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Lessons Learned: (Mathematics + Science + Higher-Order Thinking) x Second-Language Learning = ?

Devin G. Thornburg
Karen S. Karp

Introduction

Eighteen 10th-grade students are attending to the ESL science teacher, who is bilingual, at the front of the room. She has a pleasant, easy manner and offers lucid and comprehensive directions on how to use a balance scale to determine the heavier of two objects. She asks a couple of questions in English about the

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Devin G. Thornburg, PhD, is an assistant professor in educational psychology at Adelphi University in Garden City, Long Island, New York.

Karen S. Karp, EdD, is an assistant professor in mathematics and science education at Adelphi University in Garden City, Long Island, New York.

reasons for the tilt of the balance towards the heavier object. A few students raise their hands and of those who do, Michelle is called on and answers in halting English, "there is more weight on one side." The teacher responds, "That's true, but what does more weight mean?' Miquel answers in Spanish that "it means more force." The teacher smiles, accepts the answer, and directs students to pair up around balances in various parts of the room. Students are to weigh the groups of labelled objects and record which is the heaviest. All of the students quietly talk to each other in Spanish about the objects, operating the balance, and recording the data. When the teacher approaches and asks how each group is doing, the students respond in English but in one-word or two-word sentences.

Two class periods later, the same students (as well as one new female student from El Salvador who has just registered) are with the same teacher in the resource room. The teacher has brought in two toy phones for the students to practice ordering a pizza from a restaurant. The students freely interact with one another, talking in Spanish, but using more spontaneous and elaborated English when role-playing on the phone. The new student hangs back a bit but is soon approached by two other female students and asked whether she would like to try. Several other students begin asking the teacher in an animated fashion about the names of various ingredients and toppings in English.

As typical as these brief examples from two classroom situations must be to bilingual educators, they highlight several critical issues in current research explored in this project. This teacher cares about the achievement of her students and is effective in communicating knowledge in both contexts. But her science lesson, even though it is well planned, does not seem to spark the type of active inquiry or the practice of second language skills she had wanted. The pizza scenario does, involving a task that has functional relevance to these students, yet it is not part of the formal curriculum she must cover during the academic year.

The major barriers this teacher confronts in teaching these bilingual students about science or English have less to do with her expertise or the proficiencies of the students and more to do with the organization and culture of our schools. Given what Moll (1988) has called the "institutional constraints"—such as mandated curricula, texts, and grouping practices largely based on standardized test scores—on bilingual children's learning, can instructional models be articulated and implemented in the classroom that facilitate concurrent acquisition of disciplinary knowledge and the language in which it is communicated? Can children learn higher-order problem-solving and reasoning strategies in content areas while becoming academically proficient in the second language?

This research initiative was undertaken to address these questions of content

and linguistic and strategic knowledge learning through classroom-based implementation of *cognitive apprenticeship* approaches to curriculum and instruction (Collins, Brown, & Newman, 1989). These approaches reflect the basic notion that children learn best when they are placed in the role of an apprentice mastering school tasks, encouraging them to think about these tasks in ways that approximate the thinking of those who are skilled craftsmen. This notion has implications for the ways in which teaching should be organized. Teachers, as craftsmen, share knowledge with apprentices in their classrooms as that knowledge is used within the context of meaningful tasks. As in many cultures, the student in an apprentice role is taught how to accomplish a task by the teacher-craftsman through processes of modeling, supported practice, and evaluation of performance. These identified processes are central to apprenticeship approaches to instruction (Collins, Brown, & Newman, 1989).

A conceptual model was designed based upon these approaches for use with bilingual children (Thornburg, 1989). By introducing this model into several bilingual classrooms, the authors are exploring the ways in which teacher-student communication changes as a result of the model's use. It is proposed that some of the critical dimensions of effective mathematics and science instruction with bilingual students might be delineated through this research project.

In the sections that follow, the adapted model, its conceptual foundations, and relevant theory and research about second language acquisition and content-based instruction are briefly outlined, and the teachers and children who are part of the study are described. Some of the early findings from this project are summarized and discussed in the context of recent research on classroom-based language use.

