Technology Comes to College: Understanding the Cognitive Consequences of Infusing Technology in College Classrooms

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Can Technology Help Us to Promote Active Learning in College Students?

Consider the following scenario: In a large lecture class, a college professor stands on a stage and delivers a lecture from behind a podium, occasionally stopping to write on the blackboard. The students busily take notes for 75 minutes, and study them for the exams. This "talk-and-chalk" method has a long history in college teaching, but with the increasing availability of new educational technologies, this may be a good time to ask whether college teaching can be improved through the use of these technologies. In short, a major problem facing college instructors concerns how to help students learn deeply in large lecture classes where there is little apparent opportunity for student involvement.

One suggested solution to this problem is to introduce cutting-edge technologies that enable instructional methods for promoting active learning in students. Active learning occurs when students pay attention to relevant material, mentally organize the material into a coherent cognitive representation, and mentally integrate the new material with existing knowledge (Mayer, 2003). This article provides a cognitive model of technology infusion and offers a research agenda for creating research results to support evidence-based practice. First, however, we briefly explore some pitfalls in implementing technology in college classrooms.

The Disappointing History of Technology Infusion in Education

One approach to the problem of promoting active learning in college courses is to provide new cutting-edge technology to college instructors. For example, suppose the dean has allocated a substantial amount of money for the infusion of educational technology in college classes. The office of instructional development then creates a collection of high-tech classrooms that include computers with Internet access, thereby allowing instructors to show PowerPoint presentations, video, and animation, as well as to play sounds to their classes. These classrooms also contain a personal response system in which students can be asked to answer a question by clicking a button on a remote control, and the instructor can display the results from the entire class. In addition, the office of instructional development purchases a course management system that allows instructors to create course Websites with resource materials, activities, and streaming video of lectures. After a few years, the administrators notice that the vast majority of courses still are taught without technology. A few high-tech instructors, however, have made heavy use of the technology and claim that it has tremendously helped their classes.

This imaginary scenario reflects a real problem facing higher education—how should technology be used in college courses to promote active student learning? The history of educational technology has been somewhat disappointing, including the rise and fall of motion pictures in the 1920s, radio in the 1930s and 1940s, educational television in the 1950s, and programmed instruction in the 1960s (Cuban, 1986). With the rise of a new generation of educational technologies, we are challenged to not fail again.

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Three Ways to Conceptualize the Role of Technology in College Classes

In this article, we explore three ways to conceptualize the role of technology in college classes, by asking (1) What can we do with technology? (2) Which instructional methods are enabled by technology? and (3) Which cognitive outcomes can we promote with technology?

Focus on technology. First, we can take a technology-centered approach, by focusing on the menu of technology interventions that are available. In Table 1, the left column lists four types of technology aids—presentation aids, study aids, communication aids, and management aids. In the second column, we list some examples of each kind of aid. Some common presentation aids include presentation media such as PowerPoint, animation, video, static graphics, whiteboard, and Internet access; interactive devices such as a personal response system in which students can indicate their response to a question by pressing a button on a remote control, and the instructor can display the totals on the screen; and online assessment in which learners receive feedback on their assignments or tests. Some common study aids are online archives of classroom lectures through streaming video or PowerPoint slides with audio; online resources such as additional readings or study materials; and online activities or modules such as exercises on note-taking, summarizing, or detecting parts of a lecture that need clarification. Some common communication aids include communications with the instructor through synchronous or asynchronous online office-hours; communications with peers through chat rooms, bulletin boards, and threaded discussion; peer critiquing of to-be-submitted assignments; and working with peers through an online group assignment. Finally, management aids include an online syllabus, class schedule, grade posting, assignment recordkeeping, assignment submission, and/or testing.

Focus on instructional method. If we take a technology-centered approach, we ask questions such as, what is the effect of intervention X on test performance? The problem with a technology-centered approach is that it does not help us understand how a particular intervention affects learning, so it is difficult to know how the intervention will work in a different context with different learners. It may also conceal the rationale for employing technology in the first place and whatever connections exist between technological choices and pedagogic goals. Clark (2001) has argued that technology does not cause learning; rather, the *instructional methods* afforded by technology affect learning. Thus, an important question concerns which instructional method can be supported by the technology intervention under consideration.

