DOCUMENT RESUME

ED 362 531 TM 020 529

AUTHOR Bates, John A.; And Others
TITLE Content-Knowledge Structure Differences among Middle School, High School, and College Life Science Teachers.
PUB DATE Feb 93
NOTE 15p.; Paper presented at the Annual Meeting of the Eastern Educational Research Association (16th, Clearwater Beach, FL, February 17-22, 1993).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Beliefs; Biological Sciences; *College Faculty; Course Content; Educational Attitudes; Higher Education; High Schools; *Knowledge Level; Middle Schools; Science Education; Science Instruction; *Science Teachers; Secondary Education; *Secondary School Teachers; Teacher Attitudes; *Teaching Methods; Test Construction
IDENTIFIERS *Subject Content Knowledge; Teacher Surveys

ABSTRACT

As part of an ongoing study of the content knowledge, instructional beliefs, and instructional practices of middle school, high school, and college science teachers, the hypothesis that there are systematic differences across academic levels in these teachers' conceptual understanding of the same content-specific subjects was studied. Eight middle school, 10 high school, and 9 college professors have participated to date. An instrument has been developed with input from teachers to obtain information about commonly held teacher beliefs about science instruction, classroom practices, and student learning. Twelve science concepts were identified, representing three domains of the life science curriculum. Taken together, results indicate what may be fundamental differences across academic levels in life science teachers' understandings of concept meaning and interrelationship. These differences appear to exist largely independently of college coursework and teaching experience, and to include content that is common to all examined levels of life science instruction. To the extent that systematic and significant differences in science teachers' knowledge structures exist across academic levels, science students in transition from one level to the next are likely to experience confusion and frustration. One table lists categories of participants, mean number of college courses completed in six subjects, and years of teaching experience. (Contains 13 references.) (SLD)

Content-Knowledge Structure Differences Among Middle School, High School, and College Life Science Teachers

John A. Bates
Robert Warkentin Dan Rea
Georgia Southern University

Paper prepared for presentation at the 1993 meeting of the Eastern Educational Research Association, Clearwater Beach, Florida

Content-Knowledge Structure Differences Among Middle School, High School, and College Life Science Teachers

The present study is part of an ongoing investigation of middle school, high school, and college science teachers' content knowledge, instructional beliefs, and instructional practices. A primary component of this investigation has been to examine the ways in which science teachers organize content-specific concepts into coherent knowledge structures within their own semantic networks. Our goal has been to determine whether systematic differences may exist, between academic levels, among the content-knowledge structures that teachers in the same science domain have constructed to inform their own instructional practices.

Logically and empirically, effective teaching within any content area promotes students' understandings of, rather than merely knowledge about, concepts and principles (Anderson & Smith, 1987). The methodologies employed by a teacher to promote this sort of deep, conceptual understanding will depend not only on the breadth of her pedagogic skill and the characteristics of her audience, but also on her own beliefs and understandings about the subject matter (Stein, Baxter, & Leinhardt, 1990). For example, suppose two equally well educated and experienced biology teachers differ in their beliefs about the relative strengths of influence of ecosystem demands and genetic inheritance on speciation and species survival. The teacher who believes that speciation primarily is a genetic phenomenon may provide an elaborate, classroom demonstration of genetic mutations in irradiated fruitflys, and may make brief mention, in a tangental sort of way, that ecosystems provide some small contribution to the shaping of their resident species. In contrast, the teacher who believes that ecosystems are the central sources of energy for speciation may conduct illustrative field trips to various, different enviroments so as to demonstrate the dramatic differences in resident species, and take a few minutes of class time to remind the students that what somehow changes is a critter's genetic structure. The point is that, although both teachers may meet the same curriculum-mandated objectives, and although their students may display similar levels of objective knowledge, nevertheless their students' understandings (where "understanding" is defined as the degree or pattern of interconnectedness perceived to exist among the concepts) may differ substantially.

