ANNOTATED REFERENCES ON CONCEPT-BASED EDUCATION

Novak, J. D. and Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. American Educational Research Journal, 28(1), p. 117 - 153.

> Students in early primary grades were divided into two statistically significant groups to test the effectiveness of concept-based curriculum in science. The treatment group was instructed for a period of several months using a concept-based curriculum, while the control group was taught a conventional, fact-based curriculum. With no other treatments, both groups were tested for scientific understanding and problem-solving ability every two years until graduation from high school. Even after twelve years, the treatment group showed significantly better retention, depth of understanding, problem-solving ability and classroom performance.

Gagne, Robert M. (1985). The conditions of learning (4th ed.). New York: Holt, Reinhart and Winston.

> This is one of the more important texts that analyzes the processes of problem-solving and critical thinking. Drawing from a large body of academic research, Gagne defines concepts as those mental constructs common to these higher thinking processes. Much of the text is devoted to how students learn and use concepts.

> "In a review of research on the involvement of cognitive studies in problem solving, White and Whittrock (1982; unpublished manuscript of master's thesis completed by Gagne's students) found evidence that ... learners who use concepts to solve problems are better off than those who deal only with facts." (Gagne, 1985. p. 145)

Karplus, R., and Thier, H. D. (1967). A new look at elementary school science. Chicago: Rand McNally.

> An in-depth explanation and analysis of an elementary science curriculum that is concept-based, with numerous descriptions of students' superior performance compared to conventional curricula.

Jones, B. F., Palincsar, A. S., Ogle, D. S., and Carr, E. G. (1987). Strategic teaching and learning: Cognitive instruction in the content areas. Alexandria, VA: Association for Supervision and Curriculum Development.

> Summary and discussion of expert-novice research showing that experts use a concept-based approach to problem solving, whereas novices use a fact- or topic-based approach.

Taba, Hilda. (1966). Teaching strategies and cognitive functioning in elementary school children (Cooperative research project). Washington, DC: Office of Education, U.S. Department of Health, Education, and Welfare; San Francisco: San Francisco State College.

Using a controlled experiment involving 24 teachers, Taba tested the effectiveness of concepts for organizing elementary school social studies. She found that students who used conceptual organizers demonstrated equal command of the factual content while demonstrating significantly greater critical thinking abilities compared to students who experienced the conventionally taught curriculum.

Smith, Edward L., Blakeslee, Theron D., and Anderson, Charles, W. (1993). Teaching strategies associated with conceptual change learning in science. Journal of Research in Science Teaching, Vol. 30, No. 2, pp. 111-126.

This formal research study compared the effects on student learning of a concept-based approach with a conventional approach to teaching seventh grade units on photosynthesis and cellular respiration. Two groups of teachers agreed to teach towards the same set of generalizations for each unit, with one group using conventional texts, resources, lab activities and classroom strategies. The other group of teachers used specially written teacher guides and student materials that required them to use concept-based instructional strategies that clearly focused on developing a transferable understanding of the concept of energy transformation as described in the agreed-upon generalizations. All teachers were observed for at least half of the lessons devoted to the units, and frequency counts were tabulated on 15 different instructional strategies associated with concept-based instruction. All instructional materials and student responses were collected and frequency counts were tabulated according to 15 parameters also associated with the concept-based education model. All students were administered the same pre- and post-tests that had been previously validated for the agreed-upon generalizations. RESULTS: 23 of the concept-based instructional strategies and parameters had a statistically significant effect on student performance. Two parameters not usually associated with concept-based education, open-ended questioning and factual-recall questioning, had negative impacts on student learning. The highest positive effects came from teacher presentations of advance organizers describing and summarizing the conceptual context at the beginning of each unit, from the teacher's repeated references to the generalizations, and from the teacher's descriptions of applications and illustrations of the concept drawn from everyday student experiences. "The results support the claim that the recommended strategies help to promote conceptual change learning (p. 122)… [The results] seem to us to support another important contention: The conceptual change teaching strategies that we described are more powerful in combination than they are in isolation. Teachers who used only a few of the strategies successfully showed little improvements in student achievement. Thus, conceptual change teaching should probably be thought of as a coherent approach to teaching rather than as a collection of individually useful strategies" (p. 124).