Some instructional methods that have been used to promote meaningful learning (Mayer, 2003) include:

- *anchoring*—embed new material within familiar situations (e.g., teach the concept of a mathematical function by using a business situation);
- *scaffolding*—simplify portions of an academic task or activity to enable learners to succeed (e.g., ask students to solve a problem but provide hints along the way);
- *guiding*—provide direction concerning how to pay attention, organize, and integrate presented material with existing knowledge (e.g., after a section of lecture, point out the keys ideas and how they fit together);
- *exemplifying*—provide concrete examples of key concepts or elements (e.g., after giving a verbal definition of a square show some illustrations of various squares);
- *personalizing*—use conversational narration to create a sense of communication (e.g., use talking-head video clips in which authors describe their ideas or research);
- *practicing*—ask learner to do an academic task repeatedly with feedback in order to develop mastery (e.g., ask learner to outline a section of text and then see how an expert does it);
- *modeling*—provide step-by-step worked examples along with commentary concerning the rationale for each step (e.g., instructor goes over a portion of lecture, describing how he or she would take notes and why);
- *repeating*—allow learners to restudy portions of presented material (e.g., allow access to streaming video of lectures);
- *enriching*—ask learners to explain, justify, summarize, critique, or elaborate on their learning in order to develop expertise (e.g., provide exercises in which learners must summarize a portion of text);
- *collaborating*—ask learners to work with peers as a team in learning (e.g., ask students to provide peer reviews of drafts of each other's papers); and
- *managing*—ask learners to plan their use of time and study strategies (e.g., ask students to create a study schedule).

Importantly, different implementations of instructional technology can be used to foster one or more of these instructional methods.

The third column of Table 1 lists some possible instructional methods that could be implemented using each of the technology interventions listed in the second column. For example, using presentation aids such as PowerPoint, animation, video, static graphics, whiteboard, and/or Internet access, can enable a variety of instructional methods, including anchoring (in which a static or dynamic graphic can help make a concept more concrete and familiar), guiding (in which

Table 1. A framework for analyzing the cognitive consequences of technology infusion in college classrooms.

	What can we do with technology?	Which instructional methods are enabled by technology?	Which cognitive outcomes can we promote with technology?
Presentation aids	PowerPoint, animation, video, static graphics, sound, whiteboard, Internet access	Anchoring, guiding, exemplifying, personalizing	Knowledge acquisition
	Personal response system (i.e., clickers)	Practicing, modeling, anchoring	Metacognitive strategies, problem-solving strategies
	Online assessment (feedback)	Practicing, modeling, exemplifying, personalizing	Knowledge acquisition
Study aids	Online archive of lecture (e.g., streaming video, PowerPoint slides with audio)	Repeating, enriching	Knowledge acquisition
	Online resources	Enriching, anchoring, personalizing	Knowledge acquisition
	Online activities or modules (e.g., note-taking exercises, summarization exercises, clarity exercises)	Practicing, scaffolding, guiding, modeling, exemplifying	Comprehension strategies
Communication aids	Online office hours (synchronous and asynchronous)	Guiding, enriching, collaborating	Knowledge acquisition
	E-mail, chat room, bulletin board, threaded discussion, instant messaging	Guiding, enriching, collaborating	Collaboration strategies, knowledge acquisition
	Peer critiquing	Practicing, guiding, collaborating, enriching	Critiquing strategies, revision strategies
	Online interactive group assignments	Collaborating	Collaboration strategies
Management aids	Online syllabus and schedule	Managing	Time-management strategies
	Online grades, assignment recordkeeping	Managing	Time-management strategies
	Online assignment submission	Managing	Time-management strategies
	Online testing	—	—

the material can be structured in a way that highlights the main ideas and their relation to one another), exemplifying (in which a specific example of a concept can be presented), and personalizing (in which an author can be made visible by showing a video that includes the author's face and voice). Using a personal response system can enable practicing (in which students can try to apply their knowledge in answering questions and receive feedback), modeling (in which students can be asked to justify their answers), and anchoring (in which students can be asked to apply what they learned in concrete situations). Online assessment enables instructional methods such as practicing (in which the learner receives feedback), modeling (in which the instructor can describe the thought process leading to a correct answer), and exemplifying (in which the instructor can provide a worked example, that is, a step-by-step description of how to solve a problem).