Conceptual Background

Process-Oriented and Contextualized Views of Learning

The instructional model adapted for the project is based upon the recent work of John Seely Brown, Alan Collins, and their associates (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989), cognitive researchers who have discussed situated learning, the acquisition of knowledge within the contexts where that knowledge can be meaningfully used. These researchers' synthesis of cognitive studies of educational practices is partially undergirded by an information processing perspective, a framework which emphasizes exploration of the thinking processes involved in acquiring and using knowledge

as it occurs. Of the many significant insights this perspective has brought to learning theory, the two most central to apprenticeship approaches are that differences in school performance are related to differences in the use of "higher-order" cognitive strategies such as problem-solving and reasoning (Bjorklund, 1989; Case, 1985) and that strategy use by more "expert" learners can be chronicled and directly communicated to more "novice" learners (Jones, et al., 1987; Resnick & Klopfer, 1989; Weinstein & Mayer, 1986).

In mathematics, for example, teaching algorithms—either through the use of hands-on manipulatives or drill work—has been the typical form of instruction in most classrooms (Schoenfeld, 1989). Another classroom example can illustrate alternative methods for teaching mathematics from an information processing perspective. In a third-grade classroom, the teacher is talking about the reasoning strategies that might be used to interpret which mathematical operations are necessary to set up and solve a word problem involving addition of three single-digit addends. After it has been read aloud, the teacher asks the class, "how would you ask this same question, in your own words?" Emmanuel raises his hand and gives an acceptable answer, which the teacher acknowledges by responding, "very good, Emmanuel, but why did you include certain parts of the word problem in your answer?" When he does not answer, she asks, "what are the parts of the problem in your answer?" He lists these aloud as she writes them on the board. She then asks the entire class, in a series of questions, to state why each problem part is important for solving the problem. This is followed by a discussion as to whether the same parts would be as important in problems involving other operations. The teacher is emphasizing the higher-order strategies involved in solving word problems while also covering the necessary computations.

However, Collins, Brown, and Newman (1989) also emphasize the social influences upon the development of higher-order thinking, incorporating elements of a Vygotskian framework of learning. To Vygotsky (1987), development of higher-order thought is understood as internalization of social dialogue rather than the final outcome of biological growth. He proposed that all conscious mental processes are derived from interactions with others. One implication of this is that what is learned and internalized by the learner originates in the explicit imitation of behavior and speech in the social environment. Linguistic tools, such as reading, writing, or mathematics, are used to communicate with others and, with practice, are later used to think.

The path of intellectual development originates in the social realm, moving to the individual (Vygotsky, 1978). Children internalize the assumptions and knowledge of others and then transform them, using them to guide their own

independent solving of problems (Vygotsky, 1987). The more the expert can make these assumptions and knowledge explicit, the more the novice's learning is facilitated. Social role-playing during instruction allows for practice, articulation, and evaluation of knowledge to be internalized (Vygotsky, 1978).

Vygotsky's framework is an important one in the work of "cognitive anthropologists" who are interested in researching and designing classroom cultures that facilitate the development of targeted cognitive strategies (Brown, 1990; Brown, Collins, & Duguid, 1989; Wood, 1989). Collins, Brown, and Newman (1989), for example, propose that apprenticeship approaches approximate learning that is typical in more informal contexts—in a variety of cultural settings (Laboratory of Comparative Human Cognition, 1983; Rogoff & Lave, 1984; Verdonik, Flapan, Schmit, & Weinstock, 1988).

Significant gains in strategy use and scholastic achievement have been noted by cognitive researchers using instructional approaches similar to an apprenticeship approach with students across subject area, grade level, and educational program (e.g. Glaser & Chi, 1988; Hoetker & Brossell, 1989; Palincsar, Brown, & Campione, 1989). Children in need of skill remediation, in particular, seem to benefit from the use of explicit strategy instruction using hands-on and meaningful examples (Schmeck & Spofford, in press; Stone, 1989a). It seemed useful, therefore, to explore whether an apprenticeship approach could be effective with students who might need strategy instruction within the context of second-language learning.

