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Chapter Three: Development of Verbal, Quantitative, and Subject Matter Competence

Computers and Information Technology

Computers and information technology. It appears to be widely accepted that computers and related information technologies have the potential to transform fundamentally the nature of teaching and learning in postsecondary education (for example, Green, 1996; Kozma & Johnston, 1991; Kuh & Vesper, 1999; Upcraft, Terenzini, & Kruger, 1999; West, 1996). The promise is, indeed, substantial. "Used appropriately and in concert with powerful pedagogical approaches, technology is supposed to enhance student learning productivity. It does this by enriching synchronous classroom activities and providing students with engaging self-paced and asynchronous learning opportunities that enable students to learn more than they would otherwise at costs ultimately equal to or below that of traditional classroom based instruction" (Kuh & Vesper, 1999, p. 1).

Not surprisingly, during the decade of the 1990s there was an extensive body of inquiry on the use of computers and related technologies to assist or augment postsecondary instruction. We found little in this literature that would lead us to alter our 1991 conclusion that computer-assisted instruction is linked to modest increases in course-level achievement. In the early 1990s, a number of scholars produced either narrative or quantitative (meta-analytic) research reviews suggesting that computer-based instruction leads to modest improvements in subject matter acquisition with a decrease in instructional time (Cartright, 1993; Cohen & Daganay, 1992; Kulik & Kulik, 1991; Leonard, 1990; Liao & Bright, 1991; McComb, 1994; Teich, 1991; Weller, 1997).

The most comprehensive of these research syntheses is the meta-analysis of Kulik and Kulik (1991). They synthesized the results of 149 experimental and quasi-experimental studies conducted from 1984 to 1991 with postsecondary samples. The course content was in mathematics, science, social science, reading and language, and vocational training. Of these studies, 91 were classified as computer-assisted instruction (CAI), where the computer provides (a) drill-and-practice exercises but not new material or (b) tutorial instruction that includes new material; 17 of the studies were classified as computer-managed instruction (CMI), where the computer evaluates student test performance, then guides students to appropriate instructional resources and keeps records of student progress; and 35 of the studies were classified as computer-enriched instruction (CEI), where the computer (a) serves as a problem-solving tool, (b) generates data at the student's request to illustrate relationships in models of social or physical reality, or (c) executes programs developed by the student. In all three categories, computer-based instruction (versus traditional instructional approaches such as lecture, discussion, and text) produced average improvements in tested understanding of course content that were statistically significant. The average effect sizes were as follows: CAI: .27 of a standard deviation (11 percentile points), CMI: .43 of a standard deviation (17 percentile points), and CEI: .34 of a standard deviation (13 percentile points). Overall, only chance differences in effect sizes were found for studies based on true experiments and those based on quasi experiments. Weighting the effect sizes by the number of studies in each category, we computed an effect size across all three types of computer-based instruction of .31 of a standard deviation (12 percentile points).

Of the 149 postsecondary studies reviewed by Kulik and Kulik (1991), 32 also compared the instructional time for students in computer-based and traditional classes. The ratio of instructional time for computer-based students to instructional time for students in traditional classes averaged .70 across all comparisons. In other words, students in computer-based classes required about two-thirds as much instructional time as their counterparts in traditionally taught classes.

