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ABSTRACT

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Abstract

This study investigated how middle grades students, provided with free access to manipulative materials, use these mathematical tools in classrooms where their teachers are identified as Control-Oriented and Autonomy-Oriented. Also of interest in this investigation was how Control-Oriented and Autonomy-Oriented teachers administered the free access treatment in their classrooms. A Pre--Post-1--Post-2 design was used with two treatments. During treatment 1, teachers used the manipulatives for mathematics instruction using the strategies learned in the summer professional development workshop. During treatment 2, teachers provided students with free access to the manipulative materials.

Results indicated teachers' control orientations -- control versus autonomy -- were significantly different. The study also reveals that when we allow students some measure of control in the selection and use of manipulative materials, given the time to overcome their initial apprehension, they will spontaneously and selectively use these materials effectively as appropriate mathematical tools to mediate learning.

Introduction

There is considerable research on the use of manipulative materials for mathematics instruction, with a number of studies examining the difference between instructional strategies using manipulatives versus those without manipulatives. The indicator in many of these studies is a posttest in which students demonstrate their achievement following the instructional treatments (Parham, 1983; Raphael & Wahlstrom, 1989; Sowell, 1989; Suydam & Higgins, 1977). In a manipulatives versus nonmanipulatives research approach, we gain little insight into student use of these materials. Many study designs include manipulatives as a teaching strategy, whereas manipulatives, themselves, are merely mathematical tools. Teachers may be using a very traditional approach to mathematics instruction while using

manipulatives to supplement instruction (Baroody, 1989). Rather than teaching concepts, these mathematical "tools" may be used in more traditional ways, to teach algorithms, rules, or procedures. How teachers view the control of manipulatives during instruction may provide insight into how these tools are actually used in the teaching learning process.

Ideally, manipulatives should be used by students as a tool that assists their mathematical conceptual development. However, the control of the manipulatives is often claimed solely as the teacher's domain. Research has shown that teachers exert different control orientations in classroom settings. Teacher control is expressed through a variety of instructional behaviors. Deci, Spiegel, Ryan, Koestner, and Kauffman (1982) found that Control-Oriented teachers talk twice as much as their more Autonomy-Oriented counterparts. Deci et al. (1982) also found that Control-Oriented teachers allow students to work alone much less, give three times as many directives, make three times as many should-type statements, ask twice as many controlling questions, make two-and-a-half times as many criticisms, and give students much less choice. Control-Oriented teachers are more likely to praise the student, praise the student's performance, criticize the student's performance, give deadline statements, give solutions or hints, and provide leading statements. Studies have shown that if teachers are oriented toward being controlling, it is likely that the controlling aspects of their rewards or communications will be particularly salient, undermining children's intrinsic motivation and perceived competence (Deci & Ryan, 1987; Deci, Schwartz, Sheinman, & Ryan, 1981). Autonomy-Oriented teachers are more likely to provide their students with a choice, and are less likely to communicate with directives such as "should" or "put," less likely to criticize or communicate deadline statements, and talk less in an instructional

situation than their Control-Oriented counterparts (Deci & Ryan, 1987; Deci, Schwartz, Sheinman, & Ryan, 1981).

Along the continuum, some teachers are highly controlling, other teachers are highly autonomous, while others fall somewhere in between. The concept of autonomy connotes an inner endorsement of one's own actions or a choice. When acting autonomously, individuals initiate and regulate their own behavior, selecting desired outcomes and choosing how to achieve them (Deci & Ryan, 1987). In a study of 68 teachers of Grades 4 to 6 in traditional lower middle-class schools with conventional classrooms comparing Control- versus Autonomy-Oriented teachers, Deci, Schwartz, Sheinman, and Ryan (1981) found that students of more Autonomy-Oriented teachers were more intrinsically motivated and had more perceived competence. The effects of the teachers' control orientations in the Deci et al. (1981) study were seen within the first 2 months of school. Students' intrinsic motivation diminished in the classrooms of teachers with high control orientations and increased in the classrooms of teachers with high autonomy orientations. In addition to motivation, control orientation is expressed through teachers' language. In a study of control versus autonomy-supportive teaching behavior, Deci, Spiegel, Ryan, Koestner, and Kauffman (1982) found that those teachers who taught in a controlling context made three times as many utterances that tended to be controlling, such as *should, have to, must,* and *ought to* than those who taught in a less controlling context.

According to some researchers, teacher control orientations influence student thinking in mathematics. Kamii (1989) suggests that when we teach algorithms to children, we are teaching heteronomy, or a reliance on the thinking of others. By fourth grade, if we ask children to explain the steps

they follow in long division, they all say, "I don't know why [I brought down this number], but my teacher said to do it this way" (Kamii, p. 64). By teaching ready-made rules and procedures, we teach children conformity, obedience, and dependence on adults for the correct answers. This reliance on rules and procedures may become rote, making the conceptual understanding of mathematics increasingly difficult for students to achieve. "If students memorize a procedure meaninglessly, it is extremely difficult to get them to change it, even with extended, meaningful remediation" (Thompson, 1992, p.144). Teachers' control orientations may hinder the development of critical and autonomous thinking, thereby reducing the construction of knowledge in mathematics.

Every mathematics classroom is a complex system of interactions. When we examine learning within this setting and overlook the social nature of mathematical knowledge, the need for order and the sharing of control, we are neglecting a key piece of the puzzle. The learning of mathematics, like all learning, does not take place without the negotiation of control. When studying classrooms where manipulatives are being used during instruction, it is appropriate to consider how the actions and discourse of teachers and students influence the learning of mathematics for all members of the classroom community. How these tools are used by teachers and students to facilitate the development of abstract concepts is a significant issue. To understand these dynamic systems, mathematics research needs to go beyond a mere statistical analysis of changes in student achievement; research is needed on how the learning of mathematics is negotiated among the individuals involved in these meaningful interactions.

An examination of student behaviors with manipulative materials during mathematics instruction in classrooms where teachers exhibit

differing control orientations may provide significant information to improve our understanding of how students use tools to mediate their own mathematical thinking. In addition, allowing students to have greater control of and access to the manipulatives may add to our understanding of how students learn mathematics.

Theoretical Framework

Recent research in mathematics education and cognitive psychology has encouraged educators to shift from the memorization of facts and algorithms toward instruction in mathematics that recognizes the importance of students' involvement in mathematical concept construction (Cobb, 1994; Cobb, Yackel, & Wood, 1992; Peterson, Fennema, & Carpenter, 1989). However, this trend toward teaching for conceptual understanding is in conflict with the professional education many mathematics teachers have received. The historical emphasis on computation, procedures, rules, and algorithms is a dramatic change from the current theories of cognition or professional standards requirements put forth by the National Council of Teachers of Mathematics (NCTM, 1991). Because of teacher training and personal control orientations, teachers may be uncomfortable or unfamiliar with the appropriate instructional strategies to use with manipulative materials. Furthermore, many students are already quite capable and comfortable with mathematical tools such as calculators and computers, which, in some cases, results in the students being the experts instead of the teachers. This creates an entirely new set of dynamics in the mathematics classroom that may make some teachers uncomfortable, as they see themselves giving up control to their students. Teachers may feel as though they are losing their ability to control the knowledge and materials in their classrooms, thereby giving up their role as "expert."

According to some researchers, teacher control orientations influence student thinking in mathematics. A reliance on rules and procedures may become rote, making the conceptual understanding of mathematics increasingly difficult for students to achieve. Teachers' control orientations may hinder the development of critical and autonomous thinking, thereby reducing the students' construction of knowledge in mathematics.

Purpose

The purpose of this study was to investigate how students, provided with free access to manipulative materials, use these mathematical tools in middle grades classrooms where their teachers are identified as Control-Oriented and Autonomy-Oriented.