Apprenticeship Approaches and Bilingual Learning

A variety of points are made in the theoretical and empirical literature on second-language learning that justify the adaptation of an instructional model from apprenticeship approaches. First, there is a developmental interplay between multilingualism and higher-order thinking. Gaining academic proficiency in more than one language appears to facilitate the use of higher-order thought (Hamel, Palij, & Aaronson, 1987; Vygotsky, 1935). Academic proficiency in a language, in itself, involves higher-order strategies (Cummins, 1987). Explicit strategy instruction using tasks situated in meaningful contexts and emphasizing peer interactions might address some of the needs of bilingual learners who are attempting to reach minimal "threshold levels" of academic proficiency in the first language, second language, or both (Cummins, 1976). Research has highlighted that if bilingual learners are to succeed in school, they must go beyond decoding second-language-presented information into the first

language by developing a repertoire of problem-solving and learning strategies used by American monolingual students (Goldman & Rueda, 1988; Moll, 1986; Padron, Knight, & Waxman, 1986).

This is particularly true of mathematics and science learning, the focus of this research, as these subjects are being redesigned to emphasize such higher-order cognitive strategies as problem-solving and critical thinking. Researchers are confirming that explicit strategy instruction will facilitate the acquisition and application of concepts and procedures in mathematics and science (Anderson, 1988; Minstrell, 1989; Schoenfeld, 1989). Yet bilingual children often achieve less well in these subjects (Jacobson & Faltis, 1990), and teachers have been pressured to make mathematics and science more accessible to underrepresented populations (Association for Supervision & Curriculum Development; National Council of Teachers of Mathematics, 1989; National Science Teachers Association). Arguments have been made on several grounds that second language instruction could occur more readily within the mathematics and science curricula, partially because they separate languages that can involve concrete materials and experiences, and they require little reliance on instruction in the student's first language (see, for example, Wong & Fillmore-Valadez, 1986). Arguments such as these need further research as curricula become increasingly organized around higher-order thought.

A second point about apprenticeship approaches is that they might provide teachers with instructional activities that reflect recommendations by researchers concerning second language acquisition within academic subjects, including varying levels of background knowledge, the necessity of using culturally relevant instructional material, and the importance of including social communication within instructional activities (e.g. Cazden, 1988; Chavez & Chesterfield, 1985; Duran, 1985; Flores, Rueda, & Porter, 1986; Moll, 1989). Moll's (1986; 1989) work in the development of higher levels of cognition among bilingual children is ground-breaking in developing instructional approaches that address social and cultural contexts of learning documented as central to the achievement of bilingual students. In researching the apprenticeship model, the authors agreed with the unit of analysis used by Moll (1989) in his work: looking at the bilingual classroom itself as a culture where knowledge is constructed through social interaction.

Thirdly, apprenticeship approaches would provide strategy instruction with the types of tasks found to facilitate second-language learning (Wong-Fillmore & Valadez, 1986). Apprenticeship approaches support Cummins' (1987) argument that the degree of contextual support available for expressing or receiving meaning from a task and the degree of cognitive demands of a given

task are central factors in second-language acquisition. Instruction and evaluation of the higher-order thinking necessary to master a task—fundamental components of apprenticeship approaches—reduce the task's context and complexity allowing the learner the opportunity to imitate, practice, and reflect upon the language used and resulting in internalization and more effective transfer of linguistic knowledge to other situations (Cummins, 1987; Hakuta, 1987).

An Apprenticeship Model of Instruction for Bilingual Children

With these points in mind, an instructional model using several key strategies identified with apprenticeship approaches (Collins, Brown, & Newman, 1989) was adapted for use with bilingual learners (Thornburg, 1989). The argument being made was that the activities within the model would simultaneously provide instruction in higher-order thinking while providing structured experience with second-language learning. Table 1 depicts examples of how the model could be used with bilingual students in two school-related areas of learning: reading in the science content area and mathematics. All of the noted elements could be parts of a single lesson, having previous instruction and extensive practice in the use of each in other lessons.

Table 1. Cognitive Apprenticeship Activities: Science Reading and Solving Math Word Problems.

	TASK	
	Reading science text, ranking ideas/concepts in order of importance.	Solving word problems using addition.
	*MODELING STRATEGIES**	
	•Introduce modeling and reasons for its use • Read text aloud • Verbalize problem-solving strategies for ranking as they occur: generating options... deciding "importance" criteria...	•Introduce modeling and reasons for its use • Read word problem aloud • Verbalize strategies for interpreting problems as they occur: deciding relevant numerical values... deciding relevant

deciding which criteria are valued...
comparing options/ criteria...
ranking ideas...
review decisions...

operations
deciding how to set up equations...
- Verbalize strategies for calculating equation
- Review decisions and calculations

