

Research Articles on the Case Study Method: An Annotated Bibliography

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This annotated bibliography of research articles on the case method (including problem-based learning) was begun under an NSF CCLI National Dissemination Grant awarded to Clyde F. Herreid, Mary A. Lundeberg, and Nancy A. Schiller. Research studies were identified, analyzed, and annotated by graduate students under the direction of Dr. Lundeberg at Michigan State University. They included Aman Yadav, Kathryn (Hershey) Dirkin, and Michael DeSchryver. Abstracts written by them are denoted by an asterisk below. Staff of the National Center for Case Study Teaching in Science continues to add to the bibliography.

Aaron, S., Crocket, J., Morrish, D., Basualdo, C., Kovithavongs, T., Mielke, B., and Cook, D. 1998. Assessment of exam performances after change to problem-based learning: Differential effects by question type. *Teaching and Learning in Medicine* 10(2): 86-91.

The purpose of this study was to determine if changing instructional methods to problem based learning (PBL) in a single course affected students' performance on different types of exams in a medical school setting. The researchers used an experimental design. Twenty-nine volunteer students participated in the study. Students in the control group completed the standard second-year, lecture-based curriculum during the 1994 school year. Students in the experimental group completed the same curriculum in the 1995 school year with the exception that one course was taught using PBL methods. The researchers used both an existing year-end multiple choice examination and a research examination to assess outcomes. Overall scores on the year-end exam declined significantly from 1994-95, including questions that targeted material from the PBL course. However, though students in the experimental group demonstrated similar declines in performance on written questions from the research exam in areas covered by lecture courses, no decline was reported on written research exam questions targeting the PBL course. In the multiple choice questions on the research exam there was no statistically significant difference in scores, whether targeting PBL or traditional material. The researchers concluded that the lack of a decline in scores on the written research questions targeting PBL material, in light of the otherwise significant decline in scores on the existing year-end exam and other written questions on the research exam, supported the hypothesis that PBL facilitated success in retaining the more elaborated or applied knowledge that the written test questions required. [*]

Albanese, M., and Mitchell, S. 1993. Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine* 68(1): 52-81.

The purpose of this meta-analysis was to investigate the overall effects of PBL. The guiding question was: "What does the literature tell us about outcome and implementation issues related to PBL?" The authors found that when compared with traditional instruction, PBL was more nurturing and enjoyable. Other benefits of PBL included PBL graduates performed as well, and sometimes better, on clinical examinations and faculty evaluations, and were more likely to enter family medicine. Further, faculty tended to enjoy teaching using PBL. However, PBL students in a few instances scored lower on basic sciences examinations and viewed themselves as less well prepared in the basic sciences than their conventionally trained counterparts. The authors recommend caution in making comprehensive, curriculum-wide conversions to PBL until more is learned. [*]

Alvarez, M. 1993. Imaginative uses of self-selected cases. *Reading Research & Instruction* 32(2): 1-18.

The purpose of this study was to investigate the effect of case-based instruction on students' ability to activate, assemble, and incorporate new knowledge sources. The researchers used a one-group experimental design. Ninety-two eighth-graders from four intact classes participated in the study. Students' responses on essays and timed writings were used for the post-treatment analysis. The researchers reported that using thematically organized and cross-disciplinary self-selected cases facilitated students' ability to generate meaningful explanations for new information. [*]

Anderson, K., Peterson, R., Tonkin, A., and Cleary, E. 2008. The assessment of student reasoning in the context of a clinically oriented PBL program. *Medical Teacher* 30(8): 787-794.

The purpose of this study was to develop an instrument to assess students' reasoning ability on a written case-based question that was aligned to their learning in a PBL program. The method used was an instrument with 10 criteria centered on hypothesis generation, learning issues, and mechanistic explanations. Experienced clinical and medical educators validated the instrument prior to its use with 145 undergraduate first-year medical students. Results enabled the establishment of the strengths and weaknesses in the reasoning performances of individuals, as well as the overall cohort. The instrument's Cronbach alpha coefficient was 0.94, and it had high inter-rater and intra-rater reliability. Further validation of the instrument's performance was established through qualitative evidence derived from student interviews and tutor reports for this cohort. The authors concluded that aligning written assessment to the PBL process enables students and teachers to better understand how the reasoning process is developing for individuals and a cohort, and provides a basis for further investigation into the development of student clinical reasoning.

Antepohl, W., and Herzog, S. 1999. Problem-based learning vs. lecture-based learning in a course of basic pharmacology. *Medical Education* 33(2): 106-113.

The purpose of this study was to investigate whether students learned more and were more satisfied in a PBL course than a traditional lecture-based course. The researchers used a post-test-only control-group design. 123 students in a pharmacology course participated. A multiple choice/short answer test was used to measure student performance, and a questionnaire measured students' preferences for PBL or lecture-based instruction. Means for each item on the questionnaire are reported. The researchers reported that there was no difference between the control group and the PBL group in terms of performance on exams; however, students in the PBL group reported higher satisfaction. [*]

Arts, J., Gijssels, W., and Segers, M. 2002. Cognitive effects of an authentic computer-supported, problem-based learning environment. *Instructional Science* 30(6): 465-495.

The purpose of this study was to investigate whether students in a redesigned PBL environment were better prepared to apply knowledge in new situations than students in the traditional PBL environment. The redesigned PBL environment was called an Authentic Learning Environment. The researchers used a quasi-experimental design. 114 students in a second-year marketing course participated in the study. Open-ended questions were used to assess the effects of the treatment. The assessment also included a test case that had six "large" essay questions (the questions and case were developed by experts in the field and were designed to measure knowledge application and transfer). They also used a pre- and post-test to measure prior knowledge as a control. The authors reported that students' test scores in the redesigned PBL format improved significantly when compared to students in the control group (regular PBL). [*]

Bowe, C.M., Voss, J., and Thomas Aretz, H. 2009. Case method teaching: An effective approach to integrate the basic and clinical sciences in the preclinical medical curriculum. *Medical Teacher* 31(9): 834-841.

The purpose of this study was to examine the feasibility of case-method teaching (CMT) during the preclinical curricula to integrate basic science concepts in the management of clinical problems. CMT sessions were conducted with students during the first- and second-year of hybrid curricula at two U.S. medical schools. First- and second-year medical classes of 40-95 students prepared for and actively engaged in single session case discussions and were able to productively apply basic science principles in clinical problem-solving. The authors conclude that CMT represents a feasible and resource-conservative pedagogical format to promote critical thinking and to integrate basic science principles during the preclinical curriculum.

Brown, S., Boyer, M., Mayall, H., Johnson, P., Meng, L., Butler, M., Florea, N., Hernandez, M., and Reis, S. 2003. The GlobalEd Project: Gender differences in a PBL environment of international negotiations. *Instructional Science* 31(4-5): 255-276.

This study investigated changes in students' self-efficacy, knowledge, attitudes, and behavior after participating in a PBL simulation of international relations. The researchers used an experimental design. 234 high school students participated in the study. Instruments used for data collection can be found at <http://www.isspecissue.uconn.edu/>. The researchers reported that males and females had similar responses on the self-efficacy scale. Both males and females had significantly higher scores on the post-test; however, males' scores on pre- and post-tests were significantly higher. Both genders had a significant increase in academic skills, but males were higher than females. There was no significant difference on the attitude scale. [*]

Caplow, J., Donaldson, J., Kardash, C., and Hosokawa, M. 1997. Learning in a problem-based medical curriculum: Students' conceptions. *Medical Education* 31 (6): 440-447.