Access to an online archive of the classroom lecture can enable instructional methods such as repeating (i.e., providing multiple exposures to the material) and

enriching (i.e., providing opportunities to think more deeply about the presented material). Access to online resources can also enable enriching as well as anchoring (if the resource material is familiar) and personalizing (if the material presents authors using their own words). Online activities or modules can enable practicing (in which students perform tasks such as summarizing a portion of the lecture and receive feedback on the quality of their summary), guiding (in which the module identifies what is important or helps the learner relate the material to prior knowledge), modeling (in which the module describes an appropriate thought process underlying a strategy), and exemplifying (in which the module provides a step-by-step description of how to carry out some task such as summarizing a portion of a lecture).

Online office hours, chat rooms, bulletin boards, and threaded discussions allow for instructional methods such as guiding, enriching, and collaborating, whereas peer critiquing also allows for practicing (in which the learner can get practice in providing critiques and get feedback on the usefulness of the critiques) and enriching (in which learners receive input from others and then must think more deeply about what they have written). Online group assignments allow for students to mentor one another.

Management aids such as an online syllabus and grade book may enable an instructional method we call managing (in which the learner can learn to manage his or her time). Online assignment submission and testing—while allowing for efficiency—do not in themselves enable an instructional method. However, when feedback is provided (as indicated under *online assessment*), several instructional methods are enabled including practicing, modeling, and exemplifying.

Focus on cognitive consequences. Including a focus on instructional methods helps to broaden the way that we conceptualize the impact of various technological innovations, but the next step is to consider how the instructional methods promote cognitive changes in learners. By adding this level, we move from a technology-centered approach to a learner-centered approach—that is, a focus on how technology can help to bring about changes in learners. The fourth column in Table 1 explores some possible cognitive consequences produced by instructional methods enabled by various technology interventions.

Presentation aids such as PowerPoint and online assessment can enable instructional methods that help the learner to construct new knowledge such as a mental model of how some system works. We refer to this cognitive outcome as knowledge acquisition. Presentation aids such as the personal response system can enable instructional methods that help the learner build metacognitive strategies (for monitoring how well one has learned new material) and problem-solving strategies (for generating and testing hypotheses).

Study aids such as online archives and online resources enable instructional methods that promote knowledge acquisition, whereas online activities enable instructional methods that promote the development of comprehension strategies such as how to take notes, summarize, and identify unclear portions of a lecture.

Communication aids such as online office hours enable instructional methods that promote knowledge acquisition, whereas chat rooms, bulletin boards, threaded discussion, and online interactive group assignments enable instructional methods that can lead to the development of collaboration strategies, that is, skill at working with others on learning. Peer critiquing enables instructional methods that promote critiquing and revision strategies.

Finally, some of the management aids may allow students to learn strategies for how to manage their study time. This could include online assignment submission, which would monitor when students submitted their assignments and thus encourage them to turn in their assignments by the deadline.

Studying the Effects of Technology in College Classrooms

This three-faceted approach to understanding the role of technology in college classrooms suggests a research agenda, in which we compare the learning outcomes of students when a class is taught without technology and when it is taught with a particular technology intervention. This is the approach that we are taking in an ongoing project on technology in the classroom at the University of California, Santa Barbara. The same instructor will teach a course in the conventional way (i.e., without technology infusion) one term and then in a subsequent term will teach the same course with the same material using some forms of technology infusion. We will apply this approach to each of four college courses— a computer science course, a psychology course, a history course, and a writing course—but the form of technology infusion will depend on the goals of the instructor in each course.

In a computer science course, an instructor will teach the course without new technology interventions in one quarter, and will teach the same course using course management software, PowerPoint slides of some lecture material, an archive of lecture audio/video, and an interactive personal response system to allow students to answer questions in real-time in another quarter. These techniques will help students in a number of ways. First, the course management system will help students learn about the course schedule, when homework assignments and exams are due, what their grades are, and the availability of supplementary material. By encouraging students to keep up with the class, they will hopefully

learn more. Second, the PowerPoint slides and archive of lectures offer new ways of presenting content to the students. By making the PowerPoint available, students will be able to spend less time simply copying notes, and more time trying to understand the concepts. And, finally, the personal response system carries the idea of engagement one step further: When students know they will have to perform "on-the-spot," they often pay attention more. Since the answers entered via the personal response system can be recorded, their participation and answers can be made a component of their grade. These technology interventions are expected to promote knowledge acquisition, which would be reflected in improvements in test performance.