*SCAFFOLDING STRATEGIES**

- Student reads science text aloud
- Student attempts to use strategies to rank ideas
- Teacher models remaining steps or formulates questions to guide the student who is unable to complete the task

- Student reads aloud word problem
- Student attempts to use strategies to interpret word problem, set up equation, and calculate answer
- Teacher models remaining steps or formulates questions to guide the student who is unable to complete the task

*EVALUATING STRATEGIES**

- Student prompted to articulate strategies used
- Teacher "replays" student's activity
- Strategy use discussed:
  - strengths/weaknesses
  - ways to revise usage
  - applications to other activities

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*PEER COLLABORATIVE STRATEGIES**

- Student dyads role-playing expert/novice, using strategies described above

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* = Use of first or second language for each strategy, depending upon students' proficiencies.

Modeling is a strategy that involves demonstrating the steps to accomplish a task—while verbalizing the thinking process accompanying the steps and why it might be done that way—with the students imitating these steps on a different, but parallel task. Rather than merely demonstrating, for example, how to use a yardstick to measure the distance across a room before or after going over a list of directions, the modeling strategy would involve talking through the steps and the reasoning for them while measuring the room. As the teacher places a mark on the floor to indicate where the yardstick ended in the first measurement, he states, "How should I use this line to measure the next section of floor? I know I have to move the yardstick. Maybe I should go through the same steps as I did the first time." All of this is stated prior to placing the yardstick for a second measurement.

Scaffolding is the term used to describe the support offered by the teacher on those aspects of the task the student cannot independently accomplish. This support can involve modeling again the steps that remain to complete the task or reformulating a question that is too complex for the student to answer. This latter type of scaffold explicitly reveals the assumptions made by the teacher in the previous statement or action (Stone, 1989b). In the yardstick example, the teacher asks David, "why would it be important to measure a room?" When David fails to respond, the teacher scaffolds the question by asking, "What are things in your own room that have to be measured to fit your room?"

Evaluation is part of the learning process where the learner reviews the strategies used in the attempt to master presented tasks, facilitating the learner's awareness and control of what is learned. After each child measures the room and comes up with answers, the teacher states, "I want each of you to think of one thing you did well when measuring and one thing you could do better the next time." Students volunteer their responses, and the teacher explores with them why they evaluated their performance in these ways. In *collaborative peer groups*, these same strategies are used by the students to role play the expert and novice during task activities. Students take turns monitoring, evaluating, and discussing their performance measuring the room using guidelines provided by the teacher. Meaningful and relevant tasks are designed to emphasize intrinsic motivation rather than external inducements (Collins, Brown, & Newman, 1988). In the classroom example, students are motivated to measure the room since they are going to be responsible for purchasing and applying wall paint. Their motivation is based upon being responsible for their own classroom rather than any rewards by the teacher.

As Table 1 represents, structural aspects of the language and the problem itself are highlighted in the instructional model, as is repeated imitation of the

sentence patterns used by expert English users. The teacher can gradually phase in second-language production in relation to the particular task as student proficiency improves. Groups can be given explicit guidelines for the use of the first and second languages by task and function. A general consensus is that alternating languages during instruction can result in confusion or overreliance upon the first language on the part of the students (Hakuta, 1987; Wong-Fillmore & Valadez, 1986). However, there is also substantial research to suggest that alternating languages can facilitate learning the subject area and the second language if each is used for different functions. For example, the first language might be used when clarifying instructional procedures or offering behavioral feedback to students (Tikunoff, 1983; Wong-Fillmore & Valadez, 1986). In important ways, the teacher has direct control over the constraints on the students' thinking and language use through the model, monitoring the variations in their learning, while encouraging the students to develop control and monitoring strategies for themselves.

Data Sources and Methods

In the spring of 1990, several public school districts on Long Island that were known to have large populations of bilingual students were contacted to see if their teachers would participate in the study. The research team formulated plans for training teachers in the apprenticeship model in consultation with bilingual education administrators. With funding support from the New York State Department of Education's Division of Mathematics and Science Education, 29 teachers and assistants (Grades K-12) from two districts volunteered to participate in the project. These teachers—with experience in mainstream mathematics and science classrooms, content-based ESL classrooms, or resource rooms—attended a series of summer workshops totaling approximately 30 hours. Inservice training focused on apprenticeship approaches, cognitive research and instruction, curricula and methods in mathematics and science, and second-language acquisition. During the entire 1990-1991 school year, the research team observed and met with the teachers in their individual classrooms. Most of the classrooms were visited at least three times during the year. Over 400 children were involved in these classes. Most of the bilingual children were immigrants from Central American and Caribbean countries, the majority having lived in rural areas with relatively little formal schooling.

