Evidence from many studies makes it clear that many students are not learning geometry as they need or are expected to learn it (Baynes, 1998; Burger & Shaughnessy, 1986; Clements & Battista, 1992; Crowley, 1987; Fuys, Geddes, & Tischler, 1988; Mayberry, 1983; Mitchelmore, 1997; National Council of Teachers of Mathematics [NCTM], 1989; Prescott, Mitchelmore, & White, 2002; Senk, 1985; Thirumurthy, 2003; Ubuz & Üstün, 2003, 2004; Usiskin, 1982; van Hiele, 1986; van Hiele & Geldof, 1984). Especially in Turkey, students’ geometry achievement is lower than in the other areas of mathematics. In the Third International Mathematics and Science Study (Mullis et al., 2000), the mathematics and science achievement of eighth-grade students in 38 countries was measured. Turkish students had the lowest mean scores from the geometry part of the test, compared with four other content areas (fractions and number sense; measurement; data representation, analysis, and probability; and algebra). Of the 38 participating countries, Turkey was in the eighth and fifth places from the end in terms of the average of general mathematics and geometry achievement scores (Mullis et al.).

In response to this problem, there have been various attempts to make current teaching materials and approaches more appropriate and relevant to students by making them sense their world and construct their own knowledge. Cognitive psychologists’ (e.g., Bruner, 1960; Dienes, 1964, 1967; Piaget, 1960; Vygotsky, 1930/1978) studies have provided an instructional methodology. The most promising model is constructivism, whose fundamental premise is the idea that all knowledge is constructed by the learner using his or her past experiences and existing knowledge structures. The role of the teacher, from a constructivist point of view, is to create an environment in which learners can construct, develop, and extend students’ mathematical view of the world.

Concurrent with the constructivist view, drama-based instruction creates an environment in which students construct their own knowledge by means of imagining, enacting, and reflecting on their experiences with the guidance of a teacher, rather than imitating what has been taught (Bolton, 1986). It allows the students to improvise and construct a meaning of a word, concept, idea, experience, or event by the use of theatrical techniques and play processes (San, 1996). Consequently, drama-based instruction integrates mental and physical activity. Piaget (1959) indicated that dramatic play is directly related to children’s thought (Piaget). Play can help children test thoughts and concepts and by so doing make sense of them through assimilation and accommodation (Kitson & Spiby, 1997). Play assimilates a new experience to cognitive structure, called schema. If the new information is completely new and there is no existing schema to incorporate it into, or if it contradicts the existing schema, then this condition must be accommodated so that the new information may fit.

Our examination of the literature on drama indicated that few studies have focused on the use of drama in mathematics education (Omniewski, 1999; Saah, 1987; Address correspondence to Behïye Ubuz, Middle East Technical University, Faculty of Education, Secondary Science and Mathematics Education, 06531 Ankara, Turkey. E-mail: ubuz@metu.edu.tr)
Southwell, 1999). Saab reported that, in a controlled study, students who received drama-based instruction showed a significant increase in levels of mathematics achievement regarding mathematics computation but not in attitudes toward mathematics and level of creativity. Omniewski found that students who studied the mathematical concepts of patterning, sorting, classifying, and graphing through an arts infusion approach (in which music, art, dance, and drama were used) scored better on immediate and delayed mathematics achievement tests than did the other two groups, whose members studied these topics through either an innovative manipulative approach or a traditional teaching approach. However, Southwell (1999) gave only examples of the use of drama at the beginning, middle, or end of the lesson to explore mathematical ideas, challenge students, and develop conceptual understanding. In summary, we located no studies with drama-based instruction as the primary form of teaching and learning of geometry. Considering these facts, we inferred a need to design an experimental study on drama-based instruction in geometry by developing drama-based geometry lesson plans and investigating their effects on students' achievement, thinking levels, and attitudes.