Since the publication of Kulik and Kulik's (1991) meta-analysis, the impact of computer-based instruction on learning has continued to be the focus of substantial inquiry. Most of this research employs true experimental or quasi-experimental designs in which various forms of computer-based instruction are compared with traditional or conventional instructional approaches such as lecture, discussion, or text. The weight of evidence from this more recent body of research is quite consistent in suggesting that, compared with similar students taught by traditional instructional methods, the knowledge acquisition of students in computer-based courses is either significantly better (Agarwal & Day, 1998; Alavi, 1994; Askar & Koksal, 1993; Connolly, Eisenberg, Hunt, & Wiseman, 1991; Faryniarz & Lockwood, 1992; Gregor & Cuskelly, 1994; Huang & Aloi, 1991; Lowe & Bickel, 1993; Marttunen, 1997; Mose & Maney, 1993; Reisman, 1993; Riding & Chambers, 1992; Vitale & Romance, 1992; Williamson & Abraham, 1995) or not significantly different (Adams, Kandt, Thronmartin, & Waldrop, 1991; Billings & Cobb, 1992; Carlsen & Andre, 1992; Guy & Frisby, 1992; Marrison & Frick, 1993; Murphy & Davidson, 1991; Smeaton & Keogh, 1999; Taraban & Rynearson, 1998; Tjaden & Martin, 1995; White, 1999). There was only isolated evidence in which students taught by traditional methods significantly outperformed students receiving computer-based instruction (Watkins, 1998). We computed an effect size for all of the studies in this recent body of literature that provided the requisite statistical information. The average effect size favoring computer-based instruction was .28 of a standard deviation (11 percentile points). There appeared to be little or no difference in the mean effect sizes of studies using true experiments or quasi experiments. Though admittedly this is a rougher estimate, it is nevertheless quite consistent with the overall effect size of .31 of a standard deviation that we derived from Kulik and Kulik's (1991) comprehensive meta-analysis. Also consistent with Kulik and Kulik's conclusions was evidence suggesting that students in computer-based classes require less instructional time than their counterparts in traditionally taught classes (Leonard, 1992; Taraban & Rynearson, 1998; Tjaden & Martin, 1995).[10]

Although our synthesis found extensive work focusing on computer use in individual courses, we uncovered only two studies of the impact of computer use during college on student learning. Possibly because they use different measures of computer use, different institutional samples, and different measures of student learning, the results of the two studies are only partially consistent.

Kuh and Vesper (1999) analyzed data from over 125,000 students at 205 four-year institutions. With controls for such factors as college grades, age, gender, work responsibilities, parental education, and educational aspirations, a measure of the extent to which students felt they gained a familiarity with computers was significantly and positively associated with self-reported gains in such areas as writing clearly, problem solving, and self-directed learning.

Flowers, Pascarella, and Pierson (1999) considered the impact of both e-mail and different types of computer use on objective, standardized measures of end-of-first-year reading comprehension and mathematics. Their sample was drawn from the 5 two-year and 18 four-year institutions participating in the National Study of Student Learning. With controls in place for such factors as precollege reading and mathematics achievement, academic motivation, patterns of coursework taken, the academic selectivity of the institution attended, and the quality of instruction received, they found differences in the impact of computer use between the two- and four-year samples. Electronic mail use had no significant impact on either reading comprehension or mathematics for the four-year sample but had statistically significant, if modest, negative impacts on both outcomes in the two-year sample. Consistent with the literature on computer-based classroom instruction, the use of computers for class assignments had a net positive impact on reading comprehension for two-year college students. The corresponding effect for four-year college students, however, was trivial and statistically nonsignificant. Engaging in computer word processing had a small but statistically significant, positive impact on reading comprehension for the four-year sample that persisted even when additional controls were introduced for students' first-year writing experiences.

Interestingly, the extensive body of research indicating consistent, albeit modest, positive impacts of computer-based instructional approaches on student learning appears to have initiated an ongoing and vigorously contested debate in the educational technology field. Clark (1991, 1994) has argued that the results of such research and of research syntheses such as those by Kulik and Kulik (1991) are questionable because the medium of instruction does not influence learning—the quality of teaching and instruction does. The essence of his argument appears to be that studies comparing the relative advantage for student learning of one instructional medium (for example, computers) over another (for example, lecture) will inevitably confound the instructional medium with the quality or type of instruction received. Consequently, all the supposed learning benefits attributed to computer-based instruction could just as easily be explained by the specific instructional methods they support or augment (Ehrmann, 1995; Weller, 1996).