The purpose of this study was to examine students' conceptions of their learning in a PBL medical curriculum using a multiple case study design (Yinn, 1984). Two PBL groups with eight participants each were asked to participate in the study. One student did not participate in the study, leading to 15 participants. The authors collected data through open-ended questionnaires, individual student journals, actual and video-taped sessions of the PBL sessions, and focus group interviews. The open-ended questionnaires contained items to gauge students' satisfaction with PBL and their perspectives on learning and the PBL format used. The results from the study indicated that the students were satisfied with their PBL experience. [*]

Capon, N., and Kuhn, D. 2004. What's so good about problem-based learning? *Cognition & Instruction* 22(1): 61-79.

This study compared differences in student learning of economic concepts when taught in a PBL course vs. a traditional lecture-based course. The researchers used a switching replication design. 131 students in their second year of an MBA program participated in the study. The instrument used for data collection was a quiz given six weeks later. An essay test was administered 12 weeks later. The article includes examples of questions pertaining to the economic value concept. The authors reported that students who experienced PBL demonstrated that they were more often able to integrate new information with their prior knowledge. [*]

Carrero, E., Gomar, C., Penzo, W., Fabregas, N., Valero, R., and Sanchez-Etayo, G. 2009. Teaching basic life support algorithms by either multimedia presentations or case based discussion. *Medical Teacher* 31(5): 189-195.

This study compared two methods for teaching Basic Life Support (BLS) using a randomized, prospective study involving 68 medical students. BLS algorithms were taught for 60 minutes using either a multimedia presentation (Group I, n = 34) or case based discussion (Group II, n = 34). Assessments included a scenario-based quiz test and an error-pinpointing video, which the students completed before (T1) and after (T2) teaching. Comparisons between both groups were made on scores of the assessments, actual increases in scores (final value-initial value), and score gains (actual increase/potential increase). No significant differences were found between the groups in any of the recorded scores. Both groups improved their T2 scores (p values <0.001). The actual increases in scores and the score gains were similar in both groups. Test scores improved in 55.9% of students in Group I and 58.8% in Group II; video scores improved in 85.3% of Group I and in 82.3% of Group II. The researchers conclude that teaching BLS by either multimedia presentations or case based discussion equally improves the level of cognitive skills among medical students.

Castore, G. 1951. Attitudes of students toward the case method of instruction in a human relations course. *Journal of Educational Research* 45: 201-213.

The purpose of this study was to investigate students' attitudinal changes towards the case method of instruction. The researcher used a quasi-experimental design. Ninety male students in a human relations course participated in the study. The instrument used for data collection was a six-item questionnaire, included in the article. The researcher reported that in the second half of the semester students felt that course constructiveness, concentration in class discussion, stimulation of thought, and participation reduced. Instructors did not arouse consistent attitudes. The author reported that training in the use of the case method may be beneficial in reducing the instructor's influence and placing more of the burden on students. [*]

Chernobilsky, E., DaCosta, M., and Hmelo-Silver, C. 2004. Learning to talk the educational psychology talk through a problem-based course. *Instructional Science* 32(4): 319-356.

The purpose of this study was to investigate how the PBL method influences students' knowledge and language development. The researchers used an exploratory qualitative design. Thirty-four college students in an educational psychology course for pre-service teachers participated in the study. A discourse analysis was conducted on student artifacts such as learning logs and papers. The researchers reported that there was a correlation between the number of concepts discussed in both group and individual writings in terms of the depth of the knowledge demonstrated. In groups where language used in group-produced artifacts was repeated in individually produced artifacts, and vice versa, the group had the highest incidence of "transforming ideas," demonstrating deeper knowledge of concepts. [*]

Chevill, R., McGovern, A., and Bull, K. 2005. The light applications in science and engineering research collaborative undergraduate laboratory for teaching (LASER CULT)-relevant experiential learning in photonics. *IEEE Transactions on Education* 48 (2): 254-263.

The authors present a model for a two-course undergraduate sequence (called LASER CULT) in the multidisciplinary area of photonics for electrical engineering students. The two courses used case studies, team learning, and problem-based learning to make course concepts more relevant to students; provide students experience in working on a team; and use in-depth projects that build higher-level, problem-solving skills. The authors also present analysis of two years of assessment data from LASER CULT. The measures included Student Assessment of Learning Gains (SALG), student-generated portfolios containing individual reflective statements by each student, student questionnaires, instructor and course evaluations, and statistical data from WebCT quizzes. Results indicated that student feedback was generally positive. LASER CULT made the course concepts more relevant to students and provided a positive experience for students in a team learning environment with a focus on in-depth projects. [*]

Copeland, W., and Decker, D. 1996. Video cases and the development of meaning making in preservice teachers. *Teaching & Teacher Education* 12: 467-481.

The purpose of this study was to investigate changes in students meaning making of video-based vignettes of classroom teaching and learning. The researchers used a qualitative design. The 12 female participants randomly selected for the study were enrolled in an elementary education course. Interviews were used to stimulate verbal descriptions of meaning making. The researchers reported that over one-third of the topics discussed during case discussion sessions were also used when students described their own meaning making. [*]

Demetriadis, S., and Pombortsis, A. 1999. Novice student learning in case based hypermedia environment: A quantitative study. *Journal of Educational Multimedia and Hypermedia* 8(2): 241-269.

The purpose of this study was to investigate learning outcomes of novice users of a case-based hypermedia environment, as well as the impact of epistemological beliefs on learning in this environment. The design of the hypermedia environment was based on cognitive flexibility theory and covered the domain of computer networking. The researchers used an experimental design. The experimental group was exposed to case-based instruction in the hypermedia environment while the control group received the same information via a linearly structured electronic book. Thirty-nine first- and second-year computer science students participated in the study. Instruments used for data collection included a demographic questionnaire; a pre-test; an epistemological beliefs and preferences questionnaire; an attitudinal questionnaire; a knowledge acquisition questionnaire; and a delayed post-test. Sample items from the instruments are included in the article. The researchers reported that both groups performed equally well when acquiring knowledge about basic facts. However, when students were required to deal with knowledge in a more flexible way, the experimental group performed better. [*]

Dinan, F. 2002. Chemistry by the case. *Journal of College Science Teaching* 32(1):36-41.

The purpose of this study was to evaluate a course called "Chemistry by the Case" that took a PBL approach. The researcher used a one-group pre- and post-test design. The researcher reported that a greater percentage of students were able to make objective judgments and decreased subjective judgments, such as backing an environmental decision with scientific evidence automatically makes it right. Student evaluations of the course were positive. [*]

Dochy, F., Segers, M., VandenBossche, P., and Gijbels, D. 2003. Effects of problem-based learning: A meta-analysis. *Learning and Instruction* 13(5): 533-568.

The purpose of this meta-analysis was to investigate the effects of PBL in terms of impact on knowledge and skill acquisition. The study also investigated the potential moderators of effective PBL. Forty-three articles were reviewed. The assessment measures included: NBME licensing test, modified essay questions, essay questions, multiple choice, oral exam, performance-based testing, free recall, standardized patient simulation, and cases. The researchers reported that there was a positive effect of PBL on skill development. Results were non-robust for knowledge, but there is a suggestion that PBL students gained slightly less knowledge but that they remember more acquired knowledge and that any differences disappear after the second year. [*]

Dori, Y., Tal, R., and Tsaushu, M. 2003. Teaching biotechnology through case studies: Can we improve higher order thinking skills of nonscience majors. *Science Education* 87(6): 767-793.