Research Questions

1. How do Control-Oriented and Autonomy-Oriented teachers administer the free access treatment in their classrooms?
2. How do students in the classrooms of Control-Oriented and Autonomy-Oriented teachers respond when given manipulatives in a free access treatment?
3. Who initiates the use of the manipulatives during the free access treatment? Do students spontaneously use the manipulatives? If so, which manipulatives do students select?
4. Does the use of the manipulatives during the free access treatment encourage any student response or behaviors not observed prior to the free access treatment?

Methodology

The focus of this paper is on student behaviors in Control-Oriented and Autonomy-Oriented teachers' classrooms during the Free Access period. This study employed both qualitative and quantitative methods of data collection.

In the spring of 1995, working categories and themes for the classroom observations and semi-structured interviews were identified during a pilot study that included the analysis of transcribed interviews and classroom observations. A total of 15 observations in three middle grades mathematics classrooms where manipulative materials were used for mathematics instruction were conducted. Three sixth-grade teachers, who used manipulatives for the instruction of a variety of mathematics topics, were involved in these observations on a voluntary basis. A total of 25 transcribed interviews from teachers in Grades K-8 were analyzed.

Participants

During the summer of 1996, 18 middle grades mathematics teachers voluntarily enrolled in a middle grades mathematics manipulatives workshop. Teachers voluntarily completed the Problems in Schools Questionnaire, a measure of adults' orientations toward control versus autonomy with children (Deci et al., 1981). Deci's analyses of this instrument reported scores between 2.13 and 12.13, with a mean of 6.98 (SD=3.11). Deci reported the effective range of the data to be 10.00, although the actual range was 22.25. The Problems in Schools Questionnaire includes eight vignettes, each followed by four items (or subscales) that represent four different behavioral response options for the problem posed in the vignette. Respondents rate the appropriateness of each of the four options (on a 7-point scale) for each of the eight vignette situations. The four subscale responses

are one response in each of the following four categories: highly controlling, moderately controlling, moderately autonomous, and highly autonomous.

Materials

Participating teachers received the North Carolina Middle Grades Mathematics Manipulatives Kit. The kit includes: 1 set of base-10 blocks, 1 set of 6 tri-pour beaker sets, 1 set of color tiles, 1 set of 1000 snap cubes, 1 set of 10 geometric solids, 1 set of 450 rubberbands, 15 geoboards, 3 sets of dice, 3 sets of pattern blocks, 1 rocker scale, 3 sets of 10 hundreds boards, 6 sets of fraction bars, 1 set of 10 thermometers, 1 trundle wheel, 15 centimeter and inch tapes, 7 sets of tangrams, 3 mirrors, 15 triman protractors, and 15 triman compasses. Additionally, all teachers had calculators and teacher-made mathematics materials in their classrooms.

Procedures

The study occurred in three phases and employed a Pre - Post-1 - Post-2 Design (See Table 1). Data was collected on teachers' control orientations, teacher practice, and instructional behaviors, and on students' attitudes, and behaviors, throughout the study.

Table 1

Study Design and Timeline

Date	Data Source
	PRE-ASSESSMENT
6/96	Problems in Schools Questionnaire administered; 10 teachers selected.
	Teachers completed the Practice Survey.
	Tools for Cognition Workshop Instruction.
9/96	Teacher Interviews
	POST-1-ASSESSMENT
9/96-10/96	Treatment 1 - Classroom Observations, Teachers Using Manipulatives during Normal Instruction
10/96	Problems in Schools Questionnaire administered.
	Teacher Interviews
	Teachers completed the Practice Survey
	POST-2-ASSESSMENT
11/96-1/97	Treatment 2 - Classroom Observations, Teachers Using Student "Free Access" With Manipulatives
2/97	Problems in Schools Questionnaire administered.
	Teacher Interviews
	Teachers completed the Practice Survey

Note. Problems in Schools Questionnaire, (Deci, et al. 1981).

Pre-Assessment Phase. The Tools for Cognition: Middle Grades Math Manipulatives Project workshop occurred during the last 2 weeks in June 1996 and included instruction in the use of a variety of manipulatives, opportunities to participate in cognitively-based instructional strategies, a focus on mathematics standards, methods for reaching diverse learners, the use of technology, and opportunities for sharing and planning. The workshop provided the teachers with experiences with a variety of materials, including the use of the North Carolina Middle Grades Mathematics

Manipulatives Kit for students, mathematics manipulatives for the overhead projector, calculators and computers.

In September 1996, teachers participated in semi-structured interviews. The purpose of the interviews was to identify teacher background information, beliefs about mathematics and manipulatives, teacher practice, and teacher control orientation (Pre-Interview Protocol, Appendix A).

Post-1-Assessment Phase. During the Post-1-Assessment Phase of the study, teachers used manipulative materials for mathematics instruction in their classrooms using the materials and instructional strategies shared in the summer workshop (Treatment 1). In September and October 1996, each teacher was observed twice. Teacher and student verbal and non-verbal behavior was recorded with fieldnotes and audio-tape recordings. Each teacher was equipped with a lapel microphone and audio-tape recorder to preserve exact quotations. Data collected during these observations included detailed descriptions of the teachers' activities, behaviors, actions, interpersonal interactions, and direct teacher quotations, as well as descriptions of the students' behaviors and comments. Each class was observed twice, for a total of 20 classroom observations during this phase. Following the Treatment 1 observations, each teacher participated in a second semi-structured interview (Post-1-Interview Protocol, Appendix A).

Post-2-Assessment Phase. During the Post-2-Assessment Phase in November 1996 through January 1997, each teacher was asked to provide students with free access to manipulative materials during mathematics instruction (Treatment 2). Free access was defined as the opportunity for students to select and use manipulative materials they identified as necessary in providing assistance in solving a mathematical problem. Teachers were asked to provide students with a variety of manipulative materials placed in

plastic baskets located on or near student desks. Students did not need to get out of their seats to get the materials, nor did they need teachers' permission to obtain and use the materials. In essence, students had free access to the manipulatives, providing them with a measure of control in their selection and use of the tools for mathematical thinking.

Post-2-Assessment data collection began during the first 2 weeks in November 1996. Observations during this phase occurred in the same classrooms as those observed during the Post-1-Assessment Phase to document evidence of change during the implementation of student free access to the manipulative materials. Each classroom was observed twice during this period, a total of 20 observations. Following the second round of observations, each teacher participated in a third semi-structured interview (Post-2-Interview Protocol, Appendix A).

Analysis

The Problems in Schools Questionnaire was scored by calculating the mean for the eight ratings in each of the four categories (highly controlling, moderately controlling, moderately autonomous, and highly autonomous) for each teacher. The four subscales were combined to form a total scale score by weighting determined in the following manner: weight the average for the highly controlling response with -2 (minus 2); weight the moderately controlling average with -1 (minus one); weight the average for the moderately autonomous subscale with +1; and weight the average for highly autonomous with +2. The algebraic sum reflects adults' orientations toward control versus autonomy, with a higher scale score reflecting a more autonomous orientation and a lower scale score or a more negative score reflecting a more controlling orientation.

Based on the results of the administration of The Problems in Schools Questionnaire during the summer workshop, a subset of 10 teachers, 5 identified as Control-Oriented and 5 identified as Autonomy-Oriented, were invited to participate in the study. The 5 teachers with the highest control orientations and the 5 teachers with the highest autonomous orientations were selected to maximize the variance between the two groups. The 10 teachers in this study were female (7 Caucasian, 3 African American). One of the teachers held a Master's Degree and the remaining nine teachers held Bachelor's Degrees. Three of the teachers possessed a mathematics major or minor in their field of study. Six of the teachers taught sixth-grade, three taught seventh-grade, and one taught seventh- and eighth-grade classes. The mean number of years of teaching experience of the 5 Control-Oriented teachers was 8 years (SD=3.46), with a range from 5-13. The mean number of years of teaching experience of the 5 Autonomy-Oriented teachers was 17.6 years (SD=5.98), with a range from 9-25.

Research questions were answered using data sources for student behaviors during the free access treatment including: teacher reports of student behaviors, classroom observations of student behaviors, and audio-taping of student talk during classroom observations.