On the other, or at least different, side of this debate, Kozma (1991, 1994a, 1994b) and Reiser (1994) have argued that the specific ways computers or instructional technology are employed are not irrelevant to instruction or student learning. Indeed, certain technological attributes make certain kinds of instructional approaches possible or enhance their impact. Moreover, some types of computer applications may be particularly effective in supporting some kinds of instructional approaches or learning goals with some kinds of learners. In effect, computer or information technology approaches may interact with learner characteristics. The essence of these arguments would appear to be that it is probably fruitless to focus on computers as a conveyer of some type of instructional approach. Rather, what counts is how information technology or visual media integrated with instructional approaches can facilitate knowledge construction and meaning making and thereby increase learning on the part of students (Kozma, 1994a, 1994b).[11]

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Distance Learning

Distance learning. Paralleling, and indeed dependent on, the growth and development of information and media technologies has been the dramatic growth of distance or remote-site instructional offerings in postsecondary education (El-Khawas, 1995; Keegan, 1993; Moore & Thompson, 1997; Walsh & Reese, 1995). For example, a 1997 report by the National Center for Education Statistics found that about 60 percent of American public two- and four-year institutions offered distance education courses, usually in the form of either one-way prerecorded courses or two-way interactive video courses (Lewis, Farris, & Alexander, 1997). Distance education has been used to deliver remote-site or off-campus courses in a variety of fields such as religious education, business, library science, teacher education, general studies, medicine and nursing, social sciences, social work, and scientific and technical fields (Burgess, 1994).

Literally hundreds of studies have addressed the issue of whether instruction delivered to remote sites, via various media technologies, is as effective as conventional on-campus, face-to-face instruction. In most instances, this research question is essentially the same as asking whether instructional media, such as television, videotapes, two-way interactive video, or computer conferencing, positively or negatively influence student learning. In the context of on-campus versus remote-site instruction, the clear weight of evidence from this research appears to support the contention of Clark and others that the specific medium of instruction has little impact on how much students learn (Carter, 1996; Clark, 1991, 1994; Schlosser & Anderson, 1994). Students who study via distance education approaches appear to learn as much course content as do their counterparts in conventional on-campus classroom settings. This conclusion is the consensus of numerous syntheses of the research evidence (Barker, Frisbie, & Patrick, 1989; Jones, Simonson, Kemis, & Sorensen, 1992; Machtmes & Asher, 2000; Moore & Thompson, 1990, 1997; Olcott, 1992; Pittman, 1991; Russell, 1995, 1999; Schlosser & Anderson, 1994; Wetzel, Radtke, & Stern, 1994; Zigerell, 1991).[12] Moreover, the weight of evidence that does exist also suggests that per-student costs of courses offered in a distance education format are not appreciably different from those offered in a conventional format on campus (Wetzel et al., 1994).

Despite apparent consensus in the evidence, there are some inescapable methodological problems in the body of research. A recent report outlines a number of these problems (Institute for Higher Education Policy, 1999; Merisotis & Phipps, 1999). Perhaps the most important problem is that geographical constraints make it virtually impossible to conduct either true experiments, with random assignment of individual learners to treatments, or quasi experiments, with random assignment of preexisting or intact class sections to treatments. Rather, nearly every study is, understandably, characterized by students self-selecting themselves into on-campus and remote-site instructional groups. Thus, the body of evidence on distance (versus on-campus) instruction and student learning tends to be flawed by a major threat to causal inference (or internal validity)—the interaction of self-selection and course achievement (Pascarella & Terenzini, 1991). The reasons why students take courses on campus or at distant sites in the first place may represent a constellation of uncontrolled influences that bias the findings on distance learning and student achievement in unknown ways.

Active learning. Slightly more than a decade ago, Chickering and Gamson (1987, 1991) published an influential list of principles for good practice in undergraduate education. These practices were grounded in research on student development and college teaching and included, among others, such things as student involvement in active learning activities, student involvement in cooperative learning activities, faculty and student interaction in and out of class, and prompt feedback to students on their performance. Some of these principles for good practice were the focus of considerable research in the 1990s. In this section, we attempt to summarize the evidence on student involvement in active learning experiences.