Novak, Joseph D. (1977). A theory of education. Ithaca, N.Y.: Cornell University Press.

This is the seminal text for the concept-based curriculum model. It bridges the gap between cognitive theory and educational practice.

"Although concepts change in time, and may vary from culture to culture, a person's grasp for a field's concepts is the basis for understanding in that field.... This view is at once optimistic and pessimistic. It is optimistic in that education to enhance human understanding can be a focused, deliberate effort to enhance the number and quality of concepts people have; it is pessimistic in that there is no single mental strategy that can be applied wholesale to all new learning tasks." (Novak, 1977. p 61)

Concept-based learning has three important advantages: "First, knowledge... is retained longer - much, much longer in many instances. Second,... [it] adds to the capacity for easier subsequent learning of related material. Third, [it] facilitates new related learning even after forgetting has occurred." (Novak, 1977. p. 85)

" Problem solving ability [is] dependent upon the adequacy of specifically relevant concepts in the student's cognitive structure.... This ability [is the] capacity for developing and using concepts." (Novak, 1977. p. 217)

"Creative behavior... occurs when an individual makes unique associations across concepts" (Novak, 1977, p. 110)

"No curriculum theorist in the past has shown the relevance of learning theory to the design of curriculum.... If we can come to understand [concept-based] learning processes better and if we learn to apply this knowledge in the design of new instructional programs, education can be quantitatively and qualitatively much better than it has been.... Progress in [education] similar to the progress we have observed in science and associated technologies can be made." (Novak, 1977. p. 134, 190, 191)

Ausubel, David P., Novak, Joseph D., and Hanesian, Helen. (1978). Educational psychology: A cognitive view. New York: Holt, Reinhart and Winston.

This text contains the most complete and detailed explanation of the cognitive and developmental theory and research upon which concept-based education is built. It derives and explains the model in great detail from extensive research carried out by the authors as well as referencing an 82-page bibliography of research and references.

Novak, Joseph D., and Gowin, D. Bob. (1984). Learning how to learn. New York: Cambridge University Press.

This is one of the first texts to apply concept-based curriculum to classroom practice. This text introduces the technique of concept mapping, created by one of its authors, Joseph Novak.

"Much of the educational reform movement... was an attempt to get away from rote learning in schools by advancing instructional programs that encouraged discovery, or inquiry learning. Well intentioned as these efforts may have been, they did little to increase the meaningfulness of school learning" (p. 7)

"Many students classified as 'learning disabled' are really bright children who lack the skill and/or motivation for rote learning, but who can move to the front of the class when they are given an opportunity for [concept-based learning]". (p. 41)

"Nearly all students, from age 4 or 5, are capable of what Piaget called fully formal operational thinking, if they have an adequate framework of relevant concepts." (p. 144)

Erickson, H. Lynn. (2009) Concept-Based Curriculum and Instruction for the Thinking Classroom (Multimedia Kit). Thousand Oaks, CA: Corwin Press.

Erickson, H. Lynn. (2008) Stirring the head, heart, and soul: Redefining curriculum and instruction, Third Edition. Thousand Oaks, CA: Corwin Press.

Erickson, H. Lynn. (2007) Concept-Based Curriculum and Instruction for the Thinking Classroom. Thousand Oaks, CA: Corwin Press.

Erickson, H. Lynn. (1998). Concept-based curriculum and instruction: Teaching beyond the facts. Thousand Oaks, CA: Corwin Press.

Through this series of publications, Erickson describes how concept-based curriculum is capable of delivering the high student performances described in the national standards for the four major subject areas (math, social studies, science, and language arts). Both books emphazise classroom implementation, drawing from Erickson's extensive experience working with hundreds of schools across the country.

