.
- Eight media features: (a) use of one-way audio conferencing, (b) use of two-way video-conferencing, (c) use of computer-mediated communication (CMC), (d) use of e-mail, (e) use of one-way TV or video- or audiotape, (f) use of the Web, (g) use of a telephone, and (f) use of computer-based instruction (CBI).
- Nine pedagogical coded study features: (a) systematic instructional design procedures used, (b) advance course information given to DE students, (c) opportunity for face-to-face (F2F) contact with the instructor, (d) opportunity for mediated communication (e.g., e-mail, CMC) with the instructor, (f) opportunity for mediated communication among students, (g) student/instructor contact encouraged through activities and course design, and (i) use of problem-based learning or project-based learning (PBL).
- Two institutional features: (a) institutional support for instructor, and (b) technical support for students.

- Eleven demographic features: (a) cost of course delivery, (b) purpose of offering DE, (c) instructor experience with DE, (d) instructor experience with technology used, (e) student experience with DE, (f) student experience with technologies used, (g) types of control learners, (h) types of DE learners, (i) setting, (j) subject matter, and (k) average age.

Recodings and Conceptualization of Blocks of Interaction Features for this Study

A new study feature, *type of media-supported DE pedagogy,* was coded through examining the set of media and related pedagogy used in a study together. Whether media were employed to support instructor-directed learning, only individualized learning, or collaborative discussion among students were determined based on several related constructs of one-way and two-way communication, interactivity between instructor and students and among students, synchronicity or asynchronicity of communication, and flexibility for active and individualized learning. The specific recodings were as follows:

1. *Instructor-Directed.* Studies were coded as instructor-directed when synchronous videoconferencing, one-way satellite TV broadcast with two-way synchronous audio, or audiographics were used to deliver teacher-directed instruction and there was no report of discussion among students or group activities.
2. *Independent.* Studies were coded as encouraging independent learning when only asynchronous one-way TV, video tapes, and/or Web-based resources were used and there was no report of discussion among students or group activities.
3. *Discussion among Students.* Studies were coded as encouraging discussion among students when discussion board, email, listserv, audio-conferencing, telephone, or chat was used for collaborative discussion among students.

To assess the impact of the three key interactions in DE according to Moore (1989), we conceptualized three blocks of study features (combinations of pedagogy and media) that can potentially support student achievement through three kinds of interactions: student-content, student-instructor, and student-student. Each of the blocks contained four potential predictors. Table 1 presents the operational definitions of each interaction block and the study features included in each block as well as those related to demographic and methodology quality.

Table 1.
Blocks of Study Features Analyzed in Multiple Regression Modeling

Study features included in each block	Description
Student-content interaction	*Media or pedagogy that potentially support student interaction with the subject matter under study to construct meaning, relate it to personal knowledge, and apply it for solving problems*
a) Systematic instructional design (ID)	Were conventional instructional design practices and principles used in developing the course and course materials?
b) Use of one-way broadcast TV or videotape	Was broadcasting TV or videotape used to deliver instruction?
c) Use of computer-based instruction (CBI)	Was computer-based tutorials or simulations used as part of instructional materials?
d) Use of Web-based course materials	Was Web-based course materials used to deliver instruction?
Student-instructor interaction	*Media or pedagogy that potentially support dialogue between*

	students and the instructor
a) Opportunity for face-to-face meetings with instructor	Did DE students have opportunities to meet the instructor face-to-face during instruction, at an orientation session only, or have no opportunity?
b) Provision for synchronous technology-mediated communication with instructor	Were the instructor and students able to communicate synchronously using telephone, video-conferencing, or chats?
c) Use of asynchronous CMC with students	Did the instructor participate in asynchronous discussion with students via discussion board, listserv, or use email to communicate with students?
d) Activities that encourage student-instructor interactions	Was student-instructor contact encouraged through course activities or by course design? Indicators of "contact encouraged" include things like: regularly scheduled office hours, class discussions, one-on-one tutoring by instructor, survey data where students rate degree of contact with teacher, etc.
Student-student interaction	*Media or pedagogy that potentially support interaction among individual students or among students working in small groups*
a) Opportunity for face-to-face contact with other students	Did DE students have opportunities to meet other students face-to-face during instruction, at an orientation session only, or have no opportunity?
b) Provision for synchronous technology-mediated communication with other students	Were students able to communicate synchronously using telephone, video-conferencing, or chats?
c) Use of asynchronous CMC with other students	Did students participate in asynchronous discussion with other students via discussion board, listserv, or email?
d) Activities that encourage student-student interactions	Was student-student contact encouraged through course activities or by course design? Indicators of "contact encouraged" include things like group projects, group discussions, group chats, peer-tutoring, CMC, and etc.
Demographic and Context	
(a) Subject matter	What subject matter was being studied?
(b) Advance information about course	Did DE students receive information on things like equipment needs, techniques for succeeding in DE environment, technical information prior to the commencement of the course?
(c) Purpose of offering DE	What was the reason given by the course developers as to why the distance delivery option was made available? Possible reasons include: flexibility of schedule or travel, preferred media approach, access to expertise, efficient delivery or cost savings.
(d) Instructor experience with DE	Did the instructor have experience with DE?
(e) Instructor experience with technologies used	Did the instructor have experience with the technologies used in the DE course?