This study investigated the effect of using case-based instruction to teach biotechnology to students who are not science majors. The researchers used a pre- and post-test experimental design. 200 students who were non-science majors participated in the study. The instruments used for data collection were designed to measure knowledge and higher order thinking skills. Data was also collected from interviews with teachers and responses to students' portfolios. The researchers reported that for students, at all academic levels, a significant improvement in participants' knowledge and understanding and higher order thinking skills was demonstrated. Furthermore, the gap between students at the low and high academic level narrowed. [*]

Dupuis, R.E., and Persky, A.M. 2008. Use of case-based learning in a clinical pharmacokinetics course. *American Journal of Pharmaceutical Education* 72(2): 1-7.

The purpose of this study was to assess the redesign of a clinical pharmacokinetics course that incorporated case-based learning (CBL) to enhance group interaction and individual participation. The clinical pharmacokinetics course was divided into 3 sections based on content. Section 1 utilized CBL with small in-class groups; section 2 used a more traditional style of teaching; and section 3 was taught with CBL but using large in-class groups. The CBL approach was assessed using examination scores and attitudinal surveys. Assessments indicated that students enjoyed the applied format of CBL, and examination scores were higher when CBL was used than in historical controls. The authors conclude that CBL allows class time to be used for higher levels of learning and assessment instead of the more typical content delivery.

Ertmer, P., Newby, T., and MacDougall, M. 1996. Students' responses and approaches to case-based instruction: The role of reflective self-regulation. *American Educational Research Journal* 33(3): 719-752.

This study investigated students' perceptions of case-based instruction and the role of reflection in self-regulation. The researchers used a mixed methods design. Nine first-year veterinary students participated in the study. Instruments used for data collection included the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) and the Self-Regulated Learning Inventory (SRLI) (Lindner & Harris, 1992). Also, the written case analysis (used to measure learning) was based on a procedure called SOAP. Thus, the analysis needed to include students' (S) subjective and (O) objective evaluations of the animal in the case, their (A) assessment of the animal's condition, and their (P) plan of action. Interviews were also used. The authors reported that students with high self-regulation saw case-based instruction as more relevant to their needs and were more confident about learning from cases. These students also focused on process and used self-reflective strategies when dealing with cases. Students with low self-regulation skills fluctuated in terms of their perceived confidence and the value they saw in the case method. They also tended to use habitual strategies as part of their self-regulation (as opposed to reflective). [*]

Gentner, D., Loewenstein, J., and Thompson, L. 2003. Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology* 95(2): 393-408.

The purpose of this study was to investigate whether analogical reasoning with cases facilitated learning and transfer. The researchers used an experimental design. Three experiments were conducted. 48 students participated in the first experiment; 128 students participated in the second experiment; and 158 students participated in the third experiment. The appendix contains the Contingent-Contract Guided-Analogy task used for data collection. The researchers reported that in the first experiment a benefit was shown for analogical learning relative to no case study. In the second experiment, comparing two cases was reported as more beneficial than studying the two cases separately. Increasing the degree of comparison support was shown to increase the rate of transfer in a face-to-face dynamic negotiation exercise in the third experiment. [*]

Gijbels, D., Dochy, F., VandenBossche, P., and Segers, M. 2005. Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research* 75(1): 27-61.

The authors conducted a meta-analysis to investigate the influence of assessment as the main dependent variable on the effects of PBL. The authors examined the effects of PBL when the assessment of its goal focuses on: "(a) understanding of concepts, (b) understanding of the principles that link concepts, and (c) linking of concepts and principles to conditions and procedures for application." Forty studies met the inclusion criteria (31 published in peer-reviewed journals and nine in edited books). The results of the analysis showed that the effects of PBL are more positive when "understanding the principles that link concepts" is the focus of assessment. When "understanding of concepts" is the focus, students do as well as students in conventional learning environments. Finally, when the third level of knowledge structure ("linking of concepts and principles to conditions and procedures for application") was used for assessment, there was a slight (but not statistically significant) advantage for students in the PBL group. [*]

Gordon, P., Rogers, A., Gavula, N., and McGee, B. 2001. A taste of problem-based learning increases achievement of urban minority middle-school students. *Educational Horizons* 79(4): 171-175.

This study examined the use of PBL with low-income urban minority middle school students. The researchers used an experimental design. The experimental group of 88 students participated in PBL as an enrichment activity, during which they explored health science issues and careers in the health professions through small group interdisciplinary projects. The PBL activities represented only 2% of the curriculum schedule. Report cards from two different cohorts over two consecutive years were analyzed for behavior indicators and grades. The authors found that supplementing the existing curriculum with PBL 2% of the time improved behavior and increased science achievement among urban minority students. Results also showed that participants were positive about PBL, with both students and facilitators enjoying and valuing the experience. [*]

Grunwald, S., and Hartman, A. 2010. A case-based approach improves science students' experimental variable identification skills. *Journal of College Science Teaching* 39(3): 28-33.

The purpose of this study was to assess whether the use of case studies in the laboratory curriculum of a biochemistry course increased students' abilities to identify experimental variables that affect the outcome of an experiment. Summative assessment data from student groups who completed the cases relative to student groups who did not were used to assess student learning. The assessment exercise was a fictional experimental scenario presented to students on the final lab exam, which was administered to 354 students. Three semester groups of students (165) were exposed to the case studies and four semester groups of students (189) were not. After all 7 semesters of student responses were obtained, each response was coded to mask which group the student belonged in which. Using a rubric designed for the study, two evaluators independently rated each student response on a scale of 0-2. A one-way ANOVA was performed between the four-semester groups that did not complete the cases and a one-way ANOVA was performed on the three-semester groups that did complete the cases to determine if there was any statistical difference between the "without case study" groups and the "with case study" groups, respectively. Both sets of results showed there was no statistical difference between these groups, and so each was treated as a cohort for statistical analysis. An SPSS t-test was then performed on the assessment results between these two cohorts. Results showed that students who completed the case studies scored significantly higher than those who did not, confirming that incorporation of the cases promoted development of experimental variable identification skills in students.

Gukas, I.D., Leinster, S.J., and Wlaker, R. 2010. Verbal and nonverbal indices of learning during problem-based learning among first-year medical students and the threshold for tutor intervention. *Medical Teacher* 32(1): e5-e11.

During problem-based learning (PBL), students brainstorm on a problem, generate hypotheses and formulate learning objectives. Certain verbal and non-verbal expressions are used by students in response to specific learning issues. The purpose of this study was to examine the use of these expressions as indices of the learning taking place and the tutors' threshold to intervene. Common verbal expressions used by students during PBL were identified and scored on a Likert scale to indicate the learning taking place. These expressions were categorized into the following groups of learning interactions: exploratory questioning, cumulative reasoning, and handling conflicts relating to learning. The tutor's threshold for intervention was also scored on a Likert scale. Means for each learning interaction and observed non-verbal expressions were used to construct bar charts for comparison. The results indicated that when the learning interactions involve exploratory questioning or cumulative reasoning, students tend to score high on learning and tutors have high threshold for intervention. When the learning interactions involve handling conflicts relating to knowledge, students score high on learning, but teachers have a low threshold for intervention. The researchers concluded that verbal and non-verbal expressions from students during PBL are useful indices of learning and can be used to help tutors decide when and when not to intervene.