Aside from the current collection of two years of objective data on the students' mathematics, science, and language achievement (as well as the

students' and teachers' self-concepts and attitudes towards the subject areas), the research team is conducting ethnographic research within the classrooms to explore how the cultures of these classrooms have begun to change as a result of the apprenticeship model. The particular focus of these ethnographic observations is the discursive patterns used in the classroom, how these change over time, and determining how these patterns might influence the students' development of English proficiency and mathematics and science knowledge.

Over 80 hours of classroom activity have been recorded by two members of the research team in a period of five months. After transcribing the observations, these same members organized the data into I-R-E structures proposed by Mehan (1979)—analyzing the discursive sets through teacher initiation, student response, and teacher evaluation—and the more general T.R.S. structures used by Cazden (1988)—where discourse is grouped into topic related sets. These groupings were then independently coded by the two research team members to establish interrater reliability. Codes reflected a number of dimensions developed by researchers in the areas of sociolinguistics and cognitive anthropology who look at cognitive processes and classroom discourse (Brown & Levinson, 1978; Forman & McPhail, 1989; Wells, 1986; Wertsch, 1985). Interrater reliability on the coding of the discursive units was .86, which indicates that the scorers agreed upon almost nine out of every ten codes. Some of the trends established in the discursive data using these methods are described below.

Findings

Discursive Patterns: Teacher Communication

Because mathematics and science have what might be considered more explicit organizational structures than other subject areas, it has been argued that mathematics and science instruction would involve more formal, sequential talk, dominated by the teacher, and that the level of thinking required by the student would be comprehension of the material rather than higher level thought requiring analysis, inference, or reasoning (Borko & Livingston, 1989; Carlsen, 1989). This was the case in most of the classes observed, particularly for the secondary grades. As the model has been implemented, however, there has been a gradual shift in several of the classrooms to more higher-order and exploratory forms of talk by the teachers in both Spanish and English. Many of the teachers have begun to emphasize analyzing and drawing conclusions in their talk about the presented knowledge, asking open-ended questions, and showing less of a

tendency to stop student talk when it somewhat digresses from the specific task goals into a related area.

These discursive changes are noteworthy in that the teachers were not directly instructed to employ these forms of talking when using an apprenticeship approach. Of the categories of teachers (ESL versus mathematics/science), no one category showed a greater tendency to use higher-order and explanatory forms of discourse. The shift, when it did occur, was irrespective of whether the knowledge being talked about was from written text, hands-on activity, or whole class instruction. Equally important, these changes in teacher communication were not related to any individual or cluster of grade levels. The shifts were observed in lower primary grades as well as high school.

The teachers who began using exploratory forms also began to incorporate student responses into their instruction and asked for elaboration of the students' comments. For example, when one teacher asked for examples of where pumps are used, a student responded, "lifting weights," and the teacher responded that "well...weightlifting could have several kinds, yes, so could you tell me the kinds you mean." Other researchers who have noted this type of talk, argue that the teachers are doing more than merely asking for clarification as part of their evaluation of the answer (Mehan, 1987). They are signalling a receptiveness of the students' ideas and a desire to engage the students' thinking and language use further (Cazden, 1988) through what has been referred to as "co-construction of meaning" (Palincsar, Brown, & Campione, 1989). The student talk that followed reflected this engagement.

Part of incorporating student responses can be literal uptakes by the teacher (when specific word usage by the student is repeated within the evaluative response, Cazden, 1988). Although this is more typical of younger classes of monolingual children, several of the teachers of the secondary grades used this intervention with increased frequency. This was a form of dialogic rehearsal of English words, used by the student and recontextualized by the teacher to exemplify the words' usage, elaborating the student's understanding of those words. For example, 10th-grader Christina (in solving the problem $2x + 7 + 13$) stated, "you put a minus 7 under the other 7 so they cancel out each one." Rather than intervening to improve the grammar, the teacher responded, "Okay, but why do we want to cancel out each one?" This response lessens the constraint of grammatical structure to focus the student's attention on the meaning and purpose of the procedure, a strategy often used by effective bilingual teachers (Hull, 1989; Moll, 1989).