Methodology Quality Features	
(a) Type of publication	Was the study published journal articles or unpublished reports and dissertations?
(b) Outcome measure	Was the achievement outcome measured using standardized tests or teacher/researcher-made tests?
(c) Effect size estimation	Was effect size estimated from significance level or calculated?
(d) Treatment duration	Was the treatment less than one semester, one semester, or more than one semester?
(e) Treatment proximity	Was the compared data collected for both the control and experimental conditions over the same period of time?
(f) Instructor equivalence	Did the same instructor teach both the experimental and control conditions?
(g) Student equivalence	Was randomized experimental design or quasi-experimental design used to control for student equivalence across experimental and control conditions?
(h) Material equivalence	Did the DE and control students use the same instructional materials?
(i) Class size equivalence	Was the average DE class size larger, equal to, or smaller than the average control class size?
(j) Gender equivalence	Was the gender mix in the DE condition more male, equally mixed, or less male than that in the control condition?

Note: Several study features were not included due to almost no variability or over 90% missing data. These are: "use of PBL" in student-content interaction; "institutional support for instructors", "technology support for students", "student experience with DE", and "student experience with technology" in demographic and context; and "attrition ratio", "material equivalence", and "student ability equivalence" in research methodology quality.

"Asynchronous CMC with the instructor" and "asynchronous CMC with other students" were recoded from "use of CMC" and "use of email" study features in order to differentiate: whether media were for student use or instructor use; and whether CMC were asynchronous discussion board or synchronous chat.

Study features were coded by two researchers independently and then compared for reliability. The inter-coder agreement rate was 88.71% for the initial coding and 89.30% for the additional coding done for this study. Disagreements between two coders were resolved through discussion and further review of the disputed studies.

Data Analysis

Hedges and Olkin's (1985) homogeneity procedures were employed in aggregating and analyzing the effect sizes. Each effect size was weighted by the inverse of its sampling variance. Equation 3 was used in calculating the variance, and Equation 4 the weighting factor (Hedges & Olkin, 1985, p. 174):

$$\sigma^2_d = \frac{n_E + n_c}{n_E n_C} + \frac{d^2}{2(n_E + n_C)} \tag{3}$$

$$W_i = \frac{1}{\sigma^2_d} \tag{4}$$

Thus, more weight was given to findings that were based on larger sample sizes. The weighted effect sizes were then aggregated to form an overall weighted mean estimate of the treatment effect (*g*+). The significance of the mean effect size was judged by its 95% confidence interval. A significantly positive (+) mean effect size indicates that the results favor DE conditions; a significantly negative (–) mean effect size indicates that the results favor traditional classroom-based instruction.

To determine whether the findings in each dataset shared a common effect size, the set of effect sizes was tested for homogeneity by the homogeneity statistic (Q_T). When all findings share the same population effect size, Q_T has an approximate χ^2 distribution with $k - 1$ degrees of freedom, where *k* is the number of effect sizes. If the obtained Q_T value was larger than the critical value, the findings were determined to be significantly heterogeneous, meaning that there was more variability in the effect sizes than chance fluctuation would allow. Outlier analysis was conducted following the homogeneity statistics reduction method of Hedges and Olkin (1985). No outliers were identified.

Study feature analysis was then performed using weighted least squares regression analysis to identify potential predictors of student achievement, especially the ones related to the theoretical constructs and prior empirical evidence. Synchronicity was analyzed first, since Bernard et al. (2004) found that synchronous DE was different from asynchronous DE. Next, we examined the effects of different types of media-supported DE pedagogy (i.e., instructor-directed, independent, and collaborative discussion among students).

Blocks of student interaction study features were analyzed using weighted multiple regression (WMR). To control for study quality, each block was assessed on the second step of multiple regression analysis after variance due to research methodology had been removed. The blocks of demographic and contextual features were also analyzed in the same way as with the interaction blocks. The relative contribution of each block after controlling for methodology was measured using R^2 change. Significance of the individual study features in each of the blocks was assessed using the individual β for each predictor, and the standard errors were corrected according to Hedges and Olkin (1985, p. 174). The significance of β was evaluated using t = 1.96 (Hedges & Olkin, 1985, p. 172).