One well established method of representing conceptual understanding is by means of the types and strengths of relations that a person perceives among content-specific concepts. For example, as students begin to acquire expertise in a content area, they generally are better able to perceive fundamental differences among concepts that novice students tend to perceive as quite similar. Not surprisingly, knowledge structure research indicates that students' concept networks come to resemble those of their teachers (Bates, 1982; Diekhoff, 1983), and related research has demonstrated that the sophistication of a student's knowledge structure is a fairly good predictor of the student's success at using content knowledge in problem solving (Chi, Feltovich, & Glaser, 1981; Goldsmith, Johnson, & Acton, 1991; Konold & Bates, 1982).

Of course, it is unlikely that teachers in a content area will share identical understandings of content; therefore, they will not share the same knowledge structures. In fact, teachers' perceptions of the relative importance of and interconnections among concepts can differ substantially across grade levels (Anderson & Smith, 1987). At least three outcomes may result if systematic knowledge structure discontinuities exist from one academic level to the next (e.g., middle school to high school to college). First, as already noted, students in transition from one level to the next will experience very different instructional environments for the same content. Second, students will experience interference in the learning of new degrees and patterns of interconnectedness among what they thought already were familiar concepts. Third, and until a new teacher's knowledge structure comes to replace that of the old, students will display less success in the application of content-specific concepts for problem solving.

Based on the literature discussed above, the present study tested the hypothesis that systematic differences exist, across academic levels, in these teachers' conceptual understandings of the same, content-specific concepts An additional purpose of the study was to determine whether knowledge structure differences are related to either the amount of teaching experience or the number and types of college courses that teachers have completed. We speculate that, to the extent these teacher knowledge structures are inconsistent across grade levels, students' transitions from one level of science learning to the next may be inhibited.

Method

Participants

At present, eight middle school teachers, ten high school teachers and nine college professors have participated in the study. Additional participants from the same academic levels will be solicited during the

1992-93 school year, with a target total of 12 to 15 participants at each level. The middle and high schools represented are feeder schools to each other, and the college is a regional one, drawing mostly from the local population of high school graduates. All middle school participants are 7th-grade life science teachers, and all high school participants regularly teach one or more life science course (biology, anatomy & physiology, etc.), averaging 9.0 years and 11.1 years of teaching experience, respectively. The college professors (all Ph.D. level) teach an introductory biology course (general education life science requirement), and report an average of 9.8 years of teaching experience.

Instrument Description and Development

Prior to constructing the questionnaire used in the study, we interviewed four secondary-level teachers individually, in an open ended format, to obtain information regarding commonly held teacher beliefs about science instruction, classroom practices, and student learning. Based on an analysis of the interview protocols, we constructed the final instrument (Teacher Survey Questionnaire) given to all teachers.

Teacher Survey Questionnaire. The Teacher Survey Questionnaire is a self-report instrument divided into six dimensions, two of which served as the source of data for this study. These dimensions are described below.

1 - General Academic Information. Participants responded to a series of items about their own academic preparations and teaching experience. Items included length of employment as a teacher and as a science teacher, and number of college courses completed in physical sciences, life sciences, social sciences, mathematics, history, and philosophy.

2- Life-Science Concept Structure Activity. All teachers in our state are required to satisfy a set of content-specific goals, called the Quality Core Curriculum (QCC) Objectives. The QCC Objectives make explicit the domains of factual knowledge, and their central concepts, that are to constitute every student's educational experience. The complete sets of QCC Objectives for middle school and for high school life science courses were examined to reveal core concepts common to both academic levels. Twelve such concepts were identified, representing 3 domains of the life science curriculum: 1) Biochemistry (including chemical bonding, photosynthesis, respiration, and organic compounds), 2) Genetics (including chromosomes, genetic inheritance, natural selection, species, sexual reproduction, and mitosis), and 3) Ecology (including ecosystem and food web). These 12 concepts then were organized into all possible, unique pairs. The resulting 66 concept pairs were rated by participants on a 4-point scale, with a rating of "1" indicating that the concepts in that pair are unrelated or only very slightly related, a rating of "2" indicating the concepts are somewhat similar in meaning or application, a rating of "3" indicating that the concepts are moderately to strongly related, and a rating of "4" indicating that the concepts are synonomous, or that one is a component of the other.