Some caution must be taken in making these claims, as there is evidence in the research that incorporating student comments into teacher responses may be

associated with teacher control and a masking of teacher/student understanding (Edwards & Mercer, 1987; Palincsar, Brown, & Campione, 1989). What seems critical in establishing the value of this form of talk for students, however, is the particular contexts where this form of communication occurs (cf. Erickson, 1982). Usually, instances of this talk in the observations ended with an open-ended question about the student's response, suggesting that the teachers intended to facilitate mutual understanding. Although these types of questions, in themselves, have the potential function of teacher control, this is most typical when the question is related to the text or planned lesson (Carlsen, 1989)—not when student comments drift away from the lesson as in this research.

Another trend showed several of the teachers talk to change from simple, evaluative statements about student errors to what Cazden (1988) has termed a reformulation of statements or questions. These reformulations were of two types: a restatement that would reduce the semantic complexity of what was previously said or a translation of what was said into Spanish. To illustrate the former type, a teacher asked the class, "Why does this orange belong with the group of fruit over there?" When no response was given after several seconds, the teacher reformulated the question as "What does an orange have that makes it like other kinds of fruit?" Several students immediately called out responses. This type of talk is a form of scaffolding (Cazden, 1988; Palincsar, 1986; Wertsch, 1985) because it involves a breaking down of the previous statement into smaller steps (Collins, Brown, & Newman, 1989).

The spontaneous translation of a teacher's question or statement from English into Spanish when students fail to respond can be viewed as another type of scaffolding, as it is an attempt by the teacher to reduce the cognitive demands necessary to understand what is being communicated (Collins, Brown, & Newman, 1989; Stone, 1989b). As previously mentioned, the use of both languages by the teacher during a lesson has been viewed in the research as an impediment to second-language learning. Yet several of the bilingual teachers would engage in dual language instruction to facilitate students' acquisition of content and strategic knowledge. Occasionally, translating the communication into Spanish would result in correct responses by one or several students—also in Spanish—tending to confirm bilingual educators' concern that students lose important second language experience with this practice. But, more frequently, students would remain unresponsive to translated statements or questions. And, surprisingly, there were several observed interactions where the students would correctly respond to the translated communication in English.

For example, when reviewing terms in a problem requiring that a fraction be turned into a decimal value (4/38 = ?), the teacher asked in English, "What is

this?" (referring to the numerator). The student responded in English, "four." The teacher then said in English, "Yes, but what does the four represent in the fraction?" The student seemed puzzled, prompting the teacher to ask the same question in Spanish. When the student still did not respond, the teacher said in Spanish, "Thirty-eight is the denominator, four is the..." The student smiled and interjected, in English, "The numerator." The teacher used three different scaffold statements before finally reformulating what was being asked at a level of communication the student found more familiar. Arguably, the student would have more experience with the word "represent" than "denominator" but phrasing the statement to emphasize a contrast between mathematical terms was more in keeping with the way this student has previously learned than asking about the denominator's role in the fraction.

It seems that many of the teachers assumed that using Spanish was, in itself, a sufficient reformulation or scaffold as their translations were literal and not typically elaborated. This research raises, however, an important question about the *level* of scaffolding used when translating into the students' first language. The three different scaffold statements described above, for example, represent three levels. Recent cognitive research with monolingual students reveals that their capacity to understand depends upon whether the scaffolding level used by the teacher matches the levels of support the students have experienced in prior learning (Gauvain, 1990; Rogoff, 1990). This research may be highlighting the same point with bilingual students: if teachers are not aware of the communicative dynamics with which the students have been previously taught, translation into the first language may not produce the desired level of understanding of scientific or mathematical concepts or procedures. Teachers of second-language learners, therefore, should provide more than a linguistic translation. The information needs to be translated in a manner that is more historically familiar to the student for understanding to occur.

Discursive Patterns: Student Communication

Just as there has been a shift in the discourse of some of the teachers during their mathematics and science lessons, there has been a shift in the forms of talk on the part of the students. At the beginning of the observations, students tended to talk when called upon, when a question was addressed to the class as a whole, or in call-outs in response to a question asked of another student. The student's response would typically be in the language used in the teacher's initiating remarks and would be short, declarative statements with little elaboration.