In a psychology course, an instructor will teach the course without technology in one quarter and then will teach the same course using a personal response system. In each lecture, the instructor will have slides in which the class is asked to predict the results of an experiment based on a particular theory. Then, they will see how many in the class made each prediction. There will be a brief discussion leading to the correct prediction. In this way, students will learn how to apply theories to specific experiments, because prediction-generation is a major step in the scientific method in psychology. The personal response system is intended to promote the development of scientific reasoning skills in learners.

In a history course, an acclaimed instructor who has taught a course traditionally will "wire" the class using several techniques. Course management software will help first-year college students in a large and impersonal environment manage their learning tasks. Video recording of lectures and PowerPoint will assist students with repeating of material, and integrated online assignments are designed to help enrich and personalize the learning experience.

In a writing course, an instructor will teach the course without technology in one quarter and then will teach the same course in another quarter using course management software that includes a tool for peer critiquing of essay assignments. The course management system will provide basic information about the organization of the course, allow for the instructor to make handouts available online, and most importantly, will allow students to submit their essay drafts to an online repository in order to facilitate the process of peer critiquing. One of the purposes of peer critiquing is help learners understand the benefits and the process of rewriting. Another purpose is to help learners to develop and use metacognitive strategies such as critiquing and revision strategies. Using an online peer-review tool, students can submit their drafts; peers can access, read, and comment on other students' drafts. Additional possibilities might be that small groups can "discuss" each other's papers online, or that small groups could work on revising the same paper. The intention is to determine whether online peer critiquing promotes the cognitive outcomes of improving critiquing and revision strategies that would have the ultimate benefit of improved results in writing development. Previous research on peer critiquing is encouraging, but more rigorous, in-depth research is needed (McGroarty & Zhu, 1997; Nystrand & Brandt, 1989; Schultz, 2000).

Each time the course is taught (i.e., conventional version and technology version), we will collect the following data: (1) a pre-questionnaire that solicits basic demographic information and attitudes about academic learning, (2) a post-questionnaire that solicits evaluation of the course and information about the students' approaches to studying, (3) demographic information from each student's official university records, and (4) grades on all assignments and tests, including the final grade. We will also log all behaviors using the course Website for the technology version of the course.

Our primary focus is on comparing the academic performance of students in the conventional and technology versions of the course, including comparisons for major subgroups, such as men and women, high achievers and low achievers, and students who frequently use technology and those who do not. In light of Clark's (2001) well-reasoned argument that learning depends on instructional method rather than the instructional medium, it is important to avoid the trap of comparing one delivery medium with another. Thus, we are interested in examining the *cognitive consequences of various instructional methods enabled by the technology version of the courses* rather than the effects of technology per se.

In addition, we will use regression models to predict academic performance, including responses on the questionnaires. We are interested in whether the same variables predict success in conventional and technology classes. Finally, we will examine the course management system log files to determine whether students who make effective use of online resources perform better in the technology version of the course than those who do not, as well as related issues.

Conclusion

Overall, our goal is to show how it is possible to conduct methodologically rigorous, theoretically based research on the effects of technology infusion in college

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classrooms. With the ever-increasing use of educational technology at the college level, there is a need for a methodologically sound research base and an evidence-based theory of how technology interventions affect learning outcomes. □

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Additional Resources

More information on UCSB's Center for Information Technology and Society can be found on the Web at: *http://www.cits.ucsb.edu/initiatives/tie.htm*

Information about the Moodle course management software used in some of our research can be found at: *http://moodle.org*

Information about the personal response system used in some of our research is available at: *http://www.gtcocalcomp.com/interwriteprs.htm*

If you are interested in the scientific underpinnings of instructional design for computer-supported learning, we recommend the following book: Clark, R. C., & Mayer, R. E. (2003). *E-learning and the science of instruction.* San Francisco: Pfeiffer.

If you are interested in reviews of relevant research on the design of computer-based learning environments, we recommend the following books: (1) Mayer, R. E. (2001). *Multimedia learning.* New York: Cambridge University Press. (2) Mayer, R. E. (Ed.). (2005). *The Cambridge handbook of multimedia learning.* New York: Cambridge University Press.