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ABSTRACT

One direction that science education reform has taken is an investigation into the content knowledge structure, instructional beliefs, and teaching practices of middle school, high school, and college science teachers. This research study follows that same path to determine whether systematic differences exist between academic levels on these components and how such differences might be related to student disaffection with science learning. Two components are identified: (1) to examine how science teachers organize biology concepts into coherent knowledge structures; and (2) to obtain teachers' self-reports concerning their classroom practices and their beliefs about what factors affect student learning. Four major findings were: (1) qualitative differences were found between middle school and high school, as well as between high school and college teachers' conceptual understandings of the same content information; (2) middle and high school teachers report placing significantly more emphasis on supportive classroom structures such as providing frequent reviews and providing extensive feedback; (3) high school teachers report placing greater emphasis on the importance of students' behaviors and dispositions to follow directions, to be organized and prepared for class; and (4) middle and high school teachers give more worksheets and seatwork assignments during class than do college professors. Contains 20 references. (ZWH)

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DISCONTINUITIES IN SCIENCE TEACHING: A DEVELOPMENTAL ANALYSIS

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The present study is an investigation of middle school, high school and college science teachers' content knowledge structure, instructional beliefs, and teaching practices. One component of our research has been to examine the way in which science teachers organize biology concepts into coherent knowledge structures within their own semantic network. A second component has been to obtain teachers' self-reports concerning their classroom practices and their beliefs about what factors affect student learning and make a successful science student. Our goal is to determine whether systematic differences exist, between academic levels, on these components and how such differences might be related to student disaffection with science learning.

There is a growing concern among science educators and researchers that our science students are ill-prepared to enter the technological age of the 21st century (American Association for the Advancement of Science, 1989; Anderson & Smith, 1987; Hurd, 1982). Recent national surveys (ASCD Curriculum Update, 1992) indicate that students like science less as they advanced through school (taking fewer science courses), and few are prepared for college level courses after high school graduation. For example, reports indicates that only 7% of high school graduates are prepared to take a college level science course (ASCD Curriculum Update, 1992). Researchers (Eccles & Midgley, 1989) have found that students are especially prone to academic difficulties when making the critical transitions from middle school to high school and from high school to college (Thomas, Bol & Warkentin, 1992). Rather than blame science teachers at the previous level for not adequately preparing students, more constructive efforts must be offered to increase student success and opportunity in science education. This study takes one step toward this end by seeking to discover and document possible teacher and grade-level differences across these critical transition years that may impede students' continuous progress.

This study is guided by a cognitive developmental view of teaching (Eccles & Midgley, 1989). According to this view, teacher's conceptual knowledge of the subject matter, together with their knowledge about student characteristics and student learning informs their teaching practices. Such practices in turn, affect what and how students learn, and subsequently, how students' future science learning may proceed. Thus, continuities in teachers' goals, knowledge and practices across critical transitions support students' continuous progress (i.e., students' progressive construction of conceptual understandings and inquiry skills across the school years), while discontinuities are more likely to impede such systematic progress.

The first component of the present research focuses on the quality of teachers' semantic structures for a set of core life-science concepts (Borko & Livingston, 1989; Shavelson, 1972). Research has demonstrated that the manner in which teachers organize their knowledge affects the manner in which they teach, provide instructional episodes, set goals, and make connections between concepts (Stein, Baxter & Leinhardt, 1990). Available research also shows that after a period of instruction in a specific content area, students' content knowledge structures become more similar to their teachers' structure (in the configuration of concepts and their relationships) (Goldsmith, Johnson & Acton, 1991). Finally, correlational studies have shown that a positive relationship exists between the degree of configural similarity in student-teacher content structures and student learning performance (Goldsmith & Johnson, 1990). This makes sense because as students build a conceptual understanding for a set of specific concepts, their knowledge structure for these concepts becomes constrained and organized in ways similar to their teachers' understanding of those concepts. Students whose semantic structures are more similar to their teachers at the end of instruction tend to perform better on classroom test that assess knowledge of those concepts.