Students were frequently observed attempting to get the teacher's attentior when a question was asked that they knew, often blurting out the answer. These call-outs were rarely to their peers; students would maintain their focus on dialogues with the teacher. Interestingly, very little illegal talk (Cazden, 1988) occurred in either language. Inattentiveness was usually signalled by eye contact or facial expression rather than talk with peers.

As the model was introduced, student communication in several classes (at various grade levels) changed in a number of ways: responses in both languages were longer and, on occasion, reflected higher levels of thought about a topic. Students were observed initiating conversation with their teachers more frequently—usually in Spanish, if the teachers were bilingual; and students talked more with their peers about the topic or activity at hand—usually in Spanish.

Specifically, students in several classes have changed in the ways they speak about the subject matter, moving from brief responses about the disciplinary knowledge and procedures being communicated and indirect references to experiences outside of the classroom (definitions of terms, answers to focused questions, in both languages), to longer responses (in both languages, but more so in Spanish). These responses frequently involve the students' classroom experiences with the concepts or procedures, to (very recently) occasional responses reflecting the use of the disciplinary knowledge and procedures as explanatory tools of newly-presented problems or ideas (only observed in Spanish). The shifts noted were in dialogues with other students, more frequently in the classrooms where teachers began regularly using an exploratory form of talk. Some changes, however, were noted in other classrooms where the peer-collaborative components of the apprenticeship model had been implemented. The same shifts were not noted when the students spoke to the teacher, although the length of time students spoke increased when speaking Spanish.

It seems that the students largely begin with reconstructive talk (where efforts are made to make the topic concrete and personally meaningful) and are, with experience, moving towards more integrative talk (where disciplinary knowledge is integrated with one's beliefs to elaborate ideas, make predictions, or ask further questions). Student talk to teachers and students is initially restricted, becomes more spontaneous and elaborated, but then returns to a more restricted quality when students make the attempts to integrate disciplinary language into their understanding.

To illustrate this, one of the junior high science teachers (who is monolingual) used a unit on various types of salts to introduce modeling and collaborative

learning activities into his classroom. After reviewing the salts from the periodic chart and procedures for using Bunsen burners, pairs of students were challenged to determine an unidentified salt by the color of its flame in the Bunsen burner. Loraine and Noe were tentative and awkward in handling the equipment, talking in Spanish to each other about what they were to do: "Be careful with the acid," "what if the flame blows up?" and "it turned orange, then yellow—which should I write down?" The students were talking about aspects of the task, while attempting to master it, outside of the disciplinary discourse. Loraine and Noe were paired up again a few weeks later for a science experiment where their conversations (also in Spanish) seemed at another phase of the reconstructive process in relating previous class experiences to the current task. "This is like when we titrated those things" and "I don't remember him [the teacher] talking about what an isotope is."

The following week, during a comprehensive exam requiring hands-on lab work as part of the assessment, these two students initiated a discussion about the groupings of the elements and what might happen if they discovered another group of elements. At one point, Noe stated, "well, since there are solids that have melting points and gasses can condense, maybe there's a time when something isn't a solid, liquid, or gas." This type of talk seems qualitatively different from their earlier attempts to integrate everyday language with science knowledge—cited as a cognitive stumbling block to conceptual understanding of scientific terminology (Carey, 1987; Forman & McPhail, 1989; Hashweh, 1987). The students were speaking (and thinking) more like scientists, a shift in role perspective that signals deeper understanding of a subject area (Vygotsky, 1987; Wood, 1989).

This change in student discourse appears to relate to Cummins' (1976) distinction between interpersonal and academic communication. More specifically, these students are becoming increasingly academically proficient in science topics—at least with their first language. Certainly the observed collaborative work highlights the importance of peer interaction for second language acquisition in classroom settings addressed in the literature (Wong-Fillmore & Valadez, 1986). What is striking is how little the peer talk in collaborative groups appeared to veer off task; even the social communication tended to be about the topic at hand.

Although a long tradition of cooperative learning research has claimed that group work appears to diminish off-task behavior and increase interest in the activity (Forman & McPhail, 1989; Good & Brophy, 1987), Moll (1986, 1988) has cautioned bilingual educators about the use of group activities because of the possibility of discussions becoming unrelated to the work. This has rarely

occurred in this project, perhaps because of the emphasis upon explicit role-playing within the instructional model which encourages students to self-consciously develop a "script" about their collaborative activities.