Harland, T. 2003. Vygotsky's zone of proximal development and problem-based learning: Linking a theoretical concept with practice through action research. *Teaching in Higher Education* 8(2): 263-272.

The purpose of this study was to investigate how Vygotsky' notion of the zone of proximal development impacted teaching and learning in a PBL course. The researchers used a qualitative, action-research design. Up to five tutors and an undetermined number of students in a zoology course participated in this study over a five-year period. The researcher reported that the theory helped them develop better diagnostic teaching strategies (especially in the area of metacognitive and life skills), emphasize authentic activities, and re-think the roles of teachers and learners. [*]

Harrington, H. 1995. Fostering reasoned decisions: Case-based pedagogy and the professional development of teachers. *Teaching & Teacher Education* 11(3): 203-214.

The purpose of this study was to investigate the development of reasoned argumentation with pre-service teachers using dilemma based cases. An analysis was conducted using students' first and last written case analysis. The analysis focused on students' ability to demonstrate the following: (1) identify the problem (with/without a grounded explanation), (2) identify grounded alternative perspectives (both within and outside of the case), (3) propose a solution with evidence, (4) consider consequences of actions, (5) reflect on and critique their analysis. Explicit guidelines were given to students informing them that these items would need to be addressed in their analysis. The unit of analysis was at the statement level. Each case was coded at 5 different levels corresponding to the 5 different foci. The researchers used a mixed methods design. 26 students in an elementary teaching course participated in the study. The researchers reported that by the end of the course at least half the class demonstrated more sophisticated reasoned argumentation in two of the five areas measured, namely, grounding their identification of the problem and identifying multiple sources of evidence to support their solutions. [*]

Hays, J., and Vincent, J. 2004. Students' evaluation of problem-based learning in graduate psychology courses. *Teaching of Psychology* 31(2): 124-127.

The aim of this study was to understand students' perceptions of the differences between PBL instruction and traditional instruction. A 5-point Likert scale questionnaire (with a few true/false questions) was used to collect data for the study. 40 students participated in the study from three different courses. Students reported PBL was better than traditional methods in promoting interactions between students and developing critical thinking skills. It was also slightly better in allowing students to grasp concepts and to develop research and oral presentation skills. [*]

Hayward, L., Cairns, M. 1998. Physical therapy students' perceptions of and strategic approaches to case-based instruction. *Journal of Physical Therapy Education* 12(2):33-42.

This study investigated student perceptions and attitudes toward case-based instruction (CBI). The researchers used a qualitative design. Eight students from a capstone course in a physical therapy program participated in the study. Students selected represented a range of academic achievement, gender, and age. Data was collected from individual interviews with the students. The researchers reported on several themes that emerged from the data. They found that students valued CBI because it required them to integrate classroom material and collaborate with others. Students also reported that it stimulated critical thinking, motivated them extrinsically and intrinsically, and helped them organize their approach to problems. Students found some aspects of CBI stressful. They were frustrated with the amount of information, incomplete cases, and the uncertainty of whether their answers were correct. [*]

Hmelo-Silver, C. 2004. Problem-based learning: What and how do students learn? *Educational Psychology Review* 16(3): 35-266.

The purpose of this literature review paper was to describe the instructional approach known as PBL and to examine the empirical evidence on whether PBL has reached its goals. PBL is an instructional approach in which students work in collaborative groups to solve complex problems that do not have a single right answer. Students learn through facilitated problem-solving. The author reported that the goals of PBL are to help students develop: (1) flexible knowledge, (2) effective problem-solving skills, (3) self-directed learning skills, (4) effective collaboration skills, and (5) intrinsic motivation. Research has been found to support goals 1-3, but not 4-5. The author describes differences between PBL, anchored instruction and project-based science. According to the author, PBL differs from these in that it focuses on a realistic, ill-structured problem, whereas anchored instruction focuses on a videotaped story and project-based science is focused on one driving question. [*]

Hoag, K., Lillie, J., and Hoppe, R. 2005. Piloting case-based instruction in a didactic clinical immunology course. *Clinical Laboratory Science* 18 (4): 213-220.

The authors investigated the effect of case-based instruction on students' critical thinking, class attendance, satisfaction, and their opinion of case formats. Data was collected in a Clinical Immunology and Serology course, with one semester being taught without cases and the next semester taught with case-based instruction. Data from 56 students in the first semester, taught without the use of cases, served as the baseline. 77 students experienced the intervention, i.e., the use of case-based instruction in the second semester. The intervention included nine cases interspersed between the lecture and the students worked in groups of 5-6. The main outcome measures included student performance on five critical thinking multiple choice exam questions and percent student attendance on case days versus lecture days. The authors also used the student ratings on course evaluations from the two semesters to assess the effect of cases on overall student satisfaction. Student opinion on cases was obtained through surveys and a focus group. Results indicated that the student performance on critical thinking was similar in the two semesters. However, student attendance was significantly higher on the days cases were used. Instructor involvement, student-instructor interaction, and course organization were also significantly better for the intervention group. [*]

Jacobs, A., Dolmans, D., Wolfhagen, H., and Scherpbier, A. 2003. Validation of a short questionnaire to assess the degree of complexity and structuredness of PBL problems. *Medical Education* 37(11): 1001-1007.

The aim of this study was to validate a questionnaire designed to measure the complexity and structuredness of PBL problems. 244 first-year medical students participated in the study. The instrument used for data collection was a questionnaire designed to measure the structuredness and complexity of problems as perceived by the students. The instrument is described in the article. The researchers reported that in terms of the students' ability to distinguish poorly designed problems, the results showed that students were able to distinguish PBL problems that were too simple and those that were too well-structured, but they found it difficult to distinguish problems that were too complex or too ill-structured. The researchers also found that the questionnaire can be used to measure whether problems are too simple or too well-structured. [*]

Johnson, E., Herd, S., and Andrewartha, K. 2002. Introducing problem-based learning into a traditional lecture course. *Biochemistry & Molecular Biology Education* 30(2): 121-124.

This study assessed student satisfaction in a course using a combined PBL and lecture format. The PBL format was used 20% of the time and the lecture format was used 30% of the time. The study ran for three years during which the class size varied from 30-40 students. The researchers reported that student responses to a questionnaire in the first year of the study indicated that they were satisfied with the PBL program most of the time. A more informal assessment of students' responses conducted in subsequent years yielded similar results. [*]

Johnson, D.W., and Johnson, R.T. 1993. Cooperative learning: Where we have been, where we are going. *Cooperative Learning and College Teaching* 3(2): 6-9.

A meta-analysis of over 1,200 studies comparing the performance of students educated using cooperative learning strategies (including case studies) versus those taught by the lecture method showed that cooperative learning promoted greater learning and greater retention in verbal, mathematical, and physical skills. The authors reported that students enjoyed the experience more, had better attitudes toward the subject, developed better social skills, became more articulate, and were more tolerant of differing viewpoints than with the lecture style.

Kamin, C., O'Sullivan, P., Deterding, R., and Younger, M. 2003. A comparison of critical thinking in groups of third-year medical students in text, video, and virtual PBL case modalities. *Academic Medicine* 78(2): 204-211.