The 30 teacher interviews were used to identify differences between Control- and Autonomy-Oriented teachers' uses of manipulative materials for mathematics instruction and to identify the influence of student free access to the manipulatives on teachers' instructional practices. Teachers' also reported their observations of student behaviors and verbalizations during the free access treatment. Each interview was audio-taped, transcribed, and coded for themes.

A total of 40 observations were used to record student behaviors and verbalizations during the free access treatment. Audio-tapes and fieldnotes, were analyzed to provide a holistic picture of verbal and nonverbal activities in each classroom. Each observation audio-tape was fully transcribed and coded for themes.

The focus for the coding was on the students uses of manipulatives and how the classes of Control-Oriented and Autonomy-Oriented teachers differed. During the first reading, the researcher reviewed 100% of the observational and interview data to identify major themes within the transcriptions. A second reader was trained to code the observational and interview data to verify accuracy. The second reader initially reviewed 60% of the observational and interview data to gain an understanding of the content of the interviews and the context of the classroom observations. The reader identified major themes that were repeated throughout the transcriptions. These themes were consistent with those identified by the researcher. The second reader was trained to code an additional 25% of the data examining the transcriptions for the themes. A comparison of the second reader's coding and the researcher's coding of the transcriptions resulted in a reliability coefficient of 0.87 indicating very good agreement, with the second reader coding slightly fewer instances of the themes in transcriptions than the researcher. These coding differences were resolved in discussions and were attributed to the researcher's presence in both the interviews and classroom observations, thereby allowing the researcher a more acute sense of the verbalizations and behaviors in the transcriptions.

The researcher and the reader identified the following themes: Study Fidelity, Free Access Rules, Student Spontaneous Use, Teacher Initiated Use,

Student Use During Problem Solving, Student Discourse, and Non-Mathematic Behaviors.

Results

Teachers' scores on the Problems in Schools Questionnaire ranged between -3.37 and 11.0, with a mean of 3.96 (SD=3.62). The analysis of variance for the Problems in Schools Questionnaire (Deci, et al. 1981) for the two teacher groups (Control-Oriented and Autonomy-Oriented) is reported in Table 2.

Table 2

Analysis of Variance--The Problems in Schools Questionnaire

Source	M	SD	F	p
Pre-Assessment				
CO	-0.68	1.88	47.07	0.000***
AO	7.90	2.06		

Note. n=10

*** $p < .001$

On the initial administration of the Problems in Schools Questionnaire, the analysis of variance indicated that Control-Oriented teachers' scores were significantly different from Autonomy-Oriented teachers' scores on the Pre-Assessment with an $F(1,8) = 47.07$ ($p < .001$). These scores remained consistent on the Post-1-Assessment and the Post-2-Assessment of the Problems in Schools Questionnaire.

Scores on the Problems in Schools Questionnaire are interpreted as follows: a higher scale score reflects a more autonomous orientation and a

lower scale score or a more negative score reflects a more controlling orientation. Control-Oriented teachers' scores on the pretest (M=-0.675, SD=1.884) showed an increase on posttest 1 following Treatment 1 (M=1.175, SD=1.467) and a decrease on posttest 2 following Treatment 2 (M=1.075, SD=1.399). This indicates that Control-Oriented teachers' scores became more autonomy-oriented following Treatment 1 and more control-oriented following Treatment 2. Autonomy-Oriented teachers' scores on the pretest (M=-7.900, SD=2.064) showed a decrease on posttest 1 following Treatment 1 (M=7.300, SD=2.019) and a decrease on posttest 2 following Treatment 2 (M=5.950, SD=2.177). This indicates that Control-Oriented teachers' scores became more control-oriented following Treatment 1 and more control-oriented following Treatment 2.

A paired samples t-test was used to examine any significant differences and where these differences might exist between the pretest and posttest 1, the pretest and posttest 2, and posttest 1 and posttest 2 on the administration of the Problems in Schools Questionnaire. The results of this analysis are presented in Table 3.

Table 3

Paired Samples T-Test on the Problems in Schools Questionnaire

Source	Mean Difference	SD Difference	T	p
Control-Oriented Scores				
6/96 vs. 10/96	-1.850	2.303	-1.796	0.147
6/96 vs. 2/97	-1.750	1.873	-2.090	0.105
10/96 vs. 2/97	0.100	1.116	0.200	0.851
Autonomy-Oriented Scores				
6/96 vs. 10/96	0.600	1.109	1.210	0.293
6/96 vs. 2/97	1.950	1.942	2.246	0.088
10/96 vs. 2/97	1.350	2.338	1.291	0.266

Note. n=10

The paired samples t-test indicated that no significant differences existed between the paired administration dates using the scores from the Problems in Schools Questionnaire.

Control- and Autonomy-Oriented Teachers Administration of the Free Access Treatment

In the sections that follow, teacher behaviors are described for Control-Oriented and Autonomy-Oriented teachers and pseudonyms are used. (Control-Oriented teachers: Ann, Betty, Catherine, Denise, and Edith; Autonomy-Oriented teachers: Frances, Gena, Helen, Inez, and Joan.)

Study fidelity. Control-Oriented teachers had more study fidelity than did Autonomy-Oriented teachers, adhering to the study guidelines established for the use of manipulatives throughout the study and the use of

the baskets of manipulatives during the free access period. They followed the timeline accurately, beginning and ending each phase of the study as requested, turning in students' surveys on time, and providing the study directives to students for the use of manipulatives during the free access period. Throughout the free access period, the baskets in the Control-Oriented teachers classes remained accessible to students. Overall, observations and interviews indicated that Control-Oriented teachers exhibited more organized and systematic behaviors throughout the study than the Autonomy-Oriented teachers.

The Autonomy-Oriented teachers showed less study fidelity than the Control-Oriented teachers, and in some cases, did not strictly adhere to the guidelines set forth on the use of manipulatives and the use of the baskets during the free access period. Teachers were asked to state the rules for using the manipulatives and the purpose of the baskets prior to observation 3, the first observation during the free access period. This was not done by 2 of the 5 Autonomy-Oriented teachers. In Helen's classroom, the researcher was asked during the observation to explain to the students the purpose of the baskets and the rules for using them. In Inez's classroom, the baskets were introduced to the students in the middle of the lesson.

Students in the Control-Oriented teachers' classrooms had access to the baskets at their seats. In three of the classrooms, baskets of manipulatives were placed at the center of student table groups. In two of the classrooms, baskets were placed on the floor beside student desks. The close proximity of the baskets did not require students to get out of their seats to select the materials and they were not required to ask permission to use the manipulatives. At the beginning of the class, students or the teacher placed the baskets on or near student desks for the class period. One exception

occurred in Edith's classroom. She did not place the manipulatives that she was planning to use for the day's lesson in the baskets. For example, if she was planning to use the geoboards during the lesson, these were distributed to students at the point in the lesson when students were required to use them.

Autonomy-Oriented teachers were not consistent in their placement of the baskets or in providing student access to the manipulatives. Frances, an Autonomy-Oriented teacher, placed all of the baskets on the floor against a side classroom wall. Students were dismissed from their seats a few at a time to get the items they needed from the baskets. Although this Autonomy-Oriented teacher was asked to place the baskets nearer to student desks, during the next observation, the baskets still remained against the classroom wall on the floor. Gena began the school year using her own baskets by placing them on a classroom table. During the first observation, the baskets were on the floor near student desks. Autonomy-Oriented teacher Inez, placed the baskets out in her classroom 1 week later than requested by the researcher, stating that she forgot to begin to use the baskets.

Free access rules. The Control-Oriented teachers were organized and systematic in their use of the baskets of manipulatives during the free access period. Three of the Control-Oriented teachers, Ann, Catherine, and Denise, created lists of the manipulatives contained in the baskets and placed these on the side of each basket. In Catherine's classroom there was a list of directions for the proper use of the baskets posted above the shelf where the baskets were stored. Ann was curious, herself, about how much the students would use the manipulatives when they were placed in baskets on the student desk groups so she maintained a checklist of the manipulatives her students used during each lesson and kept this record throughout the free access period.