Finally, to develop a model of all predictors, a hierarchical multiple regression analysis was run. At Step 1, the block of methodology features was entered first to control for variance due to research quality; at Step 2, all 14 student interaction study features were entered to control for shared variance among the predictors; and at Step 3, the block of 5 demographic and contextual study features were entered to account for any additional variance. Data-analyses were conducted using a meta-analysis software, *Comprehensive Meta-Analysis*™ (Biostat) and *SPSS*™ (version 11).

Results

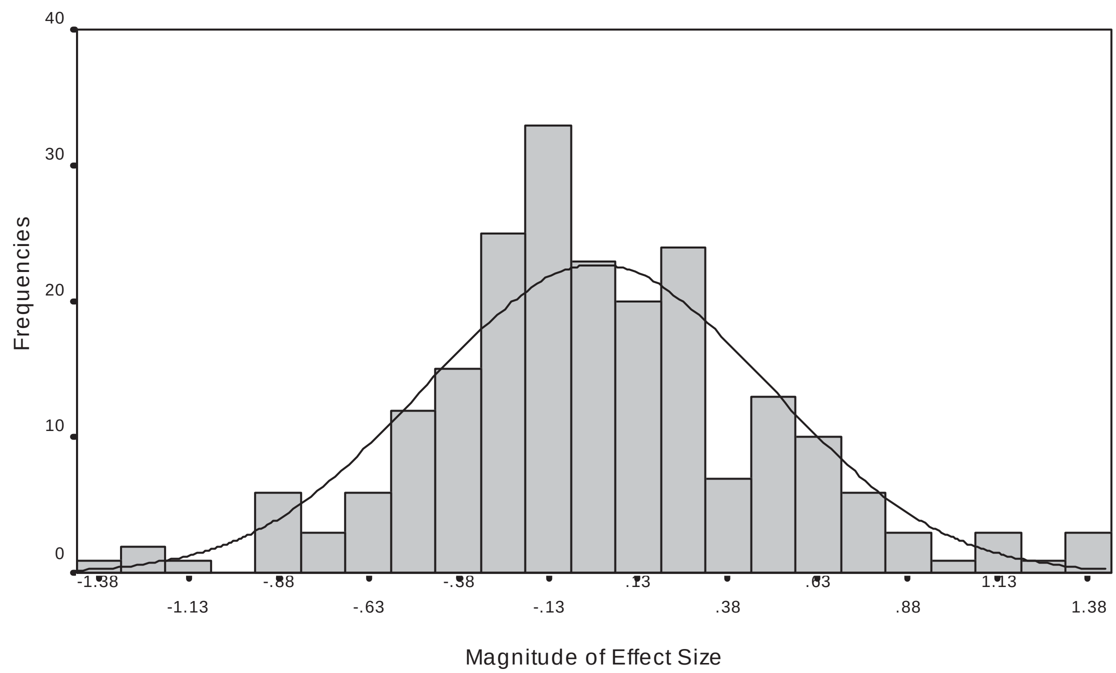
Overall Effects

In total, 218 independent findings from 103 studies representing 25,320 students were analyzed in the undergraduate dataset in this meta-analysis. On average, undergraduate students achieved similarly, whether they learned in DE courses or in the traditional classrooms (*g*+ = 0.016; 95% CI=-0.012/+0.044). The overall homogeneity statistics ($Q_T = 824.3483$, $p < .05$) indicate that the findings are significantly heterogeneous, suggesting that the mean effect size is not representative of all the findings analyzed and that the magnitude of effects may be moderated by study features. Figure 1 presents the distribution of the 218 effect sizes. While the approximately normal distribution confirms that there are no outliers in the findings, it shows a huge range of about three standard deviations from the lowest negative effect size of -1.38 favoring classroom instruction to the highest positive effect size of +1.38 favoring DE instruction. The distribution also indicates that about half of the effect sizes demonstrating small to large positive effect sizes favoring DE and about half showing small to large negative effect sizes favoring classroom instruction.

General Description of the Findings Included

Of the 218 findings included, 76 were from published journal articles, 101 from conference reports, and 41 from dissertations. For student equivalence across conditions, 11 findings used randomized experimental design, 19 were quasi-experimental designs with statistical control, and 92 did not report student equivalence across conditions. In 83% of the findings, DE and classroom courses were taught by the same instructor in the same semester. In about two thirds of the findings, the same instructional materials were used in the two conditions.