This study investigated how critical thinking differs when using PBL via different modalities. The researchers used a qualitative design. 128 third-year medical students participated in the study. The researchers used content analysis to analyze students responses to problems presented in a face-to-face (fff) text condition, a fff video condition, and a virtual video condition. The authors reported that students in the virtual course demonstrated the highest critical-thinking ratio. The video group also demonstrated a higher critical thinking ratio than the text group (with the exception of problem identification). [*]

Kaste, J. 2004. Scaffolding through cases: Diverse constructivist teaching in the literacy methods course. *Teaching and Teacher Education* 20(1): 31-45.

The purpose of this study was to investigate how instructors' use of teaching cases through the lens of a diverse constructivist orientation promoted pre-service teachers to think about literacy teaching and learning in new ways, as a first step to instigating effective literacy teaching in their future practice. The researcher used a qualitative design with 25 pre-service teachers in a teacher education literacy methods course. The author conducted qualitative analyses of university course videotapes and pre-service teachers' assignments. The results indicated that the pre-service teachers grew in their constructivist orientation when analyzing the cases. [*]

Keefer, M., and Ashley, K. 2001. Case-based approaches to professional ethics: A systematic comparison of students' and ethicists' moral reasoning. *Journal of Moral Education* 30(4): 377-398.

This study investigated how novice subjects (engineering undergraduates) understand and interpret experienced engineering professionals' analysis of ethical issues in different cases. The researchers also examined whether "novices can learn concepts and skills in a tutorial process which leads them through those analyses to help them reflect on their own processes of ethical decision-making." An experimental design was used with 24 undergraduate engineering students at two different institutions. Results indicate that, overall, ethicists' responses were superior in quality than student responses and used more problem solving (reasoning and knowledge) techniques in their resolutions to conflicts. Ethicists' and some students' responses made use of more professional knowledge, while other students made use of more general knowledge. [*]

Kesner, M., Hofstein, A., and Ben-Zvi, R. 1997. Student and teacher perceptions of industrial chemistry case studies. *International Journal of Science Education* 19: 725-738.

The purpose of this study was to determine the effects of industrial case studies on students' attitudes toward both industrial chemistry and chemistry in general. The researchers utilized both quantitative and qualitative methods. Adapted versions of the learning environment inventory (LEI), open-ended questionnaires, student interviews, and classroom observations were used as the data collection instruments. Four hundred and ten 12th-grade students who majored in chemistry participated in the study. Several results were reported. First, students whose industrial chemistry teachers had participated in comprehensive in-service training and utilized case based-instruction in the classroom reported much more positive perceptions of course relevancy and instructional techniques than students with minimally trained teachers. Second, students who did not study industrial chemistry found chemistry in general less relevant and applicable than those who had. Third, students who learned industrial chemistry via cases from teachers with minimal training were less aware of the career opportunities in both chemistry and industrial chemistry than their peers studying with better trained teachers. Finally, no significant differences in the above measures were found when boys and girls were compared. [*]

Khan, T., and Yip, Y. 1996. Pedagogic principles of case-based CAL. *Journal of Computer Assisted Learning* 12(3): 172-192.

This article reviews the recent developments in educational and cognitive learning theory that have been adopted by developers of knowledge-based computer-aided learning systems. It focuses on an artificial intelligence technology that has only recently been applied to educational applications. Case-based reasoning provides an intelligent capability for making pedagogic decisions about a diversity of issues encountered during a learning session. Illustrative examples of implemented systems in tackling a variety of pedagogic problems are presented. Numerous case-based teaching systems have been reviewed and 14 fundamental pedagogic principles that influenced their design are identified. These principles are presented with background descriptions and references to the systems they motivated. The work of the authors, which focuses on case-based task management, is described briefly. [*]

Koehler, M. 2002. Designing case-based hypermedia for developing understanding of children's mathematical reasoning. *Cognition & Instruction* 20(2): 151-195.

The purpose of this study was to assess the effectiveness of the nature of a case used in a case-based hypermedia learning tool. The multimedia tools used in this study had two views for the case. One view displayed cases as episodes of teaching while the other view displayed cases with a narrative structure. The researcher used an experimental design. The 24 students participating in this study were from a mathematics teacher education course. The researcher reported that the pre-service teachers in a narrative-enhanced condition are better at putting their orchestrated knowledge to use in designing learning activities and interpretation of student work than students in the episode only condition. [*]

Kopp, V., Stark, R., Heitzmann, N., and Fischer, M.R. 2009. Self-regulated learning with case-based worked examples: Effects of errors. *Evaluation & Research in Education* 22(2-4): 107-119.

To foster medical students' diagnostic knowledge a case-based worked example approach was implemented in the context of a computer-based learning environment. Thirty medical students were randomly assigned to the condition "with erroneous examples" and 31 students learned with correct examples. Diagnostic knowledge was operationalized using a multiple-choice test, key-feature problems, and problem-solving tasks. Cognitive load, acceptance, and subjective learning outcomes were assessed by three questionnaire scales. Students learning with erroneous examples performed better than students learning with correct examples. However, this effect was not significant. Erroneous examples significantly increased cognitive load and decreased students' subjective learning outcomes. However, they had no influence on acceptance.

Kunselman, J., and Johnson, P. 2004. Using the case method to facilitate learning. *College Teaching* 52(3): 87-92.

The purpose of this research was to lend support to the usefulness of the case method in facilitating learning, critical thinking, and understanding among students in social science courses. The researchers used a mixed methodology and collected both qualitative and quantitative data. Two criminal justice professors teaching six distinct subject areas used case studies as the primary assignments in their respective courses. Nine separate cases were used, each of which focused on helping students to: (1) understand complex and complicated issues and describe interrelated processes, (2) discuss policy- and decision-making ideologies that either are politically or socially charged, or (3) engage in informative and focused classroom discussion. Across all classes and cases, 232 students were surveyed, and more than 90% of students provided highly favorable feedback on a standardized evaluation form regarding the use of the case method. Written comments from students corroborated the highly favorable agreement suggested by the quantitative data. [*]

Levin, B. 1995. Using the case method in teacher education: The role of discussion and experience in teachers' thinking about cases. *Journal of Teaching and Teacher Education* 11: 63-79.

The purpose of this study was to empirically test whether discussion is a crucial variable in teachers' learning from cases. The study investigated what teachers understood from just reading and writing about a case compared to what they thought when also discussing it. The researchers used an experimental design and used analysis of the cases and discourse analysis. Twenty-four teachers with varying amounts of experience participated in the study. The teachers responded to seven questions associated with the cases. The researchers reported that the quality, form, and content of thinking of teachers were affected by their participation in the discussion. [*]

Liu, M. 2004. Examining the performance and attitudes of sixth graders during their use of a problem-based hypermedia learning environment. *Computers in Human Behavior* 20(3): 357-379.

The purpose of this study was to examine the impact of a problem-based hypermedia learning environment on sixth graders' performance and attitudes. The dependent variable was sixth graders' performance (science performance and problem solving) and attitudes. 155 sixth graders took part in the study. A mixed methodology was used both qualitative and quantitative data was collected. The authors used a 25-item science test to assess students' understanding of scientific concept, a nine-item attitude survey towards the PBL environment, and Germann's attitude toward science in school assessment. The authors also observed the class and collected interviews. The researchers reported that the use of hypermedia environment to present the knowledge provided appropriate scaffolding for all students. Gifted students, regular education students, and students with ESL or with some learning disability all benefited from the PBL environment. [*]

Lundeberg, M., Mogen, K., Bergland, M., Klyczek, K., Johnson, D., and MacDonald, E. 2002. Fostering ethical awareness about human genetics through multimedia-based cases. *Journal of College Science Teaching* 32(1): 64-69.