The present study meets the twofold goal of investigating the benefits of drama-based instruction in geometry and exploring the reasons of the effects of drama-based instruction in geometry. From this perspective, this study illuminates and gives a deep explanation of the quantitative and qualitative effects of drama-based instruction in geometry. The idea of combining quantitative and qualitative approaches in the present study was to seek convergence of results by minimizing the weaknesses inherent in each approach (Cresswell, Plano Clark, Guttmann, & Hanson, 2003; Johnson & Owuwegbuzie, 2004). Moreover, in the present article, we intended to bridge the gap between theoretical evidence indicating the benefits of drama-based instruction and instructional practice.

Drama-Based Instruction

Theories of cognitive psychology have helped explain the potential effects of drama-based instruction on students' cognitive outcomes. In constructivism, information is retained and understood through elaboration and constructions between previous and new knowledge (Wittrock, 1986). Students in drama-based instruction imagine, enact, and reflect on their real or imagined experiences. It integrates mental and physical activity, engaging the student in improvisational and process-oriented experiences. That is, it involves interaction and communication of students on the basis of their sensory and kinesthetic experiences. Process usually indicates an ongoing event, unlike product, a term that implies a conclusion, or result, (Andersen, 2002). Improvisation is the spontaneous use of movement and speech to create a character or object in a particular situation (Gallagher, 1997). Improvisation creates a zone of proximal development in that a student goes above his or her daily behavior. Creating a character or object can be viewed as a means of developing abstract thought. “Specifically, it creates a new relationship between the semantic (thinking) and visible (real) situations” (Vygotsky, 1967, p. 17). The pedagogical benefits of drama stem from the connection between the experiences of the learner and the subject matter (Courtney, 1990). That is, according to Vygotsky, a child's spontaneous concepts meet the systematicity and logic of adults (as cited in Fosnot, 1995).

As drama-based instruction is student-centered, it begins with the student (Courtney, 1990; Heinig, 1988; Wilhelm, 1998). Students are active participants in the learning. They construct their own knowledge by means of their experiences rather than imitating what has been taught (Bolton, 1986). Concurrent with the constructivists' view, students build their own knowledge of the world from their perceptions and experiences (Simon, 1995). Students become part of the learning process and work in groups to make decisions about the objects, phenomena, and events that they will study; the sources of information they will consult; and the kinds of acting that they will perform. Therefore, social negotiation promotes the construction of common interpretations of events and objects (Heathcote & Herbert, 1985). As emphasized by Vygotsky (1930/1978), learning is shaped both by internal processes and social interaction. Drama provides active communication among students and between students and instructors.

The classroom environment in drama-based instruction is a kind of open classroom of the humanistic approach of education founded by Rogers (1983). The climate of acceptance, psychological freedom, and open communication are provided, and different ideas, behaviors, feelings, values, and even mistakes of the students are accepted. Self-actualization as well as student choice and decision are encouraged. There is mutual trust and respect, which are essential characteristics for learning and the development of self-esteem (Heinig, 1988; Kitson & Spiby, 1997).

Teachers have a responsibility to make drama interesting for students (Kitson & Spiby, 1997). When the subject matter is relevant to the personal interests of the student, significant learning occurs (Rogers, 1983). Learning, which is challenging to the self (e.g., new attitudes or perspectives), is easily assimilated when external threats are at a minimum.

Drama-based instruction provides students opportunities to take risks in their learning without fear of punishment, face and deal with human issues and problems, and reflect on the implications of the choices and decisions they may have made in the drama-based context (Farris & Parke, 1993). Knowing others better and appreciating themselves as human beings is one of the most important goals for students regarding drama-based activities (Heinig, 1988; Philbin & Myers, 1991). It allows children to put themselves in another's shoes. Using personal experience helps students understand others' points of view. They
have the opportunity to see the world from another point of view and respond as that person would respond. If the perspectives of others can be understood, a more tolerant understanding of others and more effective communication can be developed (Heinig).

Research Questions

Our research addresses the following questions:

Research Question 1: What are the effects of the drama-based instruction, compared with the traditional teaching method, on seventh-grade students' Van Hiele geometric thinking level; attitudes toward mathematics; attitudes toward geometry; and achievement on angles, polygons, circles, and cylinders after adjustments for initial differences?