Autonomy-Oriented teachers had very few rules for using the manipulatives in the baskets. They did not have lists on the sides of the baskets or rules posted on charts on the wall. In general, they developed on-the-spot rules during the free access period.

During class time, the Control-Oriented teachers communicated their need for organization to students. Ann, Catherine, and Edith assigned students to be group leaders. It was their responsibility to distribute and collect the baskets for the group and to check the baskets to be sure all of the contents were there for the next class. Some of the students took this responsibility very seriously and would not allow other students to obtain any of the materials in the baskets, even when they were permitted to use the manipulatives. The teacher had to explain to the group leaders that each student in the group was permitted to have free access to the materials. It was interesting to hear Ann say about her students, "They were being control freaks with the manipulatives" (interview 3, p. 7, line 322).

At the beginning of the free access period, Control-Oriented teachers generally told their students the same things: "...we're going to have a lot of manipulatives in the baskets to help them every day in math. They could use whatever they wanted to help them solve problems" (Catherine, interview 3, p. 1, lines 49-50). The general rule for using the manipulatives in the baskets in the Control-Oriented teachers' classrooms was that students were not permitted to use any of the materials during the teachers' introduction of the lesson. The teacher might then instruct students to remove a specific manipulative from the basket to be used during guided practice. Following guided practice, students were permitted to use any of the manipulatives in the basket.

Perhaps it was because rules were not clearly stated by the Autonomy-Oriented teachers at the onset of the free access period that students began to play with the manipulatives and sometimes used the manipulatives inappropriately. The result of these inappropriate behaviors was that Autonomy-Oriented teachers were more likely to remove the baskets of manipulatives permanently. Many of teachers' verbalizations during class included student directives to stop making noise, stop playing with the materials, and to stay in their seats. Many lessons appeared to lack structure and purpose.

All of the Control-Oriented teachers found that giving students free access to the manipulatives in the baskets had not been problematic in their classrooms. However, all stated that this was true because they had developed clear guidelines for the use of the manipulatives and had communicated these to students at the beginning of free access. As one teacher stated, "As long as the ground rules are set, I don't have a problem with it" (Edith, interview 3, p. 3, line 157). Each of the teachers talked about rules and guidelines for using the manipulatives prior to and during free access.

Autonomy-Oriented teachers admitted to being very skeptical about trying free access in their classrooms. This may have been the reason so many of them tried it initially and then made changes in what was required by the study. Joan shared her honest opinion: "At first I thought, 'Oh boy, this is a trip'" (interview 3, p. 5, line 233). In most Autonomy-Oriented teachers' classrooms, it was somewhat chaotic the first week. Without strict guidelines and rules about the baskets, Autonomy-Oriented teachers found themselves having to reprimand inappropriate student behavior frequently. This did change as teachers began to tell students what would and would not

be acceptable. However, the initial chaos made some of the teachers uncomfortable with using the baskets.

Teacher predictions. Prior to the start of free access, all teachers were asked to make some predictions about how they thought their students might respond to the manipulatives in baskets. There were a variety of responses from the Control-Oriented teachers: "I predicted they would only use what I showed them" (Ann, interview 3, p. 2, line 104); "I thought girls would be less likely to use them" (Betty, interview 3, p. 2, line 66); "I thought the kids would just play" (Catherine, interview 3, p. 2, lines 83-84); "I thought my class would be chaotic" (Denise, interview 3, p. 2, line 94); and "I didn't think they would use them" (Edith, interview 3, p. 2, line 71).

Each of the Autonomy-Oriented teachers discussed different student responses that might occur during the free access period. Gena was at first most concerned that the materials would be left all over the desks or on the floor and would become a safety hazard. Joan and Frances were concerned that students would play with the materials and see them as toys instead of mathematical tools while Inez thought students would ignore the baskets. Helen said that her concern was that she just didn't understand what she was supposed to do at the beginning of the free access period.

Student Response in the Free Access Treatment

The way in which manipulatives were used varied greatly among the students in each of the classrooms. Control-Oriented teachers, who were more comfortable or more experienced with the manipulatives, used them with more variety and this was reflected in the behaviors of their students as well. They were more willing to allow students to explore and this gave students the opportunity to find different uses for the manipulatives. In

some Control-Oriented teachers' classrooms, they were more willing to accept diverse strategies and solutions. Students exhibited more behaviors in which they attempted a variety of solution possibilities during some of the problem solving lesson.

Autonomy-Oriented teachers, who appeared to be less comfortable or had less experience with the manipulatives, did not exhibit as much variety and rarely employed to strategy of student exploration and discovery. This lack of opportunity for exploration was reflected in observations which indicated less student exploration with the materials. Teacher interviews indicated a concern that they would be unable to control student activity and that the lessons would be chaotic. Helen explained her frustration in using the snap cubes: "Sometimes they want to play instead of work, especially when I use those snap cubes, because they stick together. That was one I really didn't like because they ended up playing. I got a little bit frustrated because they were too interested in putting them together than in what I was trying to teach them" (interview 1, p. 4, lines 169-173).

Students' initial response. Students' initial response in Control-Oriented teachers' classrooms was skepticism. Some of them thought the free access period was some kind of "trick" their teacher had devised. Denise reported that her students' reactions were, "There's a catch to this. She's not really going to let us do this" (interview 3, p. 3, line 105). Because students were apprehensive at first, teachers found that there was hesitation in using the manipulatives in the first week. Often students would continue to ask the teachers' permission to get something out of the baskets. But as time passed, and students realized their freedom in using the materials, they became comfortable obtaining the materials without asking permission.

Students' initial reactions to the manipulatives in Autonomy-Oriented teachers' classrooms were very positive. Joan remarked, "They were really excited to have everything all at once. It wasn't quite like Christmas, but it was. It was real exciting to them. They thought it was a lot of fun and was going to be a lot of fun" (interview 3, p. 2, lines 94-95). Students looked through the baskets to see what manipulatives the teachers had placed in them. At first students were apprehensive about using the materials because they were not sure when they were allowed to select the manipulatives from the baskets.

Students' responses as time passed. Control-Oriented teachers reported that during the 6-week free access period, students increasingly used the manipulatives more often and used a greater variety of materials for problem solving. Ann maintained a record of student manipulative use and reported that each day students used more of the manipulatives and a greater variety of the manipulatives. She reported that initially they used manipulatives that were familiar to them--calculators, rulers and protractors--and moved on to spontaneously use some of the new manipulatives--tangrams, snap cubes, pattern blocks, and hundreds boards--as time progressed. This was true in most of the other Control-Oriented teachers' classrooms as well.

As the weeks passed, students in the Autonomy-Oriented teachers' classrooms began to understand the purpose of the manipulatives in the baskets and they began to be more selective about the manipulatives they obtained. Frances explained, "After about 4 weeks, they knew that they were supposed to use them for specific activities, not just to have them on their desks" (interview 3, p. 2, lines 73-75). Although Helen reported that most of the time her students just let the materials sit in the baskets, other

Autonomy-Oriented teachers reported an increase in the use of the manipulatives over the 6-week free access period.

Students using manipulatives spontaneously. There were a number of instances when students spontaneously used the manipulatives to solve problems. They would reach into the baskets and select a manipulative they thought was most appropriate for the problem at hand. There were very few cases where students selected the wrong manipulatives to solve problems, and these were corrected quickly by the student or a peer.

Control-Oriented teachers reported that students who had free time at the end of class periods often used the manipulatives to return to a game or a concept previously introduced by the teacher. Denise described a lesson in which students investigated different ways to represent the concept of one-half on the geoboards. She reported that in subsequent class periods following the lesson students spontaneously returned to this investigation over and over again. Teachers also reported that students invented games of their own using the manipulatives. There were times when students removed a manipulative from the basket at an inappropriate time or used a manipulative to play or build. In these instances Control-Oriented teachers simply asked the students to return the item to the basket, or to stop the behavior, and students were reminded of the rules for using the manipulatives in the baskets.