The purpose of this study was to examine whether the use of "Case It!", a case-based simulation software, and having students do research and discuss their projects over the internet would increase students' awareness of the ethics associated with the scientific results they obtained. The authors used an experimental design. 53 students enrolled in an introductory biology course took part in the study. A class analysis task was used to measure students' awareness of ethical issues. The researchers reported that students who used "Case It!" performed better than students who did not use the simulation software. [*]

Lundeberg, M.A., and Scheurman, G. 1997. Looking twice means seeing more: Developing pedagogical knowledge through case analysis. *Teaching and Teacher Education* 13(8): 783-797.

The purpose of this study was to examine two separate instructional strategies related to case-based instruction (CBI). First, the researchers investigated whether there was value in having students analyze a case both before and after related formal instruction. Second, the researchers investigated whether, given only one chance to analyze a case, students should analyze it prior or subsequent to related formal instruction. The researchers used a mixed methods design. They evaluated quantitative data from student case analysis tasks, which measured the number of theoretical concepts discussed and the depth of analysis. They also reviewed student reflections on the case analysis tasks. Sixty-seven undergraduate pre-service teachers working in pairs in an Educational Psychology class took part in the study. Based on data from the case analyses, the researchers reported that given the opportunity for both pre- and post-analysis, students demonstrated integration of significantly more theoretical concepts to a greater depth in the post analysis. They also reported that the one-time use of a case analysis as an anchoring idea prior to related formal instruction produced more learning than the one-time use of a case analysis subsequent to formal instruction as a performance measure. Qualitative data from student reflections supported these findings. [*]

Mayo, J. 2002. Case-based instruction: A technique for increasing conceptual application in introductory psychology. *Journal of Constructivist Psychology* 15(1): 65-74.

The purpose of the study was to investigate whether the use of case-based instruction increases conceptual understanding in an introductory psychology. The authors used an experimental design. 136 college freshmen and sophomores who had taken the introductory psychology course took part in the study. The author used an exam to assess higher-level conceptual analysis and application of the six major psychological theories. Two sample test items are provided in the article. The researcher reported that the students in the case-based instruction condition outperformed the students who were not when it came to theoretical comprehension and application. [*]

Mayo, J. 2004. Using case-based instruction to bridge the gap between theory and practice in psychology of adjustment. *Journal of Constructivist Psychology* 17(2): 137-146.

The purpose of this study was to investigate whether the use of case-based instruction (CBI) transfers the Psychology of Adjustment course principles. The author used an experimental design. 122 college freshmen and sophomores who were taking the course participated in the study. The author used three unit tests and a comprehensive final exam was used and the students in the CBI condition also completed a Likert-type survey on students' perception of case based pedagogy. The researchers reported that the students in the CBI condition outperformed the students in the traditional class on comprehension and application of course principles. [*]

McNaughton, D., Hall, T., and Maccini, P. 2001. Case-based instruction in special education teacher preparation: Practices and concerns of teacher educator/researchers. *Teacher Education and Special Education* 24(2): 84-94.

This study investigated current practice and research questions concerning case-based instruction (CBI) in special education teacher preparation. 15 teacher-educators who have used CBI or presented research on the topic were interviewed about their use of CBI as well as what they perceived as benefits/barriers to the use of this technique. A multiple choice questionnaire was used to gather demographic information and 38 open-ended questions were used to gather information on instructional goals, materials and activities, benefits, barriers, and research questions. It was determined that 87% of participants used CBI where the students' acquisition of knowledge and skill was the primary instructional goal, 87% use a "decision-making" model of CBI, 87% reported that the principal benefit of CBI is the development of generalizable skills for solving real-world problems, 80% cited time as the most significant barrier to CBI, and 67% mentioned the difficulty assessing the impact of CBI on student performance as an area that needs research attention. Results with less agreement were also discussed. Overall, participant responses encouraged the careful consideration of student knowledge and experience, instructional goals, and related CBI activities to make the most effective use of CBI. [*]

Newman, M. 2004. Problem based learning, An exploration of the method and evaluation of its effectiveness in a continuing nursing education programme. Executive summary available online at: http://beteronderwijsnederland.net/files/active/0/Newman_Summary_Part20II.pdf

The author investigated whether PBL results in higher student attainment when compared to traditional curriculum in nursing education. The researchers used a randomized experimental design. 51 students completed the study (20 in PBL condition and 31 in the traditional curriculum). The author used various measures, which are described but not included in the article. The author reported that students in the PBL condition reported lower levels of satisfaction and there was a 10 times dropout rate. Also, these students did not report any benefits or "disbenefits" when compared to traditional approach. The author also reported that PBL did not meet students' expectations of teaching and learning as well as their role as students. [*]

Nobitt, L., Vance, D.E., and DePoy Smith, M.L. 2010. A comparison of case study and traditional teaching methods for improvement of oral communication and critical-thinking skills. *Journal of College Science Teaching* 39(5): 26-32.

The purpose of this study was to compare the oral communication and critical thinking skills of students in a junior forensic science majors course on expert witness testimony taught using two distinct formats: case study and non-case study. A rubric for rating student performance in these skills (included in the article) was designed based on oral communication competencies developed by the National Communications Association for college students. A total of 56 students participated in the study. Students in the course are required to give three presentations during the semester. Specifically, a traditional paper presentation method was compared to a case study format for these assignments. In the non-case condition, students were given a published research paper in forensics to read, analyze, and present on in class. In the case study condition, students were given a forensics case and then assigned the role of an expert witness in a mock trial based on the case. Rubric scoring showed a high interrater reliability and indicated that students' critical thinking and communication skills improved when using the case study method as compared to the paper presentation method, with the greatest improvement in students' ability to adapt scientific information to a lay audience and to effectively integrate information to produce a message.

Ochoa, T., Gottschall, H., and Stuart, S. 2004. Group participation and satisfaction: Results from a PBL computer-supported module. *Journal of Educational Multimedia and Hypermedia* 13(1): 73-91.

This purpose of this study was to investigate pre-service teachers' decision-making process in a PBL computer-supported unit. The authors examined the group decision-making process and individual satisfaction and participation. The groups discussed a hypothetical case of a student facing suspension from the school due to the possession of drugs. The researchers videotaped the group discussions and the participants completed a satisfaction survey. Thirty-five elementary education majors enrolled in a special education course participated in the study. The results indicate that the group discussion was strongly influenced by one or more of the students rather than the whole group and there was unequal contribution from the individuals. [*]

Pederson, S. 2003. Motivational orientation in a problem-based learning environment. *Journal of Interactive Learning Research* 14(1): 51-77.

This study examined students' motivational orientation intrinsic as well as extrinsic when using PBL when compared to a typical class activity and also which aspects of PBL improve student motivation. The researcher used a mixed method methodology. 66 sixth-grade science students participated in the study. The author used the scale of intrinsic and extrinsic orientation in the classroom (Harter, 1981) and interviews were conducted to learn about students' opinion of learning in the PBL environment. Sample survey items are included in the article. The results indicated that the students were more intrinsically motivated during the PBL activity when compared to the regular class activity. [*]

Pindiprolu, S., Pederson, S., Rule, S., and Lignugaris, B. 2003. Using web-mediated experiential case-based instruction to teach functional behavioral assessment skills. *Teacher Education and Special Education* 26(1): 1-16.