As students advance through their schooling they encounter the same set of core concepts in their life science courses. However, if systematic differences exist between teachers' semantic structures for these concepts across the academic levels, students may experience discontinuity in their sense-making attempts to understand these concepts. At best, continuous progress across academic levels means that students' organization of content knowledge at an earlier level would facilitate comprehension and knowledge-building processes at the next level (Arzi, Ben-Zvi & Ganiel, 1985). At worst, discontinuity across levels would mean that students' content knowledge organizations constructed at an earlier level might interfere with or impede students' sense-making processes at the next level -even if these structures are "accurate" at the earlier level.

A second source of possible discontinuity across academic levels involves differences in particular course features and teacher practices that are typical of courses at these levels (Thomas & Rohwer, 1987). Course features place demands on student learning (e.g., performance criteria and task requirements) or provide supports (e.g., feedback, practice, review) to enable students to successfully meet course demands. Features of courses are hypothesized to affect students' self-regulated cognition and behavior as well as their goal orientation and conceptions of academic ability (Thomas, Bol, Warkentin, Strage, Wilson, Rohwer, 1993; Ames, 1992). Systematic differences between academic levels in the nature of course features have been demonstrated and may be responsible for the difficulty some students experience in coping with their academic schooling. Investigated in the present study are teachers' conceptions of what constitutes a successful science student and what factors influence student science learning. Such conceptions influence the goals and expectations teachers set for students and the kind of learning tasks and support practices given to students.

The present study then, tests two hypotheses: 1) that systematic differences exist, across the critical transition years, in life science teachers' conceptual understandings of the same, content-specific concepts; 2) that corresponding differences exist in science teachers' conceptions of a successful student, their classroom practices and beliefs about student learning.

METHOD

Participants

Nineteen middle school teachers, sixteen high school teachers and fourteen college professors participated in the study. All middle school participants were 7th-grade life science teachers, and all high school participants regularly taught a life science course, averaging 9.78 years and 14.13 years of teaching experience, respectively. The college professors (all Ph.D) taught an introductory life science requirement course and averaged 9.18 years of teaching experience. Schools were feeder schools to each other.

Instrument Description and Development

Life-Science Concept Structure Rating Task. 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 (chemical bonding, photosynthesis, respiration, and organic compounds), 2) Genetics (chromosomes, genetic inheritance, natural selection, species, sexual reproduction, and mitosis), and 3) Ecology (ecosystem and food web). Participants' knowledge structure for these concepts was elicited by having each teacher rate all possible unique pair-wise combinations of concepts (i.e., 66 concept pairs) according to degree of similarity. Each concept pair was rated on a 4-point scale ranging from 1 (unrelated or slightly related), to 4 (synonymous or one concept is a component of the other).

The ratings were entered into the Pathfinder scaling algorithm (Schvaneveldt, 1990). Pathfinder provides a graphic representation of the semantic network implied by the subject's 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. Two comparisons can be made between the teachers' semantic network representations of these core concepts: the degree of similarity between middle school teachers' and high school teachers' networks, and degree of similarity between high school teachers' and college professors' networks. Pathfinder calculates a similarity index of the graphic resemblance between structures. This index is based on the proximity of the neighborhood of concepts surrounding each concept and therefore provides different information from linear correlational methods.

Teacher Survey Questionnaire (TSQ). The TSQ is a self-report instrument divided into four dimensions:

1 - General Academic Information. Participants responded to a series of items about their own academic preparations and teaching experience.

2- Factors that influence student learning. Five scales assessed teachers' beliefs about what factors influence students' classroom learning on a 4-point Likert scale ranging from 1 (Not Important) to 4 (Very Important). These scales are presented in Table 1.
3- Teaching activities. Four scales assessed how frequently teachers used various teaching activities on a 5-point Likert scale ranging from 1 (Very Rarely Used) to 5 (Used Every Day). These scales are presented in Table 1.
4- Indicators of a successful science student. Four scales were used to assess teachers' conceptions of a successful science student. All items were rated on a 4-point Likert scale ranging from 1 (Not Important) to 4 (Very Important). These scales are presented in Table 1.