Research Question 2: What are the effects of drama-based instruction, compared with the traditional teaching method, on seventh-grade students' retention of achievement on angles, polygons, circles, and cylinders after adjustments for initial differences?

Research Question 3: What are the students' opinions regarding the effects of drama-based instruction on their learning and attitudes?

Method

Participants

Participants were 102 seventh-grade students in a public elementary school in a socioeconomically middle-class neighborhood in the Balgat district of Ankara, Turkey. Students were aged 12–13 years and enrolled in three classes (each including 34 students). Because Asuman Duatepe-Paksu taught the courses in the experimental groups (EGs), we randomly assigned one of the two classes with coinciding mathematics lessons as the control group (CG; 22 girls, 12 boys). The remaining two classes were assigned as the experimental group (40 girls and 28 boys total: 17 girls and 17 boys from one class, and 23 girls and 11 boys from another).

Measuring Tools

Achievement tests. To determine students' achievement on angles, polygons, circles, and cylinders, we developed the Angles and Polygons Achievement Test (APA) and the Circle and Cylinder Achievement Test (CCA). We selected the original 24 questions in the APA and 25 questions in the CCA by considering the seventh-grade geometry objectives in the National Mathematics Curriculum (Milli Eğitim Bakanlığı, 2000) and submitted them to a lecturer in mathematics education and a graduate student in mathematics. Their judgments regarding the extent to which the questions were spread to cover the measured topics, language level, and cognitive level helped us to revise the APA and CCA questions. The revised 24 APA and 25 CCA questions were pilot tested on 129 and 153 eighth-grade students from two state elementary schools, respectively, to check the adequacy, clarity, appropriateness, and difficulty level of the questions, as well as the adequacy of the test duration. As a result of the pilot testing, we dropped 7 questions from the APA and 10 questions from the CCA because of the overlapping of the objectives and their difficulty level. In addition, we revised four questions in the APA and three questions in the CCA to enable participants to get all the possible answers and to make the questions more precise, understandable, and easily computable.

The final form of the APA consisted of 17 open-ended questions, the majority of which had subtasks. In total, it included 326 tasks, 72 of which related to angles (i.e., identifying adjacent, vertical, corresponding, congruent, interior, and exterior alternate angles; finding the angles in triangles; identifying angle bisectors, altitudes, and medians of a triangle) and 254 of which related to polygons (i.e., ordering the side lengths of a triangle according to its angles; drawing the triangles with given side lengths if possible; identifying polygons, squares, rectangles, diamonds, parallelograms, trapezoids, and rhombuses; finding the perimeter and area of these quadrilaterals). The final form of the CCA involved 15 open-ended questions, each containing subtasks. In total, it contained 42 tasks, 36 of which related to circles (e.g., explaining the difference between a ring and a circle by giving examples; explaining how many radii can be drawn in a circle; stating the positions of the points in a given circle; drawing the points at the outside of, at the inside of, and on the circle; drawing tangents and chords to the circle; finding the perimeter and area of a circle) and 6 of which related to cylinders (e.g., drawing and explaining the open form of cylinders; finding the area and volume of a cylinder). Sample questions are shown in the Appendix.

We scored each task in the APA and CCA by assigning the answer to each task a 1 (correct) or 0 (incorrect). For example, Question 8 in the APA (see the Appendix) included 23 tasks, with 17 tasks related to identifying whether the given figures were polygons, 1 task related to explaining why the given figures were polygons, and 5 tasks related to explaining why each nonpolygon figure could not be considered a polygon. The possible scores for the APA and CCA ranged from 0 to 326 and from 0 to 42, respectively. Kuder-Richardsen Formula 21 (KR-21) reliability coefficients were calculated as .98 and .97 for the postimplementation and delayed implementation of the APA, respectively. Postimplementation and delayed implementation of the CCA results yielded KR-21 reliability coefficients of .91 and .95, respectively.