Procedure

Teachers and professors identified by their supervisors as having taught the appropriate life science courses were contacted in person or by telephone and asked to participate in the study. Questionnaires were delivered in person to participants' schools, along with addressed, stamped envelopes for their return. Participants were requested to complete the questionnaire at their convenience (involving approximately

45 minutes), and to return it within a week. All participants were assured that their responses would be kept confidential and anonymous. Of the ten instructors at each academic level originally solicited, only two middle school teachers and one college professor have not yet returned their completed questionnaires.

Results

Table 1 includes the means and standard deviations of participants' coursework and employment experiences, obtained from their responses to the biographical information component of the Teacher Questionnaire. The

Table 1

Mean Number of College Courses Completed

and Length of Teaching Experience

	College Professors	High School Teachers	Middle School Teachers
Physical Science	7.75 (3.54)*	7.80 (3.46)	4.63 (2.77)
Life Science	19.60 (7.60)	7.80 (4.90)	6.60 (5.40)
Social Science	2.75 (2.20)	3.00 (1.70)	3.88 (4.00)
Mathematics	5.13 (1.55)	2.50 (1.08)	4.88 (3.64)
History	2.75 (1.17)	2.30 (0.48)	4.88 (6.42)
Philosophy	0.75 (0.89)	1.30 (1.83)	1.00 (1.20)
Yrs. Teaching	9.83 (8.46)	11.10 (5.67)	9.00 (7.76)
Yrs. as Sci. Teacher	9.83 (8.46)	10.50 (5.60)	6.13 (6.56)

*Values in parentheses are standard deviations

middle school, high school, and college science teachers did not differ significantly in overall years of teaching experience or in years of experience as a science teacher. The three groups also did not differ reliably with respect to the number of physical science, social science, history, and philosophy colleges courses they reported having completed.

However, the college professors reported having completed significantly more life science courses ($p < .05$) than did either of the other groups. Also, the high school teachers reported having completed significantly fewer ($p < .05$) mathematics courses than did either the middle school teachers or the college professors.

Mean ratings were calculated for each of the concept pairs in the Rating Exercise for both the college professors' responses and for the high school teachers' responses. The primary hypothesis of the study was that significant knowledge structure differences exist in the transitions between academic levels. Therefore, the college professors' set of mean pair ratings served as the standard of comparison for each high school teacher's pair ratings, and the high school teachers' set of mean pair ratings served as the standard of comparison for each middle school teacher's pair ratings. Euclidean distances were calculated between each teacher's set of pair ratings and the corresponding standard, and were used to determine mean Euclidean distances between middle school teachers' ratings and the high school criterion ($\overline{ED} = .69$, s.d. = .10), and between high school teachers' ratings and the college criterion ($\overline{ED} = .71$, s.d. = .13). A mean Euclidean distance value of zero would indicate equivalent strengths of relation perceived to exist among rated concept pairs. The high school teachers' ratings differed significantly ($p < .05$), in Euclidean distance, from those of the college professors, and the middle school teachers' ratings differed significantly ($p < .05$), in Euclidean distance, from those of the high school teachers. Euclidean distances within each grade level were not correlated significantly with any of the measures of academic preparation or teaching experience.

Analyses of Euclidean distances revealed only that the three levels of science teachers differ quantitatively with respect to the gross degrees of perceived relation among the 12 life science concepts. Of even greater relevance to the hypothesis in question is the extent to which the patterns of interrelation among concepts differed from one academic level to the next. Mean pair ratings for each of the academic levels were transformed into standard scores based on the grand mean and standard deviation for all ratings, across all subjects. (This transformation was performed to account for the observed, significant differences in Euclidean distance among ratings, so as to put all ratings on the same distance scale.) These transformed ratings were entered into the Pathfinder scaling algorithm (via KNOT-Mac statistical sosftware and a Macintosh Classic II personal computer) in the manner discussed by Goldsmith, Johnson, and Acton (1991). Pathfinder provides a graphic representation of the semantic network implied by subjects' ratings of concept interrelatedness, as well as an assessment of the internal stability of the network and its structural similarity to other networks containing the same concepts. (For a complete discussion of Pathfinder features and applications, see Schvaneveldt, 1990). Figures 1a - c are the Pathfinder networks for concept pairs rated by the middle school, high school, and college life science teachers, respectively.