Procedure

Teachers and professors were notified by telephone and asked to participate. 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, and to return it within a week. All participants were assured that their responses would be kept confidential and anonymous. All participants returned their completed survey.

RESULTS AND DISCUSSION

Biographical Characteristics

Significant differences were revealed in three areas of educational and professional experience. In the first area, shown in top part of Table 2, differences emerged with regard to the amount of coursework completed: a) both high school teachers and college professors had completed more coursework in the physical sciences than had middle school teachers; b) college professors had completed more (almost twice as many) life science courses than had high school teachers, who had completed more (over twice as many) life science courses than had middle school teachers; c) middle school teachers had completed more (about twice as many) history courses than had high school teachers or college professors. In the second area, shown in middle part of Table 2, differences between academic levels emerged with regard to the years of teaching experience: both middle school teachers and college professors had fewer years of experience in the teaching of science than had the high school teachers. In the third area, shown in bottom part of Table 2, middle school teachers were significantly less likely than either of the other groups to have begun their teaching careers as science teachers.

Cognitive Structure

The three groups of instructors did not differ in their overall, mean ratings of concept relatedness, and the mean concept-pair ratings for the three sets were strongly intercorrelated with each other. Therefore, there was no need to transform participants' responses to a standard score. The concept-pair ratings were entered into the pathfinder scaling algorithm (Goldsmith, Johnson,

& Action, 1991) to assess the qualitative features of the instructors' network structures for the 12 core concepts. The results are presented in Table 3. All three concept networks displayed high degrees of internal coherence, indicating that the concepts had been interrelated in a subjectively meaningful way. The coherence index ranges between 0 and 1. All three networks also reflected the specific life-science domains to which sets of concepts belong. These network representations (generated by Pathfinder) are displayed in Figure 1.

The similarity indices calculated between the three concept networks, however, revealed qualitative differences in their structures. The results are presented in Table 3. A similarity index of 1.00 means identical configurations, whereas a similarity index of zero indicates independent, completed unrelated graphical representations. Our results revealed an similarity index of .53 and .50. This rather weak similarity indicates that there is only sight structural resemblance between the middle school teachers' concept network and that of the high school teachers, as well as that between the high school teachers' concept network and that of the college professors. In other words, all three groups of life science instructors constructed internally coherent but qualitatively different representations of the same slice of scientific reality.

Factors that influence student learning.

Four of the scales revealed statistically significant differences in mean ratings between academic levels as shown in Table 4. For each of the scales, the differences reveal a similar pattern: High school and middle school teachers' ratings of the items did not differ from each other, but both were significantly different from the college professors' ratings.

As can be seen, high school and middle school teachers indicated that classroom support structures are more important for student learning compared to college professors. Specifically, middle and secondary teachers placed more importance on providing learning goals, frequent reviews and feedback to students. In addition, middle and high school teachers, compared to college professors, placed more importance on building relationships and developing rapport with students and on the influence of student characteristics (e.g, home environment, attitude toward school). In addition, compared to college professors, high school and middle school teachers placed significantly greater importance on performance standards and assessment measures used to evaluate learning.

Classroom teaching activities

Two of the scales revealed significant differences between academic levels as shown in Table 5. High school and middle school teachers reported using more in-class worksheets and seatwork assignments during class than college professors. Moreover, middle and secondary level teachers, compared to college professors, also reported using more in-class activities that support student comprehension, understanding of science and that provide practice (e.g., small group activities, teacher demonstrated experiment or observation, using computer during class, teacher checks students' understanding). Finally, it is notable that each of the levels reported that they very rarely ask students to conduct independent observations and design of experiments on their own.

Indicators of a successful science student.

The results shown in Table 6 reveal that high school teachers rated students' skills and dispositions for organization and management of their time, effort and behavior (e.g., attend class regularly, being prepared for class, staying on task, following directions), as significantly more important indicators of a successful student than either college or middle school teachers.

Summary of differences and main findings

It is important to note, with regard to the biographical data, that entry into a middle school science teaching career is likely to be very different from entry into a teaching career at the secondary or college level. A little more than half of our sample of middle school teachers did not begin teaching as a science teacher. What does this say about current student recruitment and preparation practices for teacher education programs? What does this say about teacher hiring and assignment practices within our schools?