Van Hiele Geometric Thinking Level Test (VHL). To determine students' geometric thinking levels of Van Hiele's geometric thinking model (Van Hiele, 1986), we used VHL developed by Usiskin (1982). According to this
model, all human beings progress through five stages (Van Hiele). Level 1 geometric thinking begins with nonverbal thinking. The student at this level perceives a figure as a whole shape and does not perceive its parts. He or she may say, “It is a rectangle because it looks like a door.” At Level 2, students can recognize properties, but properties are not yet logically ordered. At Level 3, properties are logically ordered, and one property precedes or follows another property. However, at Level 3, students do not yet understand the intrinsic meaning of deduction (i.e., the role of axioms, definitions, theorems, and their converses). At Level 4, students can understand deduction and the construction of proofs. At Level 5, students understand different axiomatic systems. In the test, the first five items represent Level 1, the second five items represent Level 2, the third five items represent Level 3, the fourth five items represent Level 4, and the last five items represent Level 5.

Because elementary school mathematics leads students to reach only Level 3 (Van Hiele), and because the elementary school mathematics curriculum in Turkey does not require deduction and construction of proof, we considered only the first 15 of the 25 multiple-choice items in the present study. Level 1 items related to identifying polygons. Level 2 items related to the properties of squares, rectangles, diamonds, rhombuses, isosceles triangles, and radii and tangents of circles. Level 3 items related to ordering properties of triangles; simple deduction; comprehending hierarchy among squares, rectangles, and parallelograms; and comparing rectangles and parallelograms.

For scoring, we assigned each answer a 1 (correct) or 0 (incorrect). The possible scores of the VHL ranged from 0 to 15. KR-21 reliability coefficients of the pre- and post-implementation of the VHL were found to be .39 and .57, respectively. These low reliability values are of concern. It is well known that reliability coefficients are greatly influenced by the difficulty of a test, small differences among the scores, and number of items. In the pre- and post-implementation of the test, the scores were clustered together, mostly around the mean, with small differences among students. The mean scores of the pre- and postimplementations of the test were calculated as 6.5 (SD = 2.04) and 7.0 (SD = 2.29), respectively, out of 15. Particularly, 88% and 73% of the students were in the first standard deviation for the pre- and postimplementations, respectively. Furthermore, when the number of items was tripled by the Spearman–Brown prophecy formula, the new reliabilities were calculated to be .64 and .80, respectively. Thus, the small differences among the scores and number of items on the test may have lowered the reliability.

Mathematics Attitude Scale. We used a unidimensional Mathematics Attitude Scale (MAS) developed by Aşkar (1986) to determine students’ attitudes toward mathematics. It comprised 20 Likert-type items with five possible alternatives (strongly disagree, disagree, uncertain, agree, strongly agree). Items included “I like mathematics”; “I get bored when I am studying mathematics”; and “Life would be exciting if mathematics did not exist.” We scored negative statements on a 5-point Likert-type scale ranging from 1 (least negative) to 5 (most negative) and scored positive statements on a 5-point Likert-type scale ranging from 1 (least positive) to 5 (most positive). The possible scores on this scale ranged from 20 to 100. In the present study, Cronbach’s alpha reliability coefficients of the pre- and postimplementations of the MAS were .95 and .96, respectively.

Geometry Attitude Scale. To determine students’ attitudes toward geometry, we used the Geometry Attitude Scale (GAS), developed by Duatepe and Ubuz (2007), which covered the components of motivation and self-confidence. Items representing motivation reflected students’ pleasure when dealing with geometry and their eagerness to continue to think about puzzling ideas outside of class. Items standing for self-confidence involved the behavior of nervousness and tension felt in geometry topics and the students’ confidence in their ability to learn and perform well on geometry examinations. Examples of items related to each component—motivation and self-confidence—included, respectively, (a) “I do not realize how the time passes when I am studying geometry” and (b) “I do not feel tension in geometry lessons.” This scale consisted of 12 Likert-type items with five possible alternatives (strongly disagree, disagree, uncertain, agree, strongly agree). We scored negative statements on a 5-point Likert-type scale ranging from 1 (least negative) to 5 (most negative) and scored positive statements on a 5-point Likert-type scale ranging from 1 (least positive) to 5 (most positive). The possible scores on this scale ranged from 12 to 60. Pre- and postimplementations of the GAS results yielded Cronbach’s alpha reliability coefficients of .92 and .95, respectively.