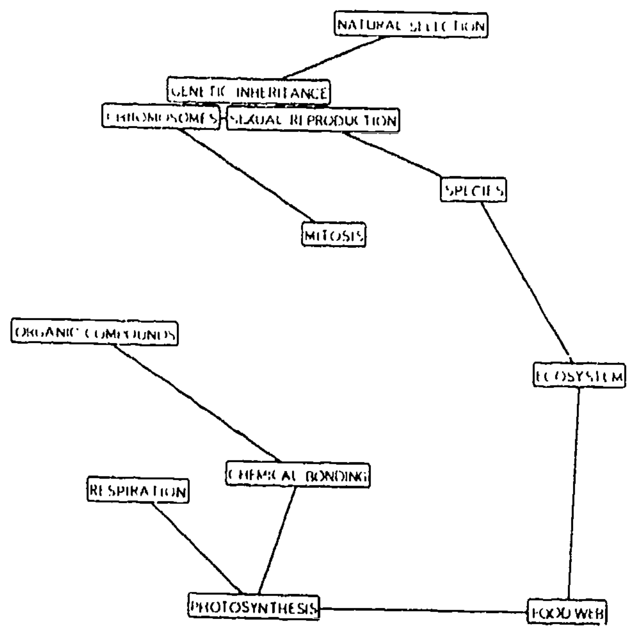
"Coherence" is the Pathfinder index for the internal stability of a network, ranging in potential value from zero to one, and may be interpreted similarly to an alpha reliability coefficient. All three networks produced in this manner displayed considerable coherence (Middle School Coherence = .85, High School Coherence = .79, College

Coherence = .84), indicating that concepts were rated by individuals with a consistent understanding of their meanings.