Four major findings of this investigation indicated discontinuities across academic levels. First, qualitative differences were found between middle school and high school, as well as between high school and college teachers' conceptual understandings of the same content information (i.e., 12 core concepts). We speculate that these differences in knowledge representation influence teachers' instructional practices, which in turn, affect students' knowledge construction in that social context (Stein, et al. 1990). In support of this, research has shown that students' representation for a set of specific concepts becomes more similar to their teacher's representation of these concepts after a period of instruction (Goldsmith, Johnson & Acton, 1991). According to our discontinuity hypothesis, as students progress from one level to the next, the conceptual constructions formed at the previous level will not facilitate future understanding and may unfortunately interfere with learning. Students attempts to construct meaningful understandings of science concepts as they progress through school might be severely thwarted under such conditions.

Second, compared to college professors, middle and high school teachers report placing significantly more emphasis on supportive classroom structures, such as providing frequent reviews, providing extensive feedback, practice and demonstrations, and setting learning goals as important factors affecting student learning. Moreover, middle and high school teachers tend to emphasize the socio-emotional aspects of learning by their focus on relationship-building and student characteristics. Research has shown the benefit of these supportive structures in facilitating student learning and on students' ability to monitor their progress (Crooks, 19; Kulhavy, 1977). However, the discontinuity hypothesis suggests that whereas students at the middle and secondary levels are likely to experience high degrees of guidance and direction, when they advance to college the nature and amount of this support changes dramatically. Such discontinuities are expected to be particularly devastating for students who lack self-regulatory skills for learning on their own (e.g., at-risk and disadvantaged students). Moreover, the finding that middle and high school teachers, compared to college professors, place significantly more importance on performance standards and assessment measures as influences on student learning supports the view that the evaluative climate of the classroom for this period of schooling is strongly associated with performance goals, external recognition and rewards (Eccles, Midgley, & Adler, 1984). Such a climate tends to induce competition for grades, social comparison and entity conceptions of ability (Dweck & Bempechat, 1983).

A third discontinuity revealed in the present study is that high school teachers report placing greater emphasis on the importance of students' behaviors and dispositions to follow directions, to be organized and prepared for class. High school teachers place significant value on regular class attendance, staying on task, completing assignments on time, being prepared for class, and following directions. Students who follow directions and comply with procedures are likely to be rewarded. In addition, high school teachers are likely to maintain expectations and goals that embody these values thus creating a different educational culture for learning science than exist at either middle school level or at college. This finding together with the previous finding, suggest that secondary-level students receive more external guidance and at the same time are expected to comply with procedures and show organized, well-disciplined behavior. These findings support the notion that for students, the shift from high school to college involves a critical shift in the nature of agency, control and responsibility. This shift involves a change from a reliance on teacher-directed or other-controlled learning during high school, to a demand for self-directed and self-controlled learning during college. Abrupt changes between high school and college, can leave many students unprepared to cope in a context where autonomous, self-regulated learning is at a premium (Thomas, et al. 1991).

A fourth discontinuity indicates that middle and high school teachers give more worksheets and seatwork assignments during class than do college professors. This finding supports the conclusion given earlier that high school environments are more regimented and other-controlled. In addition however, this finding indicates that many classrooms at the middle and high school level may still be emphasizing a passive, "receptive" learning approach to science education. In line with this, it was also noted that the incidence of requiring students to conduct and design their own experiments or to conduct an independent observation was extremely rare for all three academic levels (with all teachers reporting doing this activity "very rarely"). These findings suggest cautious interpretation regarding the impact of current instructional reform movements to bring about extensive, wide-spread change in the presentation and delivery of science education.

Implications

Rather than blaming teachers at previous levels for students' lack of preparation, we envision collaborative efforts between teachers of different academic levels that would coordinate the preparation of students to ensure facilitative transitions. Such collaboratives might begin by providing a forum for open communication to establish insightful connections from one level to the next. This might include sequencing and coordinating curriculum, and communicating goals and expectations across academic levels. Teacher collaboratives should not only take into account the coordination of teaching practices but it should also be consistent with the best of what we know about students' developmental needs. This coordinated approach promises more continuity across school years and thus, will reduce student frustration, dropout, disinterest and failure and increase students' success and persistence in academic learning.