Treatment

In the treatment period, although the experimental group learned geometry topics with drama-based instruction, the control group learned them through the traditional teaching method. The students in both groups were taught the same mathematical content at the same pace in their regular classrooms. The treatment period lasted 25 lesson hr. There were four mathematics classes in each week, two of which were on the same day. Each lesson lasted 40 min.

Drama-based instruction is an experiential approach to learning in which students learn by experiencing or living an idea, concept, or unit by expressing, explaining, discussing, criticizing, and justifying ideas and by role playing either that something is happening or that they are someone else. We conducted the lessons in this environment by using the 17 lesson plans developed by considering criteria of drama-based instruction. These lesson plans were pilot tested on sixth-, seventh-, or eighth-grade students from a school other than the one in the main study to test their appropriateness for the specified topics, applicability in
classroom settings, and attractiveness to the students. More details about this pilot testing can be found in Duatepe's (2004) article. In each lesson plan, there were three phases: introduction, development, and quieting.

In the introduction phase, warm-up activities were used to ready the students to be involved in make-believe play for the rest of the lesson, work together in harmony, and trust each other. They also helped them to relax and have fun.

The development phase required students to experience and live ideas embellished with geometry in some roles. Students generally worked in groups of 4–10 students, individually, or with the whole class. In general, students were introduced to the make-believe plays, which required them to act as if something were happening or to pretend to be someone else. Make-believe play formed the skeleton of the lesson. It helped to create a natural atmosphere for dramatic moments while requiring abstraction and imagination. In the make-believe plays, students were prompted by dramatic moments. Dramatic moments stemmed from specific conditions such as the tension of time, an obstacle to overcome, mission to accomplish, or status to be challenged. To eliminate these tensions, the students had to create some ideas and discuss them with their classmates. In this phase, Asuman Duatepe-Paksu (the teacher of the EG) encouraged students to communicate their ideas by questioning and sometimes participated in activities by taking on some roles such as scout leader, evaluator of a television program, or officer of the Ministry of Forestry. This helped her to give directions for the lesson and control the students during the teaching and learning processes. This also provided more effective relationships between the teacher and students.

In the quieting phase, the main points of the lessons were emphasized, and then the key points of the covered concept were summarized by either the teacher or students. Students reviewed what they had learned either by answering or solving the questions posed by the teacher or presenting what they had learned as an improvisation that required the use of the knowledge learned. The teacher emphasized the analogy created between the real-life conditions and geometric facts, with the help of the make-believe play and dramatic moments.

However, the traditional instruction environment was based on a textbook approach using chapters related to the angles, polygons, circles, and cylinders from İlköğretim Matematik 7 (Elementary Mathematics Grade 7; Yıldırım, 2001), the adoptive textbook for the seventh-grade students. The teaching method used in the CG was the predominant teaching strategy in Turkey. The majority of the classroom environments were developed around the classroom teacher's supplying knowledge to the students. She first explained the concept by writing definitions on the blackboard, drawing if necessary, and solving some example problems. Later, she allowed students to copy in their notebooks the definitions and solutions written on the blackboard. Lessons were continued by solving questions similar to the examples that the teacher solved. The students in this group were passive receivers. They listened to the teacher, recorded what the teacher wrote on the blackboard, and solved the questions the teacher asked mainly in their own places. Rarely did some of the volunteer students solve the questions on the blackboard. The general inclination of the teacher was to solve questions by herself to save time to solve more questions. In the present study, we took care to ensure that an appropriate comparison was attained between traditional and drama-based instruction. During the treatment period, each group received an equivalent amount of instructional time and also had the same learning objectives. Therefore, the scope of the content covered by the two treatments was found to be equivalent. The comparison of an example of the flow of the lessons in the EG and the CG is illustrated in Table 1.