The Autonomy-Oriented teachers reported that the spontaneous use of manipulatives by students increased during the free access period. In the initial weeks teachers reported that, "At first they were all dashing to get things they would not need, just to pick up something....But they stopped doing that about the second week" (Frances, interview 3, p. 2, lines 69-70, 73). During this time the teachers had to tell students not to play with the

manipulatives and had to establish that the materials were to be used as tools for mathematics learning only when needed. During one of these initial observations, Frances (observation 3) posed the "Staircase Problem" (see figure 1) to the class. One student began to solve the problem by selecting the pattern blocks. When he found that this manipulative was not an appropriate choice, he returned these to the basket and selected the snap cubes. This was a much more appropriate choice and he was able to solve the problem.

(insert figure 1)

Examples of students using the manipulatives spontaneously on their own included Autonomy-Oriented teacher Joan's report of students selecting the manipulative in the basket that was the most appropriate device for the items they were measuring during a unit on metric measure. Joan gave the students a variety of things to measure and encouraged them to select a manipulative from the basket for the task. During another lesson, Joan explained that she had begun to collect the geoboards when one of the students said, "But the geoboards would really help solve this problem" (Joan, interview 3, p. 3, lines 112-113), so she distributed the geoboards to the class again. Frances reported that her students used the centimeter cubes and the base-10 rods to determine the percentage of each cube, compared to the rods. Inez reported that students used the hundreds boards to find greatest common factors and least common multiples, and fraction bars and fraction stacks (a manipulative the teacher had obtained on her own) when they were finding equivalent fractions and adding and subtracting fractions. Autonomy-Oriented teachers also reported many instances where students

used manipulatives that were more familiar to them, like protractors, compasses, rulers, and calculators.

In some cases, students created ways to use the manipulatives that surprised their teachers. In Autonomy-Oriented teacher, Joan's class, there was one instance during an observation that students were using a tangram piece to find the areas of figures. When one student selected additional tangram pieces from the basket to lay on the figures to find the measurement, Joan told the student to put the pieces back into the basket and use only one tangram piece for the measurement. In this case, the student's selection was very appropriate for the task they were completing, and would have aided the student in figuring out how many total tangram pieces fit inside the figure. Instead, by using only one tangram piece, the student had to trace the piece over and over again to find the total number of tangram pieces that fit inside the figure. In essence, Joan wanted students to find the solution her way. The student's strategy would have been very efficient because the tangram pieces could have been manipulated and arranged on the figure until they were able to fit inside the boundary. Instead, the student had to trace and erase lines until finding the arrangement that fit.

In addition, there were students using the manipulatives to perform traditional paper and pencil tasks. One Control-Oriented teacher taught her students how to find the least common multiple using the hundreds boards and tiles. When she introduced the concept of adding and subtracting fractions, a number of her students spontaneously used the hundreds boards and the tiles to find a common denominator. The hundreds boards were also used by students to aid in reducing fractions. The hundreds boards provided students with the visual cues necessary to successfully complete this task.

(insert figure 2)

Student selection of materials during problem solving. During open ended problem solving lessons, students were able to use a variety of manipulatives to assist them in their mathematical thinking. For example, in the Restaurant Problem (see figure 2) and the Barnyard Problem (see figure 3), students were able to use many of the block-like materials, including color tiles, centimeter cubes, and snap cubes, to model and solve the problems. The manipulation of these materials provided the students with a concrete way to model the problems.

(insert figure 3)

Betty, a Control-Oriented teacher, reported observing that different students sometimes selected different manipulatives to aid them in solving the same problem. In her description of students working the "Mangoes Problem," a problem that is an excellent example for using the strategy of working backwards (see figure 4), Betty said, "I saw one group, they were using the snap cubes. Then another group, they were using the centimeter cubes" (Betty, interview 3, p. 2, lines 90-91).

(insert figure 4)

Catherine related a similar story about her class working the "Restaurant Problem" (see figure 2). She explained, "I had kids use so many different things with that problem. They used tiles. They used snap cubes. Some of them used those centimeter cubes. And they set them up so differently....I

hadn't expected that" (Catherine, interview 3, p. 3, lines 119-121, 124). These types of observations also occurred in other Control-Oriented teachers' classrooms, especially when students were engaged in group problem solving activities.

Increases in student discourse. In many of the Control-Oriented teachers' classrooms, the introduction of the baskets appeared to increase opportunities for student discourse. Denise was surprised by the way her students "...talked more about the math that they were doing. Because usually you don't hear kids sitting and talking about math" (interview 3, p. 2, lines 97-98). Students also became peer tutors with the materials. In one lesson, where students were learning to subtract mixed numerals, Catherine reported, "I had these two kids that were so patient and they taught their whole group how to subtract mixed numerals with pattern blocks....I just loved seeing that. That was a little surprising, how patient and step-by-step they were" (interview 3, p. 2, lines 92-93, 97-98). During observations there were many instances of students talking about mathematics and students using the manipulatives as concrete models to explain a concept to a peer.

Student differences. Betty reported that she saw a difference between the male and female students in her class. She observed, "I found girls picking up things more so, using them for problem solving, and boys were more playful with them" (interview 3, p. 2, lines 68-69). Catherine reported that her "A-students" were less likely to use the manipulatives. She commented that they "...just wanted to do it on paper because it was faster. I hadn't expected that" (interview 3, p. 2, lines 85-87).

Non-mathematic behaviors. A few of the students did predictably non-mathematic things like building with the blocks, drawing designs with the ruler and protractor, or throwing materials from one student to another. But

in most cases, teachers were surprised by their students' responses to the baskets of manipulatives. One of the most common student responses teachers observed was students building or creating things with the different blocks. Students specifically used the snap cubes to create geometric figures and the pattern blocks to create tessellation patterns. They also used manipulatives such as the ruler/compass, circular protractor, and measuring tapes for drawing and measuring activities. In classrooms where teachers placed calculators in the baskets, these were used spontaneously as well. The amount of each student's spontaneous use of the manipulatives varied, but student spontaneous use of manipulatives was observed in 9 of the 10 classrooms.

One Exception. Edith, a Control-Oriented teacher whose lessons were textbook-based, was the exception. Edith was very clear about her expectations for student behavior during mathematics classes: students were not permitted (literally) to move unless she directed them to do so. This was evident in all four observations. Edith was also very clear about her rules for using the baskets. Students in her classroom did not spontaneously use any of the manipulatives in the baskets during observations and the teacher reported in interviews that the students did not spontaneously use any of the manipulatives in the baskets. The only student response she reported was that the students were interested in them when she first put them out in her classroom, asking her what was in the baskets and what manipulatives would be available to them. This initial interest was the only reference students made to the baskets during the free access period. Edith had predicted that her students would not use any of the manipulatives and the students lived up to her expectations. In her final interview she commented, "I don't know if they were apprehensive because of how my class is structured" (Edith,

interview 3, p. 2, line 61). Although she was not aware of it, her students appeared to be keenly tuned in to her verbal and nonverbal behaviors that sent a message that the manipulatives in the baskets were not to be touched.

Manipulatives "walking away." For both Control-Oriented and Autonomy-Oriented teachers their main concern during free access was that students would take or misplace the manipulatives--in essence, that the materials would "walk away." All teachers reported that they had not lost the majority of their materials, with the exception of small items, like the centimeter cubes, that became misplaced. Teachers believed that students seemed to enjoy using the materials and that they saw the manipulatives as integral tools for learning mathematics. Frances explained, "After about 4 weeks, they knew that they were supposed to use them for specific activities, not just to have them on their desks" (interview 3, p.2, lines 73-75).