Figure 1
Distribution of the Effect Sizes of DE Compared to Classroom Teaching with Undergraduate Students



In about half of the studies, class sizes were similar in the DE and classroom conditions; in one sixth of the findings, DE class sizes were larger than those of control classes; and in one third of the findings, DE class sizes were smaller than those of the control classes. About one sixth of the findings reported similar gender makeup in the DE and control classes and three reported more female students in the DE classes. About two thirds of the findings were calculated from descriptive or inferential statistics and one third were estimated from significance levels. Effect sizes calculated from more complete data were slightly more positive than those estimated from significance or non-significance levels. This is expected because of common researchers' bias in more complete reporting of positively significant results. The sample sizes in the studies ranged from 13 to 1,936 students with a median of 104.

In total, 58 of the findings used synchronous media to deliver DE and classroom instruction simultaneously, and 122 used asynchronous media. In about one-fifth of the findings, students had opportunity to meet face to face with their instructors; and in one-tenth, students met with their instructors prior to, or at the commencement of, instruction only (e.g., orientation session). In more than one-third of the findings, students had opportunities to meet face to face with their peers during instruction; and in one tenth, peer meetings were limited to orientation sessions only. About one third of the findings reported provision of synchronous technically-mediated communication with the instructor, and one-fourth with students. In several studies, teacher-student and student-student contact was more encouraged in the DE classes than the control classes; in several others, the reverse was the case. A variety of media was used, including audio conferencing, one-way TV or video, discussion board, email, chat, telephone, Web, and CBT. Some studies used one medium only (e.g., video conferencing or Web materials) and some used several media (e.g., audio conferencing with one-way TV; Web materials with discussion board and chat).

The studies were conducted in a variety of subject areas: 14 in math; 57 in language courses; 50 in science, computer science, and computer applications; and 69 in social sciences and medicine. Few studies reported institutional support for instructors or technical support for students, instructor experience with DE or with technologies used, or student experience with DE or with technologies used.

Synchronous vs. Asynchronous DE

Data were first split into synchronous and asynchronous findings. The results are presented in Table 2. In synchronous DE, instruction was given by the same instructor in the host classroom and one or more remote sites simultaneously via two-way video conferencing or one-way video plus two-way audio. In each case, a comparison was made between the remote and the host sites. In most cases, the same curriculum materials were used across conditions. The weighted mean effect size for the 58 synchronous DE findings was -0.023 (95% confidence interval was – 0.088 to +0.043), indicating that the achievement outcomes were similar for remote and host students. Homogeneity statistics (Q_w = 70.536, p>.05) indicate that the effect sizes are consistent across the findings and that the mean effect size is a good measure of all the 58 synchronous DE findings integrated.

Table 2.
Weighted Mean Effect Sizes for Synchronous and Asynchronous DE in the Undergraduate Studies

Study Features	*k*	*g+*	95% CI	Q_w
Synchronous	58	-0.023	-0.088/+0.043	70.536
Asynchronous	122	+0.058	+0.025/+0.092	615.374*
Unknown	38	–0.081	–0.161/–0.002	82.658*

*p < .05

In asynchronous DE, a variety of delivery media were used. For example, some used Web-based resources, some used online course management systems with discussion board, some used listserv, and some used broadcasting TV or videotapes. The instruction in asynchronous DE was not simultaneously tied to a face-to-face host classroom, although in some cases real-time text-based chat may have been used for communication among students, or between students and the instructor. The weighted mean effect size for the 122 asynchronous DE findings was +0.058 (95% confidence interval was +0.025 to +0.092), indicating a small but significantly positive effect favoring DE students over classroom students. Homogeneity statistics (Q_w = 615.374, p <.05) indicate that the effect sizes are significantly heterogeneous, suggesting that the mean effect size may not be representative of the findings integrated and that other study features may moderate the magnitude of the effect sizes.

Types of Media-Supported DE Pedagogy

Table 3 presents the results of three major types of media-supported DE pedagogy in the undergraduate data: 1) instructor-directed, 2) independent, and 3) discussion among students. The first category contains the majority of the synchronous DE findings, which used synchronous videoconferences or TV plus two-way audio conferencing with the instructor, without reporting any student-student activities. The results show that the mean effect size for the 49 findings that employed synchronous instructor-directed DE pedagogy was not significantly different from zero ($g+$ = -0.038, 95% confidence interval was -0.108 to +0.032), indicating comparable achievement for students learning in the remote site(s) and the host site. Homogeneity statistics ($Q_w = 53.48$, $p>.05$) indicate that the effect sizes are consistent across the findings. These results are very similar to the results of the overall synchronous data reported in Table 2. Comparison of the means and confidence intervals indicate considerable overlap of the confidence intervals but studies employing instructor-directed pedagogy only showed more negative effect sizes than the overall synchronous data.