Anderson, L. W. and Krathwohl, D.R. (2001). A taxonomy for learning, teaching, and assessing; A revision of Bloom's taxonomy of educational objectives. New York, N.Y.: Addison Wesley Longman.

This revision of Bloom's taxonomy discusses and validates the original Taxonomy from multiple perspectives gained from experience and research drawn from the nearly 50 years since the original's publication and from across a range of fields. Many people reduce this important book to a suggestion it makes that has taken hold, and that is the addition of *Creativity* to the top of the Taxonomy, expanding it to six levels, each defined at sub-levels and sub-sub-levels. The synthesis of ideas around Bloom's taxonomy presented in this book is an emphatic support for defining higher order thinking skills as the ability to transfer conceptual knowledge that is carefully defined. The authors show over many examples how the many possible modes and methods of such conceptual transfer, in other words, the intellectual skills and processes described by the Taxonomy, can be organized into an increasing hierarchy of abstractness, complexity and subtlety. These authors also provide ample description and support for the detail of conceptual knowledge, with a structure that is precise and definable, albeit unique for each discipline.

"Two of the most important educational goals are to promote retention and to promote transfer (which, when it occurs, indicates meaningful learning)." p. 63.

"We describe our six cognitive process categories:… one that emphasizes retention and five that, although they may facilitate retention, emphasize transfer." p. 65

"Disciplines have different paradigms and epistemologies for structuring inquiry… and different ways of conceptualizing and organizing subject matter." p. 52

Eylon, B.S., and F. Reif. (1984). Effects of knowledge organization on task performance. Cognition and Instruction, 1:5-44.

Dufresne, R.J., W.J. Gerace, W.J. Leonard, J.P. Mestre, and L. Wenk. 1996. Classtalk: A classroom communication system for active learning. Journal of Computing in Higher Education, 7: 3-47.

Leonard, W.J., R.J. Dufresne, and J.P.Mestre. 1996. Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. American Journal of Physics, 64: 1495-1503.

This research describes how student performance on recall and on solving physics problems is significantly improved when the knowledge they are taught is organized hierarchically. Their performance also greatly improves when they are required to first perform a conceptual analysis of a problem. This research also showed how students perform significantly better when they solve problems first by identifying the most applicable concept, justifying their choice, and then describing the process they would follow of applying the concept to the specifics of the problem. Structuring content knowledge hierarchically is a useful strategy for helping novices both recall knowledge and solve problems.

BSCS, (2000). Making sense of integrated science – A guide for high schools, Colorado Springs, CO: BSCS.

Particularly in the sciences, concept-based curriculum is very close to integrated curriculum. This report contains numerous passages that discuss the critical importance of conceptual coherence for meeting the needs of a diversity of students, for students to be "successful on the increasing number of statewide assessments" (p. 12), and particularly for the deep conceptual understanding and ability to transfer knowledge that most educators strive for, even if the assessment of such abilities is still an inexact science.

Comfort, Kathy. (2000). How do we assess learning in integrated science? In *Making sense of integrated science – A guide for high schools*, Colorado Springs, CO: BSCS

Beginning with a universal definition of literacy, Comfort shows how it leads to the measurement of "students' ability to demonstrate understanding of the concepts that are connected and integrated among the science" (p. 52). Although examples are drawn from the sciences, the article's main theme applies much more widely: The effectiveness of an integrated or inter-disciplinary curriculum is measured in conceptual terms.

Rutherford, F. James. (2000). Coherence in high school science. In *Making sense of integrated science – A guide for high schools*, Colorado Springs, CO: BSCS.

Rutherford argues that a conceptual organization is needed for a curriculum that no longer follows the traditional lines between subject areas. "Integrated courses have no ready-made framework for creating coherence, and so it must deliberately be built into them…. Every major concept that appears needs to be linked logically to evidence supporting it and to related concepts…. A new generation of high school courses is needed that feature both integrated content and conceptual coherence."