Teachers' final interview comments. Both Control-Oriented and Autonomy-Oriented teachers mentioned in their final interviews how much students enjoyed having access to the manipulatives in the baskets. Teachers remarked that they believed their students' attitudes were very positive about mathematics during this time. They reported that students inquired about using the manipulatives and seemed eager to participate in mathematics activities in which they had the opportunity to select the manipulatives from the baskets.

Discussion

This study examines students' behaviors in Control-Oriented and Autonomy-Oriented teachers' classrooms in an instructional setting where students are provided with free access to manipulative materials. Of particular interest in this study was how teachers and students in these

classrooms negotiated control of the manipulative materials during the free access period.

Control-Oriented teachers demonstrated more study fidelity in following the timeline outlined by the researcher and in providing a true free access experience to students by the placement of the baskets and the amount of access to the baskets that their students were given. At each point throughout the study, they followed the guidelines and adapted to the use of the materials and to their students' responses to the manipulatives.

During free access, Autonomy-Oriented teachers did not provide students with a true free access to the manipulatives as defined by this study. This seems uncharacteristic of the support of autonomy in students. It appeared that Autonomy-Oriented teachers were not prepared for their students' enthusiastic responses to the baskets and therefore removed the manipulatives from student desk groups in some cases. The use of the baskets may have caused a shift in their classroom management style. The introduction of the baskets caused inappropriate behaviors because rules had not been established, and perhaps Autonomy-Oriented teachers were not comfortable with this more structured management style they were forced to use with the manipulatives freely available to students.

Previous studies have shown that teachers often teach mathematics the way they were taught (see for example Owens, 1993). Some of the Autonomy-Oriented teachers, with an average of 17.6 years of teaching experience, could only remember "worksheets, worksheets, worksheets." This was a significant mode of instruction in the Autonomy-Oriented teachers' classrooms when compared to those strategies employed by the Control-Oriented teachers, with an average of 8 years of teaching experience. Autonomy-Oriented teachers' experiences as undergraduates was, in their

words "a long time ago," and the use of textbooks and worksheets for mathematics instruction was the method with which they were most familiar and probably most comfortable. Due to this wide gap in number of years teaching experience, almost 10 years, it is very difficult to separate the effects of years teaching experience from the effects of teachers' control versus autonomy orientations.

Student ability levels. The ability level of the students in each of these classes may have also played a role in the students' uses of manipulatives. As a group, the Control-Oriented teachers had students in their classes who were heterogeneously grouped or of above average ability in mathematics. In contrast, the Autonomy-Oriented teachers had students who were heterogeneously grouped or below average in mathematics. There were a number of students in Autonomy-Oriented teachers' classrooms identified as being below average on the North Carolina End-of-Grade Tests and as having learning disabilities. As Jones and Carter (1994) have reported, high achieving students are better able to use tools effectively to mediate learning. Some of the Control- and Autonomy-Oriented teachers in this study concurred with that finding, reporting that their higher level students seemed to be more successful in using the manipulatives than their lower level students. These teachers also reported that once the higher level students had used the manipulatives to understand the mathematics concept and they were able to represent it symbolically, they were no longer interested in using the tools. In contrast, lower ability students may have seen the manipulatives as toys instead of tools, and therefore, used them more for play than as tools for mathematical thinking. Three of the Autonomy-Oriented teachers, Frances, Inez, and Joan, were working with students of lower ability, and this factor may have contributed to Autonomy-Oriented teachers'

frequency of use and to the way manipulatives were by the students during free access.

Effective management behaviors. Control-Oriented teachers systematically used control to employ the following effective management behaviors (Brophy & Good, 1986): (a) the control of student behavior and student movement; (b) the selection and pacing of the learning task; and (c) student thinking, allowing and encouraging diversity in problem solving and responses. To control students' attention during the lesson, Control-Oriented teachers demonstrated the concepts first, then students were given the manipulatives and assigned a specific task with a stated purpose. Brophy and Good's research reports a curvilinear relationship where the control of behavior and learning tasks are positively related to student achievement. In essence, too little or too much control decreases student achievement.

Control-Oriented teachers appeared to anticipate student behavior problems that might occur when the materials were used, and their lessons were structured to avoid these occurrences wherever possible. The lesson structure of the Autonomy-Oriented teachers showed little evidence of this consideration because teachers were most familiar with using paper-and-pencil tasks to focus student attention.

All learning involves the negotiation of control. Choices to use or not use the manipulatives were often based on the amount of control teachers believed they were able to maintain with their students, especially during the free access period. When student behavior was not at a level of control acceptable to the teachers, manipulatives were sometimes removed or the choice not to use them in future classes was made by the teacher. In essence the choice whether or not to use the manipulatives was not based on students' inherent needs to have these mathematical tools, but on student

behavior alone. For example, the protractor is seen by mathematics teachers as a necessary tool for measuring angles, but these teachers did not see the pattern blocks or the fraction bars as necessary tools in understanding operations with fractions. As an example, in the highly structured classroom of Edith, the Control-Oriented teacher, students did not use the manipulative materials from the baskets during the free access period. The result of what may have been too much control was that her students were consistently hesitant to use the manipulatives during the time when they were permitted free access to the materials.

Implications for Teachers

In a traditional mathematics classroom teachers often see themselves as the expert who dispenses knowledge to students. The use of manipulatives for mathematics instruction and current models of cognition may encourage teachers to shift their thinking of this role to one in which they become facilitators of the construction of mathematical knowledge. The findings of the present study lead us to believe it may be efficacious for teachers to examine their own control orientations and develop an understanding of the influence of these orientations on their students' learning. An awareness of the verbal and nonverbal behaviors they use to communicate with their students can assist them in creating a mathematical environment that encourages divergent thinking and variety in problem solving solutions. Utterances that seek to control their students' mathematical thinking will further perpetuate students' negative attitudes and perceived competence about their mathematical abilities.

The use of manipulative materials provides students with a concrete way to explore mathematical concepts that are often very abstract. Teachers need to learn to properly use these materials, not just for games or for

problem solving, but as tools for conceptual understanding. The teachers' perceived usefulness of manipulatives is often communicated subtly though verbal and nonverbal behaviors. Teachers who view manipulatives as a time-wasting activity or as objects to be used only in the early elementary grades will inadvertently encourage their students to see these materials are for play, rather than to appreciate the mathematical power available through the use of the manipulatives. Teachers who demonstrate how to use the manipulatives as tools for better understanding are opening doors for many students who struggle with abstract symbols. Often these symbols are introduced to students too soon and students do not have a firm conceptual base on which to build higher level mathematical thinking. Communicating the value of concrete models, such as manipulative, pictorial models, and symbolic representations through a natural progression will aid students in developing a better understanding of mathematics.

The use of manipulatives also has the potential to improve student attitudes and student intrinsic motivation. However, teachers are cautioned not to use manipulatives as simply a "fun" activity or break in the regular classroom routine of rules, procedures, and algorithms. Students will have "fun" using the manipulatives if they are used to properly communicate a mathematical concept for which the students gain an understanding. Students' feeling of success in mathematics develops when they "get it." They need many opportunities with concrete materials to build understanding and construct meaning. Their perceived competence in understanding the concept underlying a particular procedure will lead to positive attitudes toward mathematics.

In many classrooms manipulative materials are viewed by teachers as a novelty, used only for "rainy day" activities. Teachers must begin to use

manipulatives on a more frequent and consistent basis, providing students with varied experiences in their use. When students are taught to use the manipulatives as tools, they will be less likely to see them as toys. When students see the materials used daily in their mathematics lessons, they will appreciate the usefulness of these materials for constructing meaning. Increasing the frequency of use of manipulatives and allowing students more access to the materials is strongly related to the negotiation of control.

Having the materials available at student desks during free access gave the students something they had rarely experienced before with the manipulatives--time. Students had time to explore the uses of the manipulatives, time to investigate how these concrete objects might be manipulated, time to examine attributes of the materials, and time to construct understanding based on the use and manipulation of the manipulatives. This is not an opportunity many students are afforded. In the environment of a Control-Oriented teacher's classroom, the use of these materials may significantly effect student attitudes and student motivation. In most classrooms, manipulatives are hidden away in boxes or locked in storage cabinets away from the investigative hands and minds of students. Teachers need to begin to use manipulatives as often as they use rulers and protractors in mathematics, because manipulatives are also tools, and tools have a mediating function for the learner (Vygotsky, 1962; Vygotsky 1978).