Table 3.
Weighted Mean Effect Sizes for Three Types of DE Pedagogy in Undergraduate Studies

DE Pedagogy	*k*	*G+*	95% CI	Q_W
Instructor-directed	49	–0.038	–0.108/+0.032	53.48
Independent	41	–0.038	-0.086/+0.011	223.143*
Discussion among students	30	+0.109	+0.030/+0.188	165.278*

*$p < .05$

The second category included 41 findings that used only asynchronous TV broadcasting, taped TV programs, or Web-based course materials that encouraged independent learning. The mean effect size was not significantly different from zero ($g+$ = -0.038, 95% confidence interval was -0.086 to +0.011), indicating comparable achievement between DE students and classroom students. Homogeneity statistics ($Q_w = 223.143$, $p <.05$) indicate that the effect sizes are significantly heterogeneous, suggesting that the mean effect size may not be representative of the findings integrated and that other study features may moderate the magnitude of the effect sizes.

The third category included 30 findings that employed media to support discussion among students in asynchronous DE. The majority of the findings used Web-based course materials plus asynchronous CMC such as discussion board, email, and listserv. The mean effect size was significantly positive ($g+$ = +0.109, 95% confidence interval was +0.030 to +0.188), indicating superior achievement of DE students over classroom students. Homogeneity statistics ($Q_w = 165.278$, $p <.05$) indicate that the effect sizes are significantly heterogeneous, suggesting that the mean effect size may not be representative of the findings integrated and that other study features may moderate the magnitude of the effect sizes. Because homogeneity statistics indicate that effect sizes in both sets of the asynchronous DE findings were significantly heterogeneous, multiple regression modeling was conducted with asynchronous DE findings to further explore moderating factors.

Multiple Regression Modeling of Interaction and Demographic Features in Asynchronous DE

Methodology Features. In the WMR analysis, the set of 10 methodology features with sufficient variability was first entered as a block to control for variance due to study quality.

Table 4 presents the results of the WMR analyses. Methodology differences accounted for 10.81% of total variance in the asynchronous DE findings.

Table 4.
Results of WMR Analyses: Comparison of R^2 Change for Blocks of Study Feature Predictors Related to Three Key Interactions and Demographics in Asynchronous DE

Blocks of Predictors	*Total R^2*	*R^2 Change*	*Significant Predictors*	$\beta_{Adjusted}$
Methodology (10 items at Step 1)	10.81%	N/A	N/A	N/A
Student-content (4 items at Step 2)	13.51%	2.70%	• CBI • TV or videotape	+0.20* +0.17*
Student-instructor (4 items at Step 2)	20.09%	9.28%	• Student-instructor activities encouraged • Face-to-face meetings with instructor	+0.25* +0.29*
Student-student (4 items at Step 2)	17.97%	7.16%	• Face-to-face contact with other students • Asynchronous listserv or discussion board or email with other students	+0.32* +.13*
Demographics and context (5 items at Step 2)	21.96%	11.15%	• Advance information about course	+0.39*

$*p < .05$

Interaction Features. After variance due to methodology quality was removed, each of the three interaction blocks was entered at Step 2 of each regression. Student-content interaction features accounted for 2.70% of the total variance after controlling for methodology quality. Two media features, "use of CBI" and "use of one-way broadcasting TV or videotape", significantly predicted DE student achievement ($\beta_{Adjusted}$ = +0.20 and +0.17, respectively). "Web-based course materials" and "systematic instructional design" were not significant due to their correlation with the two significant predictors.

Student-instructor interaction features accounted for 9.28% of the total variance after controlling for study quality. Two pedagogical design features, "student-instructor activities" and "opportunity for face-to-face meetings with instructor", significantly predicted DE effects ($\beta_{Adjusted}$ = +0.25 and +0.29, respectively). "Instructor participation in asynchronous communication with students" (e.g., listserv, discussion board forums, and email) and "instructor participation in synchronous communication with students" (chat and telephone) were not significant, but each was significantly correlated with the significant predictor, "student-instructor activities".

Student-student interaction features accounted for 7.16% of total variance after controlling for study quality. The significant predictors in the student-student interaction block were similar to those in the student-instructor interaction. They are: "opportunity for face-to-face contact with other students" and "participation in asynchronous listserv or discussion board forums with other students" (β= +0.32 and +0.13, respectively). Another study feature, "student-student activities", was not significant due to its correlation with the significant predictor, "asynchronous discussion with other students".

Demographic and Context Features. The five demographic and context features accounted for 11.15% of total variance after controlling for study quality. Of the five features entered, only one feature, "advance information about DE courses" significantly predicted DE effects. The other four demographic and context features, "subject matter", "purpose of offering DE", "instructor experience with DE", and "instructor experience with technologies used" were not significant.