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Table 1. The three dimensions of the Teacher Survey Questionnaire (TSQ)

1. Factors that influence student learning dimension (five scales):
   - Supportive classroom structures for feedback and guidance (three items): providing students with feedback on homework and class assignments; daily or weekly review of material; providing learning goals and objectives.
   - Motivating students and making class interesting (three items): motivate students by using a variety of instructional methods; make material interesting or diverse; use hands-on science experiences.
   - Teacher-student relationship and rapport (two items): develop trust and friendship with students; positive teacher attitude.
   - Performance standards and assessment measures (two items): use multiple assessment measures such as multiple choice and essay; expectations and standards for performance.
   - Student characteristics (five items): student's attitude toward school; student's knowledge of science; emotional tone of student's home; student's ability to complete assignments and be organized; student's ability to use learning strategies.
2. Teaching activities dimension (four scales):
   - Use in-class worksheets and seatwork (one item): have student complete individual written assignments or worksheets in class.
   - Students conduct independent observations and experiments (three items): students independently design and conduct own science projects; students turn in written reports on experiments or systematic observations; students give individual oral or written reports.
   - Provide support for student understanding and practice events (six items): teacher demonstrates experiment or systematic observation; teacher checks students' understanding via questioning; small group work; use computers for instruction; students read supplementary materials; students do systematic observation in class.
   - Provide integrative information (three items): discuss current issues and events in science; discuss career opportunities in scientific and technological fields; discuss controversial inventions and technologies.
3. Indicators of a successful science student dimension (four scales):
   - Organized time and effort management skills (eight items): attends class regularly; follows instructions; comes to class prepared; completes assignments on time; stays on task; reviews on a regular schedule; takes organized notes.
   - Learning goal orientation approach (four items): enjoys learning science; shows curiosity about science; keeps open mind to new concepts; solves problems creatively.
   - Uses cognitive learning strategies (three items): seeks to understand concepts; applies science concepts to ideas outside of class; relates science concepts together.
   - Self-efficacy and academic self-concept (three items): knows where to go to find answers; makes extra effort for difficult concepts; sets realistic goals.

Table 2. Biographical Data

Mean College Courses Completed

	Middle school		High school		College		F
Physical Sciences	4.16	(4.50)	9.38	(3.86)	7.69	(3.09)	7.97*
Life Sciences	5.00	(4.26)	12.73	(12.09)	23.21	(10.21)	16.13*
Social Sciences	4.37	(4.39)	3.29	(1.77)	3.39	(2.63)	<1
Mathematics	5.11	(4.52)	2.79	(1.31)	5.31	(1.65)	2.87*
History	4.74	(4.37)	2.29	(.47)	2.77	(1.01)	3.38*
Philosophy	1.22	(1.40)	.93	(1.58)	1.08	(1.32)	<1

Mean Years of Teaching Experience

	Middle school		High school		College		F
As s Teacher	9.78	(7.63)	14.13	(8.09)	9.18	(7.86)	1.79
As a Science Teacher	7.11	(6.45)	13.63	(7.91)	9.18	(7.86)	3.49*

First Teaching Position in the Sciences?

	Middle school	High school	College	Chi Sqr
Yes	9	14	14	13.92*
No	10	2	0	

Values in parenthesis are standard deviations
*p < .05

Table 3. Pathfinder analysis using the life-science concept rating task.

Similarity Index	
Middle school :: High school	.53
High school :: College	.50

Coherence Index	
Middle school	.86
High school	.81
College	.86

Intercorrelation Matrix	
Middle school, High school	.91
High school, College	.93
Middle school, College	.88

Table 4. Mean scale scores and ANOVA results on the Factors the Influence Student Learning dimension for the three academic levels. Scores are based on a 4-pt. scale: 1=not important to 4=very important.