Limitations. These results are to be interpreted with respect to a number of important considerations that are influential to the data. First, teachers who voluntarily sign-up for a 2-week professional development workshop with follow-up experiences are by definition interested in their professional growth and demonstrate a willingness to act upon that interest by enrolling themselves in a workshop that teaches them about new

materials and pedagogy. A randomly selected teacher group from the general population may have produced a group that was much less willing to comply with the use of the new materials and the introduction of baskets of manipulatives into their mathematics classrooms.

Secondly, the number of years of teaching experience of each of the teacher groups was significantly different. Although Deci's research in the development of the Problems in Schools Questionnaire (Deci, et al. 1981) instrument indicated no significant differences in number of years teaching experience for the Control-Oriented and the Autonomy-Oriented groups, the differences in experience for the two groups of teachers can not be discounted. Perhaps it was a coincidence that the Control-Oriented teachers had far fewer years teaching experience than the Autonomy-Oriented teachers, or perhaps not. But this is certainly an important consideration in interpreting the results of this study and a matter to pursue in future research on teacher control orientations. In light of the differences in teaching experience, it is important to consider that the behaviors exhibited by each of the groups in this study may have been more a result of the teachers' experience than of their control orientations. If number of years teaching experience is the main construct that distinguished these two groups, a number of factors, including the way the teachers had learned mathematics as children, the professional training they had received as undergraduates, their prior professional development experiences, and the availability of resources as in-service teachers play a major role in their beliefs and teaching practices.

Conclusion

The teachers in this study, who received the same materials and had the same professional development training, demonstrated a variety of different teaching behaviors that were most likely influenced by factors such

as teaching experience, personal control orientations, and beliefs about how students learn mathematics. Control-Oriented teachers in this study were more likely than Autonomy-Oriented teachers to use the manipulatives for problem solving and group activities, were more likely to demonstrate fidelity to the guidelines of the study, and were more likely to set up rules and communicate behavioral expectations during the free access period. The Autonomy-Oriented teachers in this study were less familiar and less comfortable with the use of the manipulative materials, were more likely to provide unstructured time for the use of the manipulatives, and more likely to use the manipulatives as a reward for appropriate behavior than the Control-Oriented teachers.

The results also show that although teachers participate in the same professional development on the uses of manipulatives and pedagogy, there are many factors, including prior experiences, personal control orientations, and professional constraints, that influence individual teachers and that reveal themselves as differences in the way these tools are actually used by teachers in their classrooms. This data suggests that manipulative materials do have the potential to mediate teachers' instructional practices, encouraging paradigm shifts as teachers make accommodations in their teaching to implement manipulatives as tools for mathematical learning. Manipulatives also have the potential to change student attitudes and motivation orientations, even in classrooms where teachers' control orientations may be an opposing influence.

The main teacher concern at the beginning of the study was that the manipulative materials would "walk away." Teachers did not find this to be true, even during the free access period when students were much more likely to have the availability of the manipulatives. A significant aspect of

this data is that when students were provided with experiences on how to use manipulatives effectively for their own mathematical learning, many students began to see these materials as necessary tools in their mathematics environment. This study reveals that when we allow students some measure of control in the selection and use of these tools, given the time to overcome their initial apprehension, they will spontaneously and selectively use these materials effectively as appropriate mathematical tools to mediate learning. Allowing students the free access to explore the possibilities of the use of these tools encourages them to not only use them efficiently as they are intended, but also to create other uses as students explore their mathematical thinking in divergent ways.

The use of manipulatives for the instruction of mathematics in the middle grades and opportunities for students to have some measure of control in their selection and use of these materials--such as "free access"--is an important goal of future research as we seek to define successful models of mathematics instruction for all students.

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APPENDIX A
TEACHER INTERVIEW PROTOCOLS

Tools for Cognition: Middle Grades Math Manipulatives Project
Pre-Interview Protocol (September 1996)

Teacher Background Information
Name, Sex, Race
What grade do you teach?
How many years have you been teaching? At what grade levels and subjects?
What type of certification do you possess?
Describe the subjects/levels you taught this past year.
Describe the mathematics that you studied/learned in college. Since then. Did you enjoy your classes?
Describe your best mathematics teacher(s). Why? Can you tell me more?
Describe your worst mathematics teacher(s). Why? Can you tell me more?

Attitudes/Beliefs about Math
What are your goals for teaching mathematics? Can you tell me more?
What is your belief about how students learn mathematics? Can you tell me more?

Teacher Practice
What are your students' attitudes toward learning mathematics?
How do the students in your class respond to your methods of teaching mathematics?

Attitudes/Beliefs about Manipulatives
What have been your experiences with manipulatives?
Do you believe manipulatives should be used for mathematics instruction? Why or why not? Can you tell me more?
In your opinion, what is the purpose of using manipulatives for mathematics instruction?
Which are the easiest manipulatives to use? Why?
Which are the most difficult manipulatives to use? Why?
Are there some manipulatives you prefer not to use? Why?

Control Orientation - If manipulatives are used:
How have you obtained manipulatives for your classes?
Do you use manipulatives more for demonstration or for students to use in their problem solving?
How do you manage the manipulatives? How do you keep them from "walking away"?
How do you distribute manipulatives when you are teaching? How do you collect manipulatives when you are teaching? Where are manipulatives stored?
Do student problems occur when you use manipulatives? Give examples. Can you tell me more?
What concerns do you have about using manipulatives? Can you tell me more?

Tools for Cognition: Middle Grades Math Manipulatives Project
Post-1 Interview Protocol (October 1996)

Background Information
Name

Teacher Practice
What are your students' attitudes toward learning mathematics? Have you seen changes?
How do the students in your class respond to your methods of teaching mathematics?
Have you made any changes in your teaching this year?
Do you think your views have changed about teaching mathematics in the past few months? If so, how?

Attitudes/Beliefs about Manipulatives
Have you used any manipulatives since school started? Tell me about these.
Did you use any that were new to you?
Has your use of manipulatives in teaching mathematics changed since August? How?
Tell me about the most recent lesson in which manipulatives were used.
Do you use manipulatives to teach a mathematics concept, or more for enrichment, or for some other purpose? Can you tell me more?
In your opinion, what is the purpose of using manipulatives for mathematics instruction?
Do you think manipulatives teach 'real math' or are they mostly for student enjoyment?
Which are the easiest manipulatives to use? Why?
Which are the most difficult manipulatives to use? Why?
Are there some manipulatives you prefer not to use? Why?

Control Orientation - If manipulatives are used:
Do you use manipulatives more for demonstration or for students to use in their problem solving?
How do you manage the manipulatives? How do you keep them from "walking away"?
How do you distribute manipulatives when you are teaching? How do you collect manipulatives when you are teaching?
Where are manipulatives stored?
Do student problems occur when you use manipulatives? Give examples. Can you tell me more?
Have you noticed any changes in your classroom management since you have been using manipulatives? Can you tell me more?
What concerns do you have about using manipulatives?

Tools for Cognition: Middle Grades Math Manipulatives Project
Post-2 Interview Protocol
January 1997

Background Information
Name

Teacher Practice - Free Access
For the past few weeks you were asked to give the students in one of your mathematics classes "free access" to manipulative materials by placing a variety of manipulatives in baskets and making them available to students. Tell me about your experiences.