Hierarchical Multiple Regression. A hierarchical multiple regression analysis with all predictors was run to estimate unique variance accounted for by each block and overall variance explained by the model of all predictors. After variance due to research methodology was removed, the 12 interaction predictors accounted for 14.57% of the total variance, indicating some co-linearity among the three blocks, especially student-instructor interaction features and student-student interaction features. After variance due to methodology and student interactions was removed, five demographic and contextual features accounted for an additional 8.82% of the total variance. Together, the model accounted for 34.21% of the total variance. Homogeneity statistics (Q_E = 405.00, df = 94, $p < .05$), indicate that a significant amount of variance remains unexplained, suggesting that other features not analyzed may account for additional variance.

Discussion

The results of this review indicate that types of media-supported DE pedagogy and types of interactions provide a useful framework for synthesizing DE comparative studies and understanding the variability in the findings. Discussion of the findings is organized into the following sections: a) synchronous instructor-directed DE, b) asynchronous independent DE and student-content interaction, c) discussion among students and student-student interaction in asynchronous DE, d) student-instructor interaction in asynchronous DE, e) DE student readiness, f) strengths and limitations of the meta-analysis, g) recommendations for DE practice; and h) recommendations for DE technology design and research.

Synchronous Instructor-Directed DE

The majority of the undergraduate studies providing synchronous DE findings used two-way video conferencing to support instructor-directed DE pedagogy. Based on the finding of homogeneity of effect sizes, there is consistent and reliable evidence that undergraduate students achieved equally, whether they learned in the remote site(s) or the host site. This finding is important. In the Bernard et al. (2004) meta-analysis, where all types of students were analyzed, the mean effect size for synchronous DE was found to be small but significantly negative and heterogeneous. The results of this more focused analysis of undergraduate DE studies helped us not only resolve the variability but also understand the underlying nature of the comparison in this type of DE study. As Clark (1983, 1994, 2003) has long argued, it is not the medium of instruction, *per se*, that matters. It is how the medium is used to support instruction and facilitate learning that impacts on student achievement outcomes. The following generalization, then, seems warranted: In synchronous instructor-directed undergraduate DE , when media are used to deliver the same instruction simultaneously by the same instructor and with the same course activities and materials, there is little reason to expect undergraduate students to learn differently in the remote site(s) than the host site. It might be argued, then, that synchronous undergraduate DE is simply a form of simulated classroom experience that is not overly affected by distance from the host site and the use of a medium of communication such as videoconferencing. These results concur with the overall results of closed-circuit studies (e.g., Carpenter & Greenhill, 1955; 1958) which found "no significant difference" between the live classroom and the remote site.

Asynchronous Independent DE and Student-Content Interaction

Independent asynchronous DE pedagogy has been around since the implementation of correspondence courses and worldwide is perhaps the most common manifestation of undergraduate DE instruction. The results of this meta-analysis indicate that when media were used to support individualized learning only, there was, on average, no significant difference in achievement between DE students and regular classroom students, but effect sizes varied significantly across the findings. The finding of heterogeneity of effect size indicates that the mean effect size was not representative of all the effect sizes integrated in this set of findings. When learning was largely dependent on individual students' self-regulation, and student interactions were limited to student-content interactions, some DE applications performed better than classroom instruction and some performed more poorly.

In our exploration of student-content interaction study features in asynchronous DE, we found that student-content interaction study features accounted for a small but significant amount of total variance in the findings. Two media study features, "use of computer-based instruction" (e.g., tutorials and simulations) and "broadcast TV or videotape", significantly predicted more positive DE student achievement as compared to classroom instruction. A pedagogy design feature, "systematic ID", although not a significant predictor, was positively related to the two media predictors. These results indicate that systematically designed interactive or flexible multimedia may help engage DE students and assist them in understanding and therefore learning more effectively. In the student-content interactions, however, we were not able to assess the impact of the coded study feature, use of PBL, because of low variability and missing information for this study feature.

Discussion among Students and Student-Student Interaction in Asynchronous DE

When media were used to support collaborative discussion among students in asynchronous undergraduate DE, DE students on average significantly outperformed classroom students. This finding is consistent with group learning literature, with or without computers (e.g., Lou, Abrami, & d'Apollonia, 2001; Lou, Abrami, Spence, Poulsen, Chambers, & d'Apollonia, 1996), where small group learning on average was found to be superior to individual learning with respect to student achievement. According to social cultural theories of learning and the cooperative learning literature, student-student interaction can enhance student learning through cognitive elaboration, distributed cognition, and peer help-giving and help-receiving (Abrami, Chambers, Poulsen, De Simone, d'Apollonia, & Howden, 1995). Asynchronous discussion activities among students may not only provide opportunities for students to learn reflectively and actively, but also provide them with multiple sources of feedback and help students develop meta-cognitive and self-regulated skills in learning through peer modeling and mentoring (Lou, Dedic, & Rosenfield, 2003). In asynchronous DE, student-

student interactions may also help ameliorate problems of isolation by providing mutual emotional and cognitive support (De Simone, Lou, & Schmid, 2001).