Consistent with our previous synthesis, the evidence we reviewed for the 1990s suggests that lecturing is still by far the modal instructional approach most often used in postsecondary education (Bonwell & Eison, 1991; Carlson & Schodt, 1995). In the hands of a skilled instructor, lecturing can often be an effective method for presenting major aspects of course content. Yet it is usually the case that lecturing requires students to assume the role of passive learners—absorbing concepts and facts and, ideally, incorporating them into some form of long-term memory. Lecturing is not a particularly effective approach for exploiting the potential efficacy of the learning that occurs when students are actively engaged in processing information in new and personally relevant ways and, in a very real sense, "constructing" their own knowledge (Baxter Magolda, 1998; Baxter Magolda & Buckley, 1997; Gagne, Yekovich, & Yekovich, 1994; Meyers & Jones, 1993; Nunn, 1996; Reynolds & Nunn, 1997).

A substantial amount of both experimental and correlational evidence suggests that active student involvement in learning has a positive impact on the acquisition of course content. For example, Lang (1996), reported in Murray and Lang (1997), conducted an experiment in which course topics in an undergraduate psychology course were randomly assigned to be taught by either an active participation method or a control lecture-only method. For the topics taught by the active participation method, at least 75 percent of class time was spent in activities requiring active participation (for example, small-group discussion, question-answer dialogue, case study debates). At the end of the course, mean student performance on both multiple-choice and essay examination questions was significantly better for topics taught by active participation than for topics taught by lecture. (From the graphic information reported in Murray & Lang, we could not compute an effect size.)

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Chapter Four: Cognitive Skills and Intellectual Growth

Computers and Information Technology

General Pedagogical Approaches. There is substantially less evidence with respect to the impact of general or broad-based pedagogical approaches on cognitive skills and intellectual growth than there is with respect to their impact on verbal, quantitative, and subject matter competence. Nevertheless, some research does exist, and we have organized it into the following three categories: computer and information technology, collaborative-cooperative learning, and interventions designed to increase cognitive growth.

Computer and information technology. Interestingly, the most extensive research we uncovered on computers and the development of general cognitive skills and intellectual growth focused on the impact of learning a computer program language. A fairly large number of studies have addressed this issue. Fortunately, Liao and Bright (1991) have conducted a meta-analysis of some 65 of these studies. Their criteria for inclusion of a study were as follows: (1) it had to assess the relation between computer programming and general cognitive skills such as planning skills, thinking skills, reasoning skills, and metacognitive skills (all cognitive skills were measured by standardized tests); (2) it had to take place in an actual classroom setting; and (3) it had to have a control group that did not require students to learn a computer language. Of the 65 studies in their meta-analysis, only 9 were conducted with postsecondary samples. Those 9 studies yielded 20 effect sizes. We took the raw statistical data provided by Liao and Bright for the postsecondary studies and estimated that college students required to learn a computer program language had an advantage of .35 of a standard deviation (14 percentile points) in various general cognitive skills over their counterparts who did not learn a computer program language. This effect size was statistically significant at $p < .05$. Thus, it would appear that the impact of learning a computer language may extend beyond the specific computer language to the development of general cognitive capabilities.

Although they do not focus specifically on learning a computer program language, reasonably consistent results are reported in correlational studies by Flowers, Pascarella, and Pierson (1999) and Kuh and Hu (2000). Analyzing the National Study of Student Learning data, Flowers et al. sought to determine if different types of computer use influenced critical thinking during the first year of college. To this end, they introduced controls for an extensive series of confounding influences such as precollege critical thinking, academic motivation, full- or part-time enrollment, coursework taken, and quality of instruction received. In the presence of these controls, the extent to which coursework required students to learn to use computers had a modest, but significant, positive relationship with end-of-first-year scores on a standardized critical thinking measure for students in five community colleges. The corresponding effect for students at four-year colleges was not significant. In analysis of data from over 70 four-year colleges, Kuh and Hu found that using computers for such learning activities as searching the Internet for course material, analyzing data, and making visual displays each had small, positive effects on student self-reported gains in intellectual development (for example, synthesizing, thinking analytically and logically). These positive effects persisted even in the presence of statistical controls for such factors as sex, race, socioeconomic background, grades and educational aspirations, academic major, work responsibilities, and institutional characteristics.