Bransford, John D., et al. (1999). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press.

This report brings concept-based education to the forefront of curriculum design. It clearly establishes that concept-based curriculum design must be the foundation for educational programs focused on the higher thinking skills, the transfer of knowledge, problem solving, and critical thinking. The report was commissioned by the U.S. Department of Education, requesting the National Research Council to appraise the scientific knowledge base on human learning and its application to K-12 education. They canvassed the research literature in the cognitive sciences, developmental psychology, neuroscience, anthropology, and research on learning in subject areas such as science, math, and social studies. Most of the major curriculum development projects funded by both the National Science Foundation and the Department of Education are now using this report as the basis for designing instructional materials and programs that will become available over the next decades.

"Learning must be guided by generalized principles in order to be widely applicable… Transfer most likely occurs when the learner knows and understands underlying principles that can be applied to problems in new contexts."

"The research… shows clearly that "usable knowledge" … is connected and organized around important concepts."

"The transfer literature suggests that the most effective transfer may come from a balance of specific examples and general principles, not from either one alone."

"Hierarchical structures [of knowledge] are useful strategies for helping novices both recall knowledge and solve problems… Helping students to organize their knowledge is as important as the knowledge itself, since knowledge organization is likely to affect students' intellectual performance."

"Outstanding teaching [is] … knowledge centered in the sense that the teachers attempt to help students develop an organized understanding of important concepts in each discipline."

Wells, Malcolm; Hestenes, David; Swackhamer, Gregg. (July, 1995). A Modeling Method for High School Physics. American Journal of Physics, 63(7), p. 606-619.

Findings of the *Modeling Workshop Project* (1994-99): Final NSF project report, November, 2000.

> These reports describe and provide compelling data on student academic performance in physics resulting from the use of a concept-based curriculum. The first report focuses on the development of the curriculum and its implementation by one of the developer teachers. The second reports on the performance of students of over 600 teachers. Using excellent pre-and post-tests of student achievement in comparison with many different control groupings, both reports show stunning improvements. Aggregated results show at least a 10 percentage point increase in student performance. "Students' gains in understanding of the force concept *typically doubled to tripled* (original emphasis), [and] most teachers' understanding of the force concept improved to mastery level [regardless of prior science training]."
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> Student improvement was also shown to be directly correlated with the degree of implementation of the curriculum. Even the students of those teachers who had only used parts of the curriculum showed a significant proportional improvement. The benefits of the curriculum were not lost on the teachers: "More teachers implemented the method more fully in succeeding years of their participation in the program, and their students' gains went up accordingly."
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> The reported research also shows the additional effect of a concept-based curriculum on top of a student-centered, inquiry approach to instruction: "The data… strongly supports the conclusions that [the concept-based] method is a considerable improvement over [the] cooperative inquiry method and clearly superior to the traditional method." Under-prepared students were also shown to benefit particularly from the approach, and long-term retention of learning months after instruction was also demonstrated.
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> An interesting result of the research was also to show that for both traditional and inquiry-based instructional approaches, there was no relationship between student learning and a teacher's experience and academic background. However, teachers using a concept-based approach generally showed a steady improvement in their students' performance over the three years of data included in the second study.

System Dynamics Curriculum. Home web site http://sysdyn.mit.edu/ PK-12

Newsletter: The Creative Learning Exchange http://www.clexchange.org/cle_homepage.html.

> The System Dynamics in Education Project (SDEP) is a group of students and staff in the Sloan School of Management at the Massachusetts Institute of Technology, working under the guidance of Professor Jay W. Forrester, the founder of system dynamics. There are presently hundreds of teachers across the country, and world, using system dynamics as an approach to teaching all manner of topics from across the subject areas, with