However, the results of this meta-analysis also indicate that the findings involving discussion among students were significantly heterogeneous, indicating that while some types of discussions were effective on student achievement, some were not effective. The variability in the findings of asynchronous DE with discussion among students may be due to a number of factors. Among the possibilities are: common problems associated with group learning when specific cooperative learning strategies are not employed (Abrami et al., 1995), misunderstanding among the group members and unequal participation (Abrami & Bures, 1996), and student expectations and readiness (Bernard, Brauer, Abrami and Surkes, 2004).

An unexpected although not surprising predictor identified in our weighted multiple regression analyses of student-student interaction study features was "opportunity for face-to-face interaction with other students". The online collaborative learning literature has repeatedly pointed out the challenges and problems involved in online group learning via discussion forums (e.g., Abrami & Bures, 1996). Perhaps face-to-face interaction with peers helps students know each other better, reducing possible misunderstandings and ill-feelings due to the challenges of asynchronous communication, such as time delay and different frequencies of online presence.

Student-Instructor Interaction in Asynchronous DE

An interesting finding from the analyses of the three interaction blocks of study features was the relative magnitude of the three types of interactions in predicting student achievement. Student-instructor interaction accounted for the largest amount of significant variance in asynchronous DE (R^2 *Change* = 9.28%). The significant student-instructor interaction positive predictors are "student-instructor activities" (such as instructor participation in discussion forums) and "face-to-face meetings with the instructor". These results emphasize the role of the instructor in mentoring and guiding student learning in asynchronous DE. Because students play a more active role in their own learning in asynchronous DE, prompt instructor feedback and guidance helps keep students on the right track and feel they are making progress (Anderson, 2003; Holmberg, 1989, 2003).

As with face-to-face interaction with other students, the more positive effect when face-to-face interaction with instructor was provided in asynchronous DE was unexpected, although not surprising. On one hand, this finding emphasizes the importance of interaction between student-instructor and among students. On the other hand, it indicates that current technologies may not yet provide the high interactivity that a face-to-face setting affords. An interesting line of future research is to investigate whether the use of synchronous media, such as desktop video and chat, provide a more sufficient means of interaction with the instructor and other students.

DE Student Readiness

In addition to exploring media and pedagogy study features in the three patterns of student interaction, we also analyzed a block of five demographic and contextual study features with sufficient variability. Of the five, advance information about DE courses significantly predicted more positive undergraduate DE students' achievement, accounting for 11.15% of total variance after controlling for methodological quality and 8.82% after controlling for methodological quality and the three types of interaction. It is possible that having advance information about the courses meant less surprise for the DE students during the course, which may have better prepared the students for the DE courses. Student readiness for online learning has been investigated by Bernard, Brauer, Abrami, and Surkes (2004) through the use of a 38-item online learning readiness questionnaire. Factor analysis indicated a four-factor solution and was interpreted as "general beliefs about DE," "confidence in prerequisite skills," "self-direction and initiative," and "desire for interaction." Two of these factors predicted end-of-course achievement performance. This research suggests, as does the current study, that student readiness is an important issue that should not be ignored in DE course development and implementation.

Strengths and Limitations of the Meta-Analysis

Since Gene Glass pioneered meta-analysis in the 1970s, the use and impact of quantitative synthesis have grown not only in education, but throughout the social, natural and medical sciences. Quantitative reviews serve as important tools both for knowledge generation and knowledge mobilization. Because good quantitative reviews synthesize evidence from a large collection of studies, they can answer questions about what is known and what is not known, which no single study can ever completely address. And because quantitative reviews provide evidence on the overall magnitude and variability of effects, they can help guide policy-makers interested in determining what works and in understanding the important conditions that modify effectiveness.

Using a theoretical framework and systematic methodology, we have identified in this meta-analysis patterns of media and pedagogy use in undergraduate DE, estimated the effect magnitude of the three most commonly used media-supported pedagogies in undergraduate DE, estimated the relative impact of three key interactions in undergraduate DE and conditions of best practice. Using a theoretical framework helped us synthesize the empirical research and better understand the variability across the findings.