The purpose of this study was to examine the effects of three web-mediated case-based teaching tactics on pre-service teachers' knowledge and application of information related to conducting functional behavior assessment (FBA). A pre-/post-test group experimental design was used. The cases in this study were used to practice the application of skills and knowledge presented prior to the case through lecture and other formats, and were presented using three separate case-based teaching tactics: (1) text based, (2) interactive text individually, and (3) interactive text in groups. 79 volunteer undergraduate students were randomly assigned to the three intervention groups. Two separate post-tests were used, one for declarative knowledge and another measuring application. The researchers discovered that all three teaching tactics were equally effective in facilitating the application of FBA skills with pre-service teachers, and outlined the advantages and disadvantages of each. However, students' perceptions about the relevance and meaningfulness of their experience were somewhat different. In addition, issues with technology and feedback were discussed as variables that may have affected the post-test results. [*]

Prince, K., vanMameren, H., Hylkema, N., Drukker, J., Scherpbier, A., and vanderVleuten, C. 2003. Does problem-based learning lead to deficiencies in basic science knowledge? An empirical case on anatomy. *Medical Education* 37: 15-21.

The purpose of this study was to examine the differences between PBL and non-PBL students in perceived and actual levels of knowledge of anatomy. 411 medical students participated in this study. The researchers used a perceived knowledge questionnaire and students completed a computerized anatomy test. The two questions from the questionnaire and the anatomy test are described in the article. The results from the study indicate that PBL students had the same perceived level of anatomy knowledge as the non-PBL students and there were no significant differences in knowledge between PBL and non-PBL knowledge. [*]

Reicks, M., Stuebner, T., and Hassel, C. 2003. Evaluation of a decision case approach to food biotechnology education at the secondary level. *Journal of Nutrition Education* 28: 33-38.

The purpose of this study was to evaluate student reactions to a case-based instruction (CBI) approach to teaching biotechnology awareness related to the labeling of genetically engineered products. The researchers utilized both quantitative and qualitative methods in the study. 200 secondary students and eight teachers from six separate schools participated. Three instruments were used to measure the effects of a decision-based case on students: (1) a pre-/post-assessment of attitude related to biotechnology, (2) a post-intervention survey of learner reactions to the related group work, and (3) a pre-/post-assessment of changes in abilities related to critical thinking and decision making. The researchers reported that students were more aware of how biotechnology affects their life after working through the case. Also, most students reported both positive experiences and learning experiences in reaction to the group work. The data reflected high correlations between positive experiences and learning experiences, as well as high correlation between self-reported level of involvement and both types of experiences. No significant change was reported when measuring the impact on critical thinking and decision-making skills from pre- to post-test. [*]

Richmond, G., and Striley, J. 1994. An integrated approach: Implementing a case study and team teaching curriculum. *The Science Teacher* 61: 42-45.

In this study, the researchers explored and implemented a team-taught integrated science curriculum in three 10th-grade classes. The course was built to represent how scientific problems are solved in the real world. The authors collected quantitative as well as qualitative data over the course of the class such as interviews, observations, student questionnaires, etc. The results indicated that the students were learning more than in other science classes and also understood why they were learning something. [*]

Rosier, G. 2002. Using reflective reports to improve the case method. *Journal of Management Development* 21(8): 589-597.

The purpose of this paper was to examine the use of case-based instruction (CBI) and reflective reports in management education. The author argues that most business schools emphasize reflection through “reflect-in-action” during case study discussion. Furthermore, the author claims that reflective learning after the activity can enhance the effectiveness of CBI and make its use more consistent with adult learning theory regarding reflection. The author provides analysis of the use of reflective reports after CBI activities in his graduate level management classes. From this analysis, his most significant conclusion is that transfer of learning to the workplace is enhanced. [*]

Saye, J.W., and Brush, T. 2002. Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research & Development* 50(3): 77-96.

The purpose of this study was to examine what kinds of scaffolding would support students' inquiry process in multimedia-supported PBL environments. The researchers used a series of generative design experiments for this study. Eighteen students from an 11th grade U.S. history class studying a unit on civil rights participated in the study. The authors used outcome data on student presentations, student interviews, student path data through database, and classroom observation as data sources. The researchers reported that “expert guidance may be embedded into the learning environment to give students conceptual and strategic road maps that assist them in understanding the process of disciplined inquiry.” [*]

Scaffa, M., and Wooster, D. 2004. Effects of problem-based learning on clinical reasoning in occupational therapy. *American Journal of Occupational Therapy* 58(3): 333-336.

The purpose of this study was to examine the effects of a five-week intensive PBL-based course on the development of clinical reasoning skills of undergraduate occupational therapy students. The researchers used a quasi-experimental design. Forty-eight undergraduate seniors participated in a 30-hour course during which small group case-based tutorials were conducted. The Self-Assessment of Clinical Reflection and Reasoning (SACRR) evaluative instrument was used to measure changes in clinical reasoning. Mean pre- and post-test scores for all 26 questions were provided. Statistically significant improvements were reported for 11 of the 26 items, as well as for students' overall scores. [*]

Schmidt, H.G., Van der Molen, H.T., Te Winkel, W.W.R., and Wijnen, W.H.F.W. 2009. Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school. *Educational Psychology* 44(4): 227-249.

The authors undertook a meta-analysis of over 270 studies in which the performance of students or graduates of the PBL curricula at Maastricht University's medical school was compared to that of students or graduates from at one of the seven other Dutch medical schools with conventional curricula. Studies selected for review and analysis compared students' acquisition of: (a) knowledge, (b) diagnostic competencies, (c) interpersonal and other general professional competencies, and (d) practical medical skills as well as (e) student perceptions of the quality of PBL versus conventional education and, as the focus was on the relative efficiency of the curricula as a whole, (f) graduate rates and study duration of students. For most of the 270 comparisons, the authors were able to compute effect sizes. In addition, within the different dimensions of performance were interested in [(a) through (f), above], overall effect sizes were computed weighted according to the size of the populations or samples involved. The authors found that the results supported the following conclusions: Effects of PBL are strongest in the professional skills domain, and particularly strong in the area of interpersonal skills; students in the PBL curriculum perform consistently better with regard to practical medical skills; the educational approach represented by PBL seems to be highly appreciated by students; students from the problem-based school graduate faster and in larger numbers. Small effects were found with regard to medical knowledge acquired and diagnostic reasoning; students studying the problem-based curriculum did not know much more about medicine than those studying in conventional schools and their diagnostic competencies did not differ much. In concluding, the authors found that there was no indication, however, that students in a problem-based curriculum learn less content knowledge. In addition, PBL seems to promote, more than conventional education does, the development of professional skills.

Schrader, P., Leu, D., and Kinzer, C. 2003. Using internet delivered video cases to support pre-service teachers' understanding of effective early literacy instruction. *Instructional Science* 31(4/5): 317-340.