As previously mentioned, student talk with teachers remains brief, topic-related, and unelaborated—particularly when speaking in English. Student talk to some classroom teachers is becoming lengthier when speaking in Spanish, but continues to be more personal and anecdotal to the lesson. Undoubtedly, this reflects the students' greater comfort with topic-related communication in the first language. But there has been a notable increase in some of the classrooms in the frequency of student-initiated comments to the teachers about the topics they are studying—more so in Spanish with bilingual teachers. Admittedly, call-outs would fit into this category of student talk. But call-outs are noted in the literature on classrooms as referring to responses to a question the teacher asks of another student (Mehan, 1979). What has been observed in this project, instead, is an increase in questions or statements by students when teachers are talking to the class as a whole about the topic or related assignments. Most frequently, this student-initiated talk occurs in classrooms with a teacher using a more exploratory mode, but there have been increases in other classrooms as well.

This represents a shift in the **participation structures** (typical arrangements of speakers and listeners with implicit rules for taking part in conversation, Carlsen, 1989; Schultz, Erickson, & Florio, 1982) in the classroom and links back to the discussion of teacher scaffolding and assessment of the ways in which the students' learning is scaffolded in their homes and communities. Similarly, if the participation structures that are more familiar to the student from learning out of the classroom are also implemented, instructional communication and understanding are enhanced (Au & Mason, 1983; Carlsen, 1989; Lemke, 1982). Apprenticeship approaches allow for such shifts in the participation of teachers and students through formal role-playing and modeling, as well as through an emphasis upon collaboration with hands-on tasks.

Conclusions: Lessons for Teachers

Some tentative conclusions can be reached about the adapted apprenticeship model from this research. Bilingual teachers appear able to communicate both second language skills and higher order thinking within mathematics and science lessons through modeling, scaffolding, and evaluative strategies with meaningful tasks. The model appears to facilitate their responsiveness to

students' efforts to comprehend, apply, and reason through concepts and procedures using the second language. This responsiveness is evidenced by their incorporation of students' remarks into the lesson. This research tends to confirm previous findings that teachers of bilingual students should emphasize the meanings and cognitive levels of their students' communication in their instruction rather than, for example, grammatical correctness. This will, in turn, encourage students to talk more extensively about their lessons in the second language and to initiate more use of higher order strategies in learning mathematics and science. Students do seem encouraged to talk with each other about school tasks using the second language in more elaborate ways and at higher levels through the teaching strategies and collaborative activities emphasizing role play.

Translations into the first language may be problematic, unless done in a systematic and functional manner, both in terms of second language acquisition and in matching the level of communication students have experienced in previous successful learning. On the one hand, the teachers need to be careful to provide second-language instruction formally and frequently enough (as suggested on Table 1) so students do not remain dependent upon first language proficiency for comprehension of science and mathematics, a phenomenon frequently noted in bilingual education research (Moll, 1988). On the other hand, the risks some of the students are already taking to use English more to explore a topic are important first steps in becoming academically proficient in mathematics and science learning.

This research is a continual challenge, both in how these teachers can be helped to alter classroom instruction to reflect the model and in how to understand the changes observed in the classrooms. Only recently have there been initiatives to implement methods for bilingual education grounded in the areas of research addressed here, requiring that a more exploratory approach be used. The use of insights gleaned from cognitive anthropology and sociolinguistics to design instruction for bilingual students will offer a clearer view of the potential constraints on their learning and the types of classroom cultures that develop as these approaches are introduced.

The organization and culture of the collaborative effort with the participating teachers has changed, as well. As the work continues, it becomes clearer that the teachers must be actively involved in determining how to implement a curricular and instructional approach such as this. As the teachers become more knowledgeable about the application of an apprenticeship approach in their classrooms, our roles have begun to change within the project. In a striking way, collaborations with the teachers have paralleled the apprenticeship approaches

they are implementing. The teachers were once apprentices in learning to use the model and, through practice, have mastered the task and are now both applying the model to other lessons and critically evaluating its effectiveness. This has been an important insight and has, once again, served as a reminder of how instruction may change the way one thinks and talks about a subject.

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