The most important limitation of this study was that Asuman Duatepe-Paksu taught the EG and a classroom teacher taught the CG. Although there is value in having the same teacher instruct the EG and CG to control for extraneous variables, such as teacher's years of teaching experience, there may be some concerns regarding confounding effects such as the teacher's perceptions of the new experimental approach and comparability of the two groups. In the present study, we took care to ensure that an appropriate comparison was made between the EG and CG. The nature of the study and difficulty in finding an experienced teacher to apply drama-based instruction did not allow us to increase the sample size and have the classroom teacher teach the EG. To use drama-based instruction effectively and efficiently in the classroom requires necessary training like that given by associations such as Contemporary Drama Association (Okvuran, 2001). Asuman Duatepe-Paksu gained the necessary qualification by attending 168 hr of such courses. However, the classroom teacher and most of the other teachers did not have this training. For these reasons, the EG was instructed by Asuman Duatepe-Paksu with an observing teacher to control the flow of the lesson in terms of the objectives covered and the researcher bias. However, the CG was instructed by the classroom teacher—not by Asuman Duatepe-Paksu—to control the implementation bias. Asuman Duatepe-Paksu was also present in the CG classroom for 2 lesson hr per week, which did not coincide with the EG's mathematics lessons.

Data Collection and Analysis

The study design was quasi-experimental. At the beginning of the study, students in the EG and CG were asked to respond to the VHL, GAS, and MAS to measure their thinking level and attitudes prior to the treatment. These tests and scales as well as some achievement tests were also administered to students in both groups at the end of treatment. Four months after the treatment, the achievement tests were given to both groups to measure the level of retention in the topics covered.
by the tests. All these tests were administered to the students within one or two scheduled 40-min mathematics class sessions, allowing students 60, 40, 40, 15, and 15 min for the APA, CCA, VHL, MAS, and GAS, respectively.

Furthermore, interviews were conducted with 13 students from the EG on completion of the treatment to get their views related to the effects of drama-based instruction on their learning and attitudes. To have the best representative sample, we selected students by considering their degree of participation in the activities, gender, post-GAS score, and total achievement score (computed by adding their achievement scores from the postimplementations
of the APA and CCA). Students’ degree of participation in activities was scored according to the consensus of Asuman Duatpe-Paksu and the observing teacher. Students received a grade of 1–5, which reflected the degree of their participation in the activities in terms of demonstrating enjoyment in being involved in activities, working well in group work, interpreting and analyzing others’ work, contributing to the discussions, and criticizing ideas willingly. The characteristics of the interview participants in terms of their gender, quartiles of geometry attitude and total achievement test scores, and degrees of participation appear in Table 2.

Asuman Duatpe-Paksu, who was the teacher of the EG during the treatment, conducted each interview individually in a quiet area of the school, such as the library or an empty classroom. Despite the limitation of those dual responsibilities, we provided an essential perspective with regard to the relation between drama-based instruction and learning. To increase the probability of honest responses, the students were informed that their names and other personal information would be kept confidential and would not be used in the research report. Although there was no time limitation for the interviews, each individual interview lasted approximately 25–35 min. Although interviews were primarily structured, the interviewer’s reacting spontaneously to student’s explanations to make them clearer provided some flexibility.

All interview data were tape recorded and transcribed. To categorize individual students’ and the observing teacher’s views about drama-based instruction, we (a) analyzed the verbatim transcripts to find similarities and differences between their respective ideas about drama-based instruction and (b) constructed categories that characterized the qualitatively different ways in which they expressed themselves. The data collected were analyzed through descriptive and inferential statistic multivariate analyses of covariance (MANCOVAs). To aid in the interpretation of the MANCOVA results, we used test scores for each group at each time to conduct univariate follow-up tests.