The purpose of this study was to pilot the first iteration of Case Technologies Enhancing Literacy Learning (CTELL) on pre-service teachers and provide information for upcoming studies of CTELL. Thirty-three students participated in one of three reading/literacy methods course environments: traditional, traditional plus video, and traditional plus CTELL cases. Within CTELL, the cases are delivered with images, voice, and video via the Internet. The study took place during the final design phases of the CTELL interface, and as such, only limited cases were available. The researchers used a pre-post concept web, which described the students' understanding of effective reading instruction, as the outcome measure. Results indicated that the students in all three courses felt equally confident in their ability to teach reading. In addition, there was no difference between the three sections in their performance on several measures obtained from the concept map. A variety of findings that would guide further study of the system also were discussed, the most important of which was the extent to which a professor could become familiar with a complex case before using it in his/her class. [*]

Segers, M., Dochy, F., and DeCorte, E. 1999. Assessment practices and students knowledge profiles in a problem-based curriculum. *Learning Environments Research* 2: 191-213.

The authors of this paper describe five criteria that were formulated for the Maastricht School of Economics & Business Administration in order to make assessment practices consistent with problem-based learning (PBL) principles and practice. One central criterion stated the important role that sufficient domain-specific knowledge plays in the productivity of PBL. The researchers used a correlational design to investigate the relationship between a well-organized domain-specific knowledge base and outcomes on application of knowledge assessments. Thirty-four Marketing & Organization undergraduate volunteers participated in the study. The results of a knowledge test (measuring students' knowledge base), a sorting task (measuring the organization of students' knowledge base), and an overall test (measuring the extent to which students were able to apply the knowledge which they acquired) were utilized as measures for the study. The results indicated that both organization and understanding of domain-specific knowledge showed statistically significant positive correlations to the ability to apply that same information to define, analyze, and solve authentic problems in the same domain. [*]

Stepich, D., Ertmer, P., Lane, M. 2001. Problem-solving in a case-based course: Strategies for facilitating coached expertise. *Educational Tech. Research & Development* 49(3): 53-69.

This study examined changes in students' problem-solving skills as they analyzed case studies. The study collected qualitative data from student responses to each case. 37 students enrolled in three different instructional design courses that spanned three semesters participated in the study. In general, analysis of student responses to case studies showed both novice-like and expert-like responses unevenly distributed throughout the semester. As a result, the researchers' focus shifted from an emphasis on what students could or could not do, to what they, as the instructors, did or did not do in their role as coaches. In an attempt to explain the "uneven" results, they re-examined on-line case discussions to identify if, and how, specific coaching strategies may have supported student performances relative to the established characteristics of expert problem-solving. It was concluded that the primary influences on students' case analyses appeared more external than internal, including the way the case discussion was set up by the instructors. From the secondary analysis of discussion data, several strategies that instructors can use to guide their own coaching efforts emerged. [*]

Theroux, J., and Kilbane, C. 2004. The real-time case method: A new approach to an old tradition. *Journal of Education for Business* 79(3): 163-167.

The authors evaluated the efficacy of real-time case method (RTCM) teaching in a course on entrepreneurship. RTCM cases differ from traditional cases in that they have "extended coverage" through which they report on one company for the entire semester. They also provide real-time interactivity between students and decision makers at the company around which the case documents have been generated. 109 students enrolled in courses utilizing the RTCM in four separate universities participated in the study. Quantitative and qualitative data were collected from standard course evaluation instruments as well as from a web-based evaluation survey specific to RTCM. Each instrument included multiple choice and open-ended questions. Students indicated that they were very satisfied with their experience using RTCM, and were highly engaged with the case material. They also reported gains in their appreciation of the complexity of business decision making. The researchers indicated their intention to extend this line of research with a more systematic inquiry using experimental design. [*]

Valle, R., Petra, I., Martinez-Gonzalez, A., Rojas-Ramirez, J., Morales-Lopez, S., and Pina-Garza, B. 1999. Assessment of student performance in problem-based learning tutorial sessions. *Medical Education* 33: 818-822.

The purpose of this study was to develop an instrument to assess student performance as a result of participation in PBL tutorial sessions in a medical school setting, and report on the initial phase of its evaluation, specifically with respect to its construct validity and reliability. A questionnaire was designed with which PBL group tutors evaluated medical student participants based on four factors: (1) independent study, (2) group Interaction, (3) reasoning skills, and (4) active participation. 152 first- and second-year students were evaluated with the questionnaire, of which 140 were completed fully and thus used in the quantitative analysis. Results obtained confirmed the construct validity of the questionnaire and the reliability of each factor. Further studies of the questionnaire were suggested, but the success of this analysis encouraged use of the questionnaire as a useful tool for both formative and summative evaluation of PBL group tutorial settings. [*]

Vaughan, D., DeBiase, C., and Gibson-Howell, J. 1998. Use of case-based learning in dental hygiene curricula. *Journal of Dental Education* 62(3): 257-259.

The purpose of this study was to determine the existence and extent of case-based learning (CBL) in the curricula of dental hygiene programs nationally. A nine-item survey was mailed to 215 dental hygiene programs in the U.S. 141 surveys were returned. The survey revealed that approximately 70% of the programs surveyed had implemented CBL into one or more courses in their curricula, but the extent of usage varied greatly. In addition, 95% of the responding program directors desired additional instruction in the case-based methodology for their faculty. [*]

Woody, M., Alvarez, M., and Hines, T. 1999. Directed case studies in baccalaureate nursing anatomy and physiology. *Journal of Nursing Education* 38(8): 383-386.

The purpose of this study was to assess students' perception of case-based learning (CBL) in anatomy and physiology labs for entry-level nursing students. 92 students were surveyed after one semester using CBL. Both quantitative and qualitative data were collected. Students indicated that case studies were moderately to very helpful in learning concepts related to anatomy and physiology, in applying concepts to clinical situations, and in expressing or explaining a concept in front of a group. According to individual student comments, the elements of CBL students liked best included the following: acquiring in-depth information about a case, learning to work with a group, cases being real patient problems, public speaking exposure, and using a research process including learning to use the library. Students also identified the following problem areas: lengthy presentations, difficulty meeting with group members, boring presentations related to speaker quality issues, and low point value related to amount of student effort. Instructor evaluations most often identified similar strengths and weaknesses. [*]

Yadav, A., Shaver, G.M., and Meckl, P. 2010. Lessons learned: Implementing the case teaching method in a mechanical engineering course. *Journal of Engineering Education* 99(1): 55-69.

The purpose of this study was to examine (1) the influence of case studies on students' conceptual understanding compared to traditional lecture method and (2) student attitudes towards cases. Seventy-three students from two sections of the same mechanical engineering course participated in the study (section A = 31, section B = 42). Two cases (included in the article) were developed, one in fluid systems and the other in thermal systems. Both cases involved hypotheses and mitigation strategies for component failure in complex systems. Section A was given a case study for the thermal systems topic and a lecture for the fluid systems topic. Section B switched the teaching method for the two topics, with the traditional method used for the thermal topic and the case method used for the fluid systems topic. A pre-post test was used to assess students' conceptual understanding of the two case topics. Students completed each of the two knowledge pre-tests (one for each case) before the topic was introduced in class and then completed the post-test after the topic was covered in class. The ANCOVA results revealed that cases did not have a significant impact on the students' conceptual understanding of the case concepts as compared to traditional lecture. As part of the study, the participants also completed a 22 Likert-item survey to assess their attitudes towards the use of the case studies. Survey questions were designed to collect information on student perceptions of the influence of cases on their learning, critical thinking, and engagement. The results suggest that students had an overall positive attitude towards the use of case studies in the course.