Are the manipulatives currently in the baskets in your classroom and available to the students?
Approximately how many weeks have the manipulatives been in the baskets and available to the students?
Did you put the baskets of manipulatives out in all of your classes or only in the class of students I observed? Why?
Describe what "free access" to the manipulatives was like in your classroom?
What did you say to the students when you started the "free access" period?
What were the students told about being able to use the manipulatives in the baskets?
Did you set up a set of rules for using the baskets of manipulatives? What, if any, were these rules?
What manipulatives did you place in the baskets? Did you change the manipulatives you placed in the baskets during this "free access" period? (If yes, probe about the specifics.)
Where were the baskets of manipulatives placed in your classroom during this period?
What were your concerns when you first made the baskets of manipulatives available to students? Were there problems that occurred related to these concerns? Tell me more.
What did you predict would happen when the manipulatives in baskets were made available to the students? Did this occur? What happened? Was there anything that surprised you or that you did not anticipate?
How did the students react to their access to the manipulatives when you first placed them out in your classroom? Did you notice any changes in student behavior as the weeks passed?
Did the students use the manipulatives spontaneously on their own? For example, can you remember an instance where a student or group of students used ____ without your prompting them to do so? (tangram pieces, snap cubes, color tiles, hundreds boards, tape measures, calculators, rulers, compasses, cm cubes, base ten blocks, circular protractors, pattern blocks, geoboards, fraction bars, dice, any other materials) Tell me all of the examples of this you can remember.

Can you think of an instance where a student selected a manipulative during problem solving that wasn't helpful in finding a solution?
Tell me about the most recent lesson in which manipulatives were used.
Have your views about teaching mathematics with manipulatives changed at all during the "free access" period? If so, how have they changed?
Have your views about how students learn mathematics changed at all during the "free access" period? If so, how have they changed?
Will you make the baskets of manipulatives available for students to use independently for the remainder of the school year? Why or why not?

Attitudes/Beliefs about Manipulatives

What do you think your students' attitudes are toward learning mathematics at this time? Have you seen changes in their attitudes during the free access period?
How do the students in your class respond to your methods of teaching mathematics?
Have you made changes in your teaching this year? Has your use of manipulatives in teaching mathematics changed since August? How?
Do you use manipulatives to teach a mathematics concept, or more for enrichment, or for some other purpose? Tell me more.
Do you use manipulatives more for demonstration or more for students to use in their problem solving?
Do you think manipulatives can be used to teach 'real math' or are they just for 'fun'? Tell me more.
Which have been the easiest manipulatives to use? Which have been the most difficult? Are there some you prefer not to use?
Do you think your views about teaching mathematics have changed since the beginning of the school year? If so, how?
How do you feel about giving students free access to manipulatives? Has this been effective or problematic? Explain.

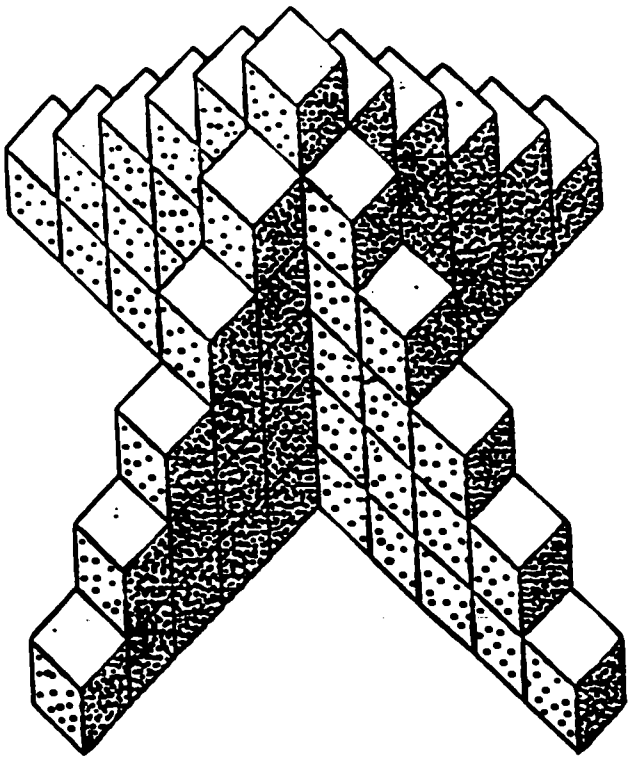
Control Orientation

Have you changed the way you manage the manipulatives? How do you keep them from "walking away"?
How do you distribute the manipulatives when you are teaching? How do you collect the manipulatives when you are teaching? Where are the manipulatives stored?
Do student problems occur when you use manipulatives? Give examples. Can you tell me more?
Have you noticed any changes in your classroom management since you have been using manipulatives? What new concerns do you have about using manipulatives?
Describe your goals for teaching mathematics for the remainder of the school year. What will a typical math class be like in your room?
Do you think you will do things differently next year? If so, how?
Would you like to make any additional comments about your experience?

APPENDIX B
FIGURES

Figure 1

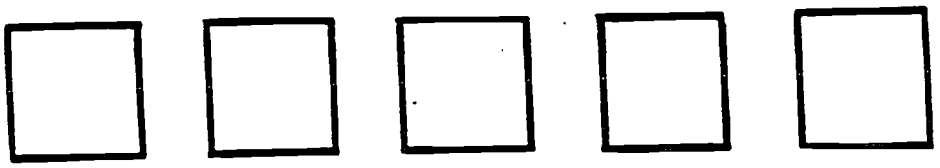
The "Staircase Problem"



1. How many cubes are needed to build this tower?
2. How many cubes are needed to build a tower like this, but 12 cubes high?
3. Explain how you worked out your answer to question 2.
4. How would you calculate the number of cubes needed for a tower n cubes high?

Figure 2

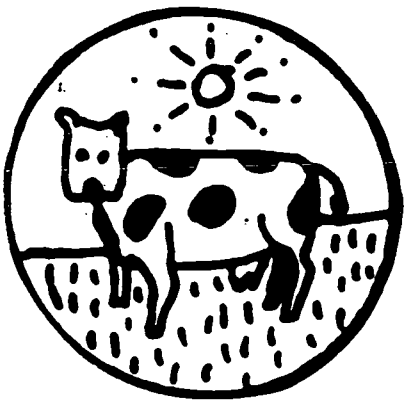
The "Restaurant Problem"



A restaurant is arranging square tables, side to side, in one long row for a banquet. Each square table seats one person on each side of the table. If 30 people are attending, how many tables will be needed?

Figure 3

The "Barnyard Problem"

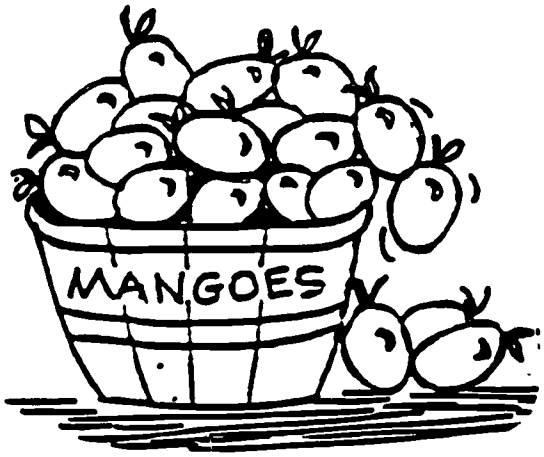


There are 11 animals in the barnyard. Some are cows and some are chickens. If there are 34 legs, how many of the animals are chickens and how many are cows?

There are 15 animals in the barnyard. Some are pigs and some are chickens. If there are 40 legs, how many of the animals are chickens and how many are pigs?

Figure 4

The "Mangoes Problem"



One night the King couldn't sleep, so he went down into the Royal kitchen, where he found a bowl full of mangoes. Being hungry, he took 1/6 of the mangoes.

Later that same night, the Queen was hungry and couldn't sleep. She, too, found the mangoes and took 1/5 of what the King had left.

Still later, the first Prince awoke, went to the kitchen, and ate 1/4 of the remaining mangoes.

Even later, his brother, the second Prince, ate 1/3 of what was then left. Finally, the third Prince ate 1/2 of what was left, leaving only three mangoes for the servants.

How many mangoes were originally in the bowl?

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