Because the treatment in the present study has previously been unknown in the literature, even a small or medium effect size may have practical significance. At the beginning of the present study, the effect size was set to high. In the analyses, the probability of making Type-I errors (probability of rejecting the true null hypothesis) was set to .01. For the MANCOVA based on the posttest measures as dependent variables, there were 102 participants in the sample and five covariates. The statistical power of the study for these values was calculated to be between .90 and .95. For the MANCOVA based on the delayed posttest measures as dependent variables, there were 96 participants in the sample and 10 covariates. The statistical power of the study for these values was calculated to be between .85 and .90.

Results

Quantitative Results

Means and standard deviations were computed for the EG and CG on each variable. The means and standard deviations related to the APA and CCA for the EG and CG are given in Table 3. The means and standard deviations related to the VHL, MAS, and GAS for the EG and CG are presented in Table 4.

Determination of covariates. Prior to conducting MANCOVAs for comparing the posttest scores, we determined five independent variables as potentially confounding factors: gender, mathematics grade in previous year (MGP; ranging from 1 to 5), the PREVHL (pre-VHL), the PREMAS (pre-MAS), and the PREGAS (pre-GAS). Means

| TABLE 2. Distribution of Interviewees in Terms of the Degree of Participation, Gender, Quartiles of Geometry Attitude Score, and Total Achievement Test Score |
|-----------------|-----------------|-----------------|-----------------|
| Student | Degree of participation | Gender | POSTGAS quartile | TOTALACH quartile |
| 1 | 5 | Male | 4 | 3 |
| 2 | 5 | Female | 3 | 4 |
| 3 | 4 | Female | 4 | 3 |
| 4 | 4 | Male | 4 | 4 |
| 5 | 4 | Female | 1 | 4 |
| 6 | 3 | Male | 4 | 3 |
| 7 | 3 | Female | 3 | 4 |
| 8 | 3 | Female | 2 | 4 |
| 9 | 2 | Male | 2 | 4 |
| 10 | 2 | Female | 4 | 4 |
| 11 | 1 | Male | 2 | 3 |
| 12 | 1 | Female | 1 | 2 |
| 13 | 1 | Male | 2 | 1 |

Note. POSTGAS = post-Geometry Attitude Scale; TOTALACH = total achievement test.
and standard deviations of MGP for the EG and CG were equal ($M_{\text{EG}} = 3.17$, $SD = 2.90$; $M_{\text{CG}} = 3.23$, $SD = 2.88$, respectively).

To determine which of the independent variables should be considered as covariates, they were correlated with the dependent variables (Table 5). All the potential covariates had significant correlations with at least one of the dependent variables. Thus, apart from this variable, all of them were considered as covariates. These scores were used as covariates to eliminate extraneous variations from the gain scores, thus increasing measurement precision.

**MANCOVA assumptions.** For the MANCOVA to be valid, there were assumptions that must be met: normality, homogeneity of regression, equality of variances, multicollinearity, and independency of observations.

For the normality assumption, skewness and kurtosis values of the scores were checked. Skewness and kurtosis values were in the acceptable range for a normal distribution. Box's test of equality of covariance matrices for the MANCOVA showed that observed covariance matrices of the dependent variables were equal across groups. This indicated that the multivariate normality assumption for both MANCOVAs was satisfied. Homogeneity of regression assumption requires that the regression of dependent variables on covariates must be constant across different values of a group membership. To check this assumption, a multivariate regression correlation (MRC) was conducted. The results of the MRC for both MANCOVAs indicated that there were no significant interactions between covariates and group membership. This implied that the homogeneity of the regression assumption was validated for the analyses. The equality of variance assumptions was satisfied by the results of Levene's test of equality. All $F$ values were nonsignificant, meaning that the error variances of the dependent variables across groups were equal for both analyses. For the multicollinearity assumptions, the correlations between covariates were checked. Because the correlations between covariates were smaller than .8, the assumption of multicollinearity was satisfied. Independency of observations in testing was supplied by observing the classrooms during the administrations of the tests. The observations were done by Asuman Duatpe-Paksu and the classroom teachers of the groups to make the students work on the tests independently of one another. Because we could not control the dependency in other situations, we took the more radical approach of setting the level of significance to .01, as suggested by Hair, Black, Babin, Anderson, and Tatham (2006).