We also uncovered one study that focused on the use of electronic mail as a pedagogical tool for influencing aspects of general cognitive development. Marttunen (1997) conducted a study in which undergraduates practiced informal argumentation with each other using e-mail. Argumentation was based on ideas presented in two books, and level of argumentation was determined by the extent to which an argument was grounded in reason or evidence. Over a six-week period, the student groups did not have face-to-face meetings, but there was a significant increase in the level of their argumentation in e-mail messages. The absence of a control group of individuals who engaged in the same type of argumentation, but without using e-mail, makes it difficult to determine the unique effects of e-mail itself. Nevertheless, the results do suggest the possibility that electronic mail is a feasible tool in practicing and improving one's level of argumentation.

Collaborative-cooperative learning. An interesting correlational study by Karabenick and Collins-Eaglin (1996) suggests why one might expect collaborative or cooperative learning approaches to foster general cognitive skills and intellectual growth. Using data from over 1,000 students in 57 classes, they found that the greater the class emphasis on collaborative learning and the lower the emphasis on grades, the more likely students were to use higher-order learning strategies of elaboration, comprehension monitoring, and critical thinking. (Elaboration is the attempt to relate ideas in one's class to ideas in other courses, comprehension monitoring is the attempt to try to figure out a point when one becomes confused, and critical thinking refers to consideration of alternatives to a conclusion or point made in class.) To the extent that use of higher-order learning strategies leads to the development of higher-order thinking skills, one might then expect collaborative and cooperative approaches to learning to facilitate the development of general cognitive skills and intellectual development during college. Although not unequivocal, there is a body of evidence to support this expectation.

Qin, Johnson, and Johnson (1995) conducted a meta-analysis of 43 experimental and quasi-experimental studies that considered the effects of cooperative versus individualistic or competitive learning approaches on general problem-solving skills. Problem solving was operationally defined as "a process that required participants to form a cognitive representation of a task, plan a procedure for solving it, and execute the procedure and check the results" (Qin et al., 1995, p. 131). Four types of problems were considered: linguistic problems, which are primarily solved in written or oral languages; nonlinguistic problems, which are primarily represented and solved in pictures, graphs, mazes, symbols, or formulas; well-defined problems, which have well-defined operational procedures and solutions (for example, a chess problem); and ill-defined problems, which have uncertainty with regard to operational procedures and ultimate solutions (for example, real-world problems such as deciding which car to buy). We took the raw statistical data provided by Qin, Johnson, and Johnson for 20 of the 43 studies that were carried out with postsecondary samples and conducted our own (secondary) meta-analysis. We estimate that, compared with their counterparts not learning in a cooperative format, college students learning in cooperative groups had a statistically significant advantage in overall problem solving of .47 of a standard deviation (18 percentile points). The magnitude of this advantage was largely unchanged by differences in the methodological quality of studies. (Estimates of the methodological rigor of each study were provided in the Qin, Johnson, and Johnson meta-analysis.) Similarly, it appeared that the advantage in problem solving accruing to students engaged in cooperative learning was essentially the same for both well-defined problems (.46 of a standard deviation) and ill-defined problems (.49 of a standard deviation).

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Chapter Twelve: Implications for Research, Practice and Policy

New Information Technologies

New Information Technologies. Fourth, the explosion of new information technologies during the 1990s led to the extension and refinement of earlier findings on the cognitive effects of computer-assisted instruction, including hypertext, learning a computer language, use of information technologies in the classroom, and various unstructured and classroom applications of electronic mail. Immense potential remains in computer and information technologies to change the nature of teaching and learning fundamentally, presaging substantial future research. Salient lines of inquiry include how computers and information technologies influence students' cognitive processes, the role of the instructor, the psychosocial climate of teaching and learning, and the extent and nature of a student's interaction with peers and faculty. Similarly, the effects of various forms of technology-mediated distance education, particularly asynchronous instruction, loom as an immensely important area of study. Current research in this area is generally atheoretical and methodologically unsophisticated, although we readily acknowledge the considerable methodological challenges these topics present. Conventional research designs and data-collection methods are often ill suited to studying distance learners, and the enabling technologies for distance learning have such a brief shelf life that they and their related pedagogies can change even while a study is under way. Such volatility in the nature of technology-mediated instruction presents considerable challenges to researchers to develop creative designs and data-collection mechanisms.

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