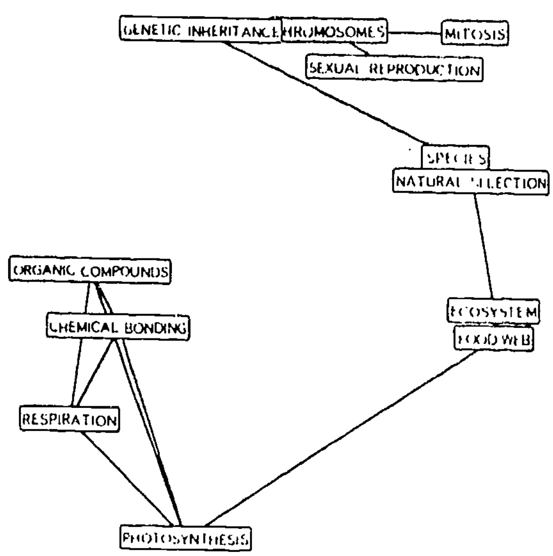
Figure 1

Concept Networks Derived from Transformed Concept-Pair Ratings

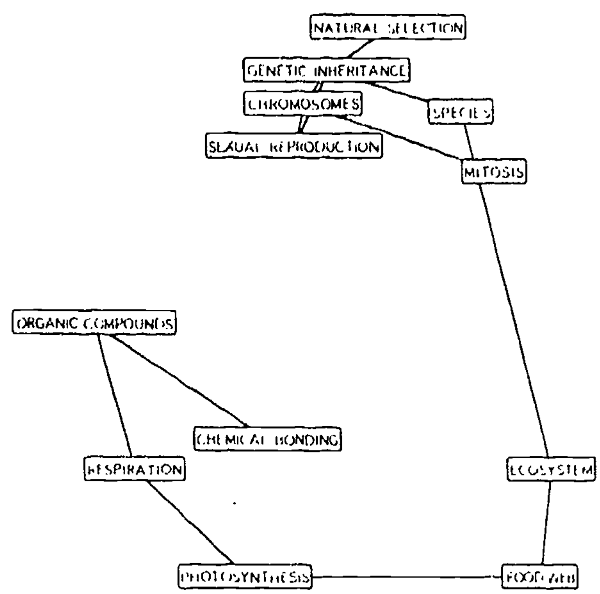
a. Middle School Teachers



b. High School Teachers



c. College Professors



Not surprisingly, all networks also demonstrate two meaningful clusters--one containing Genetics concepts, and the other containing Biochemistry concepts. The Ecology concepts of ecosystem and food web, although linked directly in each network, differ both in closeness of connection and in position relative to the other two clusters across the networks. A Pathfinder analysis of structural similarity among the networks revealed that the network produced from middle school teachers' data shared only 44% of its connections among concepts with the network produced from the high school teachers' data. The high school network shared 53% of its connections with the network produced from the college professors' data. Curiously, the middle school and college concept networks had 71% of their connections among concepts in common.

Discussion

Taken together, these results indicate what may be fundamental differences across academic levels in life science teachers' understandings of concept meaning and interrelation. These differences appear to exist largely independently of college coursework and teaching experience, and to include content that is common to all examined levels of life science instruction. It is well established in the knowledge structure research literature that students' cognitive representations of content knowledge come more and more to approximate those of their teachers. To the extent that systematic and significant differences in science teachers' knowledge structures exist across academic levels, science students in transition from one level to the next are likely to experience confusion and frustration.

On a positive note, all the science teachers we have surveyed seem to demonstrate an honest enthusiasm for their work, and the middle school teachers, in particular, appear to strive for creative, hands-on classroom experiences that should excite student interest. But for science students, as for students in any academic area, it probably also is important to experience a coherent representation of content knowledge into which later knowledge may be integrated most meaningfully.

References

Anderson, C.W, & Smith, E. L. (1987). Teaching science. In D.C. Berliner, U. Casanova, C.M. Clark, R.H. Hersh, & L.S. Shulman (Eds.) Educator's Handbook. New York & London: Longman.

Bates, J. A. (1982). Interactive strategies in statistics concept structuring and course achievement. Paper presented at the annual meeting of the American Educational Research Association, New York.

Chi, M. T., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

Diekhoff, G. M. (1983). Testing through relationship judgements. Journal of Educational Psychology, 75, 227-233.

Goldsmith, T. E., Johnson, P. J., & Acton, W. H. (1991). Assessing structural knowledge. Journal of Educational Psychology, 83, 88-96.

Hurd, P.D. (1982). State of precollege education in mathematics and science. Report prepared for the National Convocation of Precollege Education in Science and Mathematics, May 12-13, 1982, National Academy of Sciences and National Academy of Engineering, Washington, DC.

Konold, C E., & Bates, J. A. (1982). The episodic/semantic memory distinction as an heuristic in the study of instructional effects on cognitive structure. Contemporary Educational Psychology, 7.

National Commission on Excellence in Education (1983). A nation at risk: The imperative for educational reform. Washington, DC: U.S. Department of Education.

National Education Longitudinal Study (NELS) (1988). First follow-up; Teacher questionnaire science version. Sponsored by: U.S. Department of Education Center for Education Statistics.

Schvaneveldt, R. W. (1990). Pathfinder associative networks: Studies in knowledge organization. ABLEX Publishing: Norwood, NJ.

Stein, M. K., Baxter, J. A., & Leinhardt, G. (1990). Subject-matter knowledge and elementary instruction: A case from functions and graphing American Educational Research Journal, 27,(4), 639-663.

Thomas J. W., Bol, L., & Warkentin, R. W. (1991). Antecedents of college students' study deficiencies: The relationship between course features and student's study activities. Higher Education, 22, 275-296.

Thomas, J. W., & Rohwer, W. D., Jr. (1987). Grade-level and course-specific differences in academic studying: Summary. Contemporary Educational Psychology, 12, 381-385.