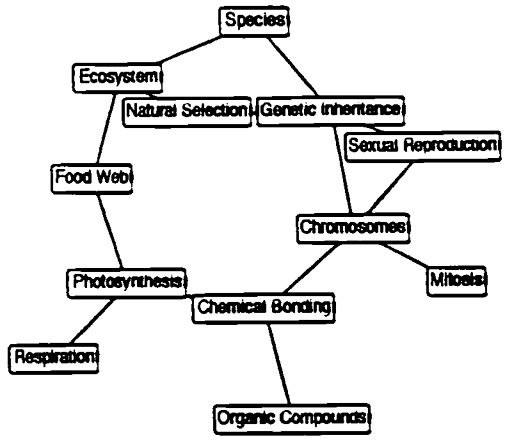
	Academic Levels			ANOVA	
Scales	College	High sch	Middle sch	F	p
Supportive structures for feedback and guidance	2.88	3.52	3.56	9.97	.0003
Teacher-student relationship and rapport	3.28	3.69	3.68	3.92	.02
Student characteristics	3.04	3.41	3.22	3.48	.03
Performance standards and assessment measures	2.61	3.31	3.42	9.01	.0005
Motivating students and making class interesting	3.40	3.65	3.67	<1	

Table 5. Mean scale score and ANOVA results for five Teaching Activities dimension for the three academic levels. Items rated on five point scale ranging from 1= very rarely to 5=every day.

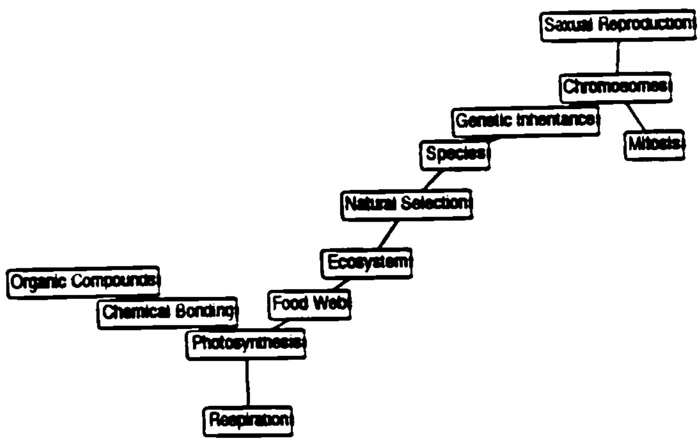
	Academic Levels			ANOVA	
Scales	College	High sch	Middle sch	F	p
Use in-class worksheets and seatwork	1.50	3.31	3.74	30.50	.0001
Students conduct independent observations and experiments	1.93	1.81	1.84	<1	
Provide support for student understanding and practice events	2.51	2.95	2.80	4.18	.02
Provide integrative information	2.19	2.15	2.30	<1	

Table 6. Mean scale scores and ANOVA results for the Indicators of a Successful Science Student dimension for the three academic levels. Scores are based on a 4-pt. scale: 1=not important to 4=very important.

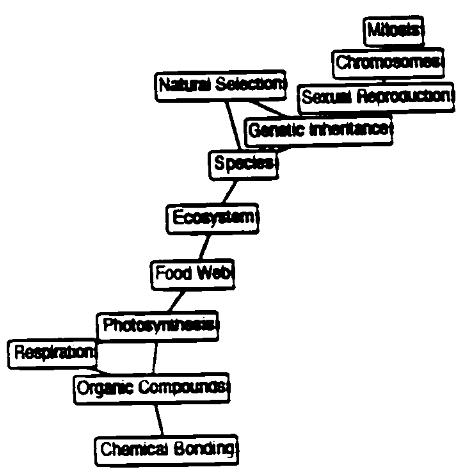
	Academic Levels			ANOVA	
Scales	College	High sch	Middle sch	F	p
Organized time and effort management skills	3.22	3.60	3.37	3.18	.05
Learning goal orientation approach	3.45	3.29	3.29	<1	
Uses cognitive learning strategies	3.54	3.60	3.52	<1	
Self-efficacy and academic self-concept	3.48	3.54	3.42	<1	



Middle School Teachers



High School Teachers



College Professors

Figure 1

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