This meta-analysis, like any meta-analysis, however, has several limitations. First, meta-analysis is correlational in nature. Therefore, strong causal interpretations, especially regarding moderating features, are not warranted. Second, the extent of meta-analysis is limited to the characteristics of the primary studies available. One of the greatest problems in the comparative research of DE, which limits the establishment of clearer guidelines for practice and policymaking, is missing information in the literature. A number of coded study features, such as "student experience with DE", "institutional support", and "use of PBL", could not be analyzed because of missing descriptions of these study features. Third, the quality of DE studies in general has been criticized by a number of researchers (e.g., Bernard, Abrami, Lou, & Borokhovski, 2004). In this meta-analysis, we found that a small number of findings reported randomized experimental control or statistical control. However, we believe that in addition to student equivalence, more methodological features, such as instructional materials equivalence, instructor equivalence, and class size, may moderate the study results. Therefore, we chose to code and model 10 methodological features in multiple regression analyses to control for study quality. Three other coded methodology features including task time equivalence, ability equivalence, and attrition rate were not included due to insufficient information.

Our weighted multiple regression modeling analyses also showed that some of the study features were correlated. For example, several media and pedagogy features in the student-content interaction block were correlated. Similarly, the hierarchical multiple regression with all predictors indicates that there is collinearity among the student-student interaction predictors and student-instructor interaction predictors.

We acknowledge that DE/classroom comparative research represents only one, albeit large, sector of the complete DE literature. There are many comparative studies of within DE conditions (i.e., DE vs. DE), as well as correlational, survey, and qualitative research, that could be synthesized to form a more complete picture of what it means to teach and learn at a distance.

Until larger-scale syntheses, such as the one described here, are undertaken, the field will continue to base practice on fragmented evidence and the often contradictory findings of individual studies. We hope, however, that the results of this meta-analysis will help guide DE practice and future research based on the cumulative evidence of empirical research.

Recommendations for DE Practice

In summary, based on the results of this meta-analysis, undergraduate DE students can learn equally well at remote or host sites in synchronous instructor-directed DE. In asynchronous DE, independent DE pedagogy alone was, in general, less effective than DE that supports collaborative discussion among students. Student learning in asynchronous DE may be optimized when:

1. systematically designed interactive multimedia are used to provide more effective student-content interaction;
2. collaborative discussion among students is structured using asynchronous communication media with some opportunity for peer face-to-face meetings for more effective student-student interaction;
3. student-instructor interaction is encouraged through planned activities such as instructor participation in discussion board forums, question and answer chat sessions, and opportunity for face-to-face meetings with the instructor; and
4. students are provided with advanced information about DE courses so that they are better prepared and more ready for the DE courses.

The overall findings in this meta-analysis are consistent with the seven principles of good undergraduate instruction (Chickering & Gamson, 1987; Chickering & Ehrmann, 1996). It appears that active learning, structured cognitive interactions among students, and instructor guidance are also principles of good instruction in undergraduate DE.

Recommendations for DE Technology Design and Research

The results of this meta-analysis indicate that media and pedagogy that support interaction with the instructor and other students are more important than media and pedagogy that are used to establish individual student interactions with content only. These results support Keegan's (1996) differentiation between "distance teaching" and "distance learning". It also provides some evidence to support Kozma's (1994) point that interactive technologies may function in different pedagogical ways from non-interactive technologies.

While studies comparing DE versus classroom instruction are necessary for establishing the legitimacy of DE as an alternative to the more traditional classroom instruction, more research is needed to investigate how different media can be effectively used to support a variety of sound instructional strategies for more effective student-content, student-student, and student-instructor interaction and more effective learning. Up to now, two-way video has been used mainly to support instructor-directed lecture presentation. An interesting line of future research would be to investigate how synchronous video, such as desktop or portable video conferencing, may be used to support student-student interactions (e.g., group projects) and student-instructor interactions (e.g., project advising and providing interactive feedback).

Research that has examined small group learning and group interaction has pointed out the many difficulties of establishing and maintaining effective group work in online courses (Abrami & Bures, 1996). Lou (2004) investigated the use of between-group collaborative strategies in project-based online courses and found positive effects. More research is needed to establish the range of pedagogical strategies for successful collaborative PBL in DE.

We believe that a number of research methodological features pose threats to internal validity. In addition to using randomized experimental design to control for student sampling bias, empirical DE studies should also strive for rigorous control of other methodological factors, such as instructor equivalence, instructional materials equivalence, and task on time differences. Future primary studies should provide more complete descriptions of instructional conditions, descriptive statistical information and methodological procedures, particularly of the classroom conditions, so that a more complete picture of the effectiveness of DE practices can be developed.

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