excellent results. (See the edited listserv k-12sd@sysdyn.mit.edu to follow an active discussion.) System Dynamics is a "conceptual model" with clear and explicit components drawn from two basic concepts: Change/Process, and Regulation. As a curriculum, it is an excellent model of how a concept-based approach looks in the classroom. It is also an illustration of how a well-defined, transferable concept such as Change or Regulation can provide profound insights, even for the youngest students, into an astonishing variety of topics. This curriculum program shows how students can build sophisticated skills, such as graph construction in first grade and computer modeling in third, through the active application of these concepts to specific questions and phenomena. By focusing on one conceptual "package" throughout the K-12 span, System Dynamics also illustrates the development in understanding of such a conceptual unit over time, starting with cooperative, inquiry-based discovery of the basic generalizations in the early elementary grades, and spanning to sophisticated computer modeling of highly complex systems.

Ausubel, David P. (2000). The acquisition and retention of knowledge: A cognitive view. Boston: Kluwer Academic Publishers.

In this short yet dense book, David Ausubel focuses on classroom learning, with particular attention paid to secondary classrooms where reception learning predominates. Ausubel, whose Assimilation Theory of learning largely began the cognitive revolution in educational psychology almost fifty years ago, has finally collected in one book the arguments and research on what it means to teach and learn creative problem solving and critical thinking within the realities of classroom learning. Recognizing that open inquiry and discovery have a role to play, particularly at the early elementary level, this book "contains an exposition and elaboration of the major principles of meaningful reception learning and retention" (p. 38). With barely a statement made without reference to supporting research, Ausubel makes a strong argument that educationally powerful conceptual structures can be derived from the existing structure and developmental changes of the human intellect. He proposes that classroom reception learning organized and sequenced according to conceptual structures generates "*long-run* (author's emphasis) acquisition of stable and usable bodies of knowledge (and of intellectual skills) and … the development of the ability to think systematically, independently, and critically in particular fields of inquiry" (p. 31). He discusses how "provocative, meaningful, and developmentally appropriate instruction" stimulates "the development of motivations and interests that are currently non-existent" (p. 33). This book provides ample research and rationale for basing classroom teaching and learning on conceptual structures. It is also the rare, if not only, convincing model for designing teaching and learning that honors and even exceeds the intellectual and creative demands that the twenty-first century is requiring of high school graduates.

Finley, Sandra J. (September, 2000). Instructional coherence: The changing role of the teacher. Austin, TX: Southwest Educational Development Laboratory.

One of the major features of Concept-Based Education (CBE) is that it places a teacher's classroom practice at the beginning and center of reform efforts. CBE is intellectually demanding in that it asks teachers to consider deeply the nature of the knowledge that they are teaching and what it means to understand such knowledge. This report provides an excellent rationale and explanation for why and how student learning will only be significantly improved by reforms that focus on classroom practice and see "professional development as teacher learning." The systemic reform issues that surround classroom practice are necessary but not sufficient, nor even pre-requisite, for affecting student learning. The report states that "reforms will have little impact on how and what children learn unless there also are changes in the 'core' of educational practice, that is, in how teachers understand knowledge and learning and how they operationalize their understandings. So, teacher understanding becomes a critical piece in reform." The report provides an excellent discussion of what various approaches to professional development imply about teachers' own learning and their professional role as knowledge experts, as opposed to information experts. For example, effective teacher collaboration is "about teaching and learning that is grounded in the specifics of the classroom." This view of professional collegiality is embedded throughout the Concept-Based Education professional development program.

Hake, Richard R. (1998). Interactive Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. American Journal of Physics, Vol. 66, p. 64 – 74. Available on-line at www.physics.indiana.edu/~sdi/ajpv3i.pdf

This detailed research uses one of the largest samples of subjects of any research on the effectiveness of classroom strategies for improving student learning, comparing the performance of 6542 students in high school and college physics classes using a concept-based approach to 2084 similar students taught in "traditional" courses. Measuring the conceptual and problem-solving performance of students in mechanics, the research found that students in concept-based classes achieved an average gain of almost two standard deviations above those in traditional classes. The author concludes that the use of concept-based methods in classrooms can increase mechanics-course effectiveness well beyond that obtained in traditional practice.