**MANCOVA models.** To answer Research Question 1, we analyzed data by using a MANCOVA. The results of this analysis are presented in Table 7. As seen from the table, significant differences were found (Wilks’s $\lambda = .385$, $p = .000$) between groups in favor of the EG on the collective dependent variables of the POSTVHL, POSTMAS, POSTAPA, and POSTCCA, simultaneously. The results of the analysis of covariance (ANCOVA) conducted

---

**TABLE 3. Means and Standard Deviations Related to the APA and CCA, for the Experimental and Control Groups**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Post</td>
<td>Delayed</td>
</tr>
<tr>
<td>APA scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>173.49</td>
<td>145.08</td>
</tr>
<tr>
<td>SD</td>
<td>58.71</td>
<td>35.50</td>
</tr>
<tr>
<td>CCA scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>22.74</td>
<td>20.39</td>
</tr>
<tr>
<td>SD</td>
<td>8.36</td>
<td>10.83</td>
</tr>
</tbody>
</table>

Note. APA = Angles and Polygons Achievement Test; CCA = Circle and Cylinder Achievement Test.

**TABLE 4. Means and Standard Deviations Related to the VHL, MAS, and GAS for the Experimental and Control Groups**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>VHL scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>6.15</td>
<td>7.41</td>
</tr>
<tr>
<td>SD</td>
<td>1.63</td>
<td>2.06</td>
</tr>
<tr>
<td>MAS scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>60.36</td>
<td>63.23</td>
</tr>
<tr>
<td>SD</td>
<td>23.05</td>
<td>21.66</td>
</tr>
<tr>
<td>GAS scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>36.92</td>
<td>41.44</td>
</tr>
<tr>
<td>SD</td>
<td>14.10</td>
<td>13.70</td>
</tr>
</tbody>
</table>

Note. VHL = Van Hiele Geometric Thinking Level Test; MAS = Mathematics Attitude Scale; GAS = Geometry Attitude Scale.
to test the group differences for each of the dependent variables revealed that there was a statistically detectable difference between groups in favor of the EG for the POSTAPA, POSTGAS, and POSTCCA, $F(1, 95) = 76.008$, $p = .000$, $\eta^2 = .444$; $F(1, 95) = 91.381$, $p = .000$, $\eta^2 = .490$; and $F(1, 95) = 15.473$, $p = .000$, $\eta^2 = .056$; respectively, at the .002 level. Although the ANCOVA results related to the POSTVHL and the POSTMAS—$F(1, 95) = 6.599$, $p = .012$, $\eta^2 = .140$; and $F(1, 95) = 5.665$, $p = .019$, $\eta^2 = .065$—indicated that there was no statistically significant difference between groups according to these dependent variables at the .002 level, their pre- and posttest mean scores displayed in Table 4 show that the posttest mean scores of the EG students were consistently slightly higher than were those of students in the CG. Because the probability of a Type-I error increases in the use of ANCOVA, the adjusted alpha level (adjusted $\alpha = \frac{\text{overall } \alpha}{\text{number of tests}}$) was used in any separate ANCOVA analysis to control for Type-I error rates. The adjusted alpha for ANCOVA analysis here was calculated as $.002 (.01 / 5)$.

To answer Research Question 2, we analyzed data by using MANCOVAs. The results of this analysis appear in Table 8. As seen in the table, significant differences were found (Wilks’s $\lambda = .829$, $p = .001$) between groups on the collective dependent variables of delayed
Dealing with the authentic situation instead of routine
context, rather than as abstract learning out of context.

Interview responses showed that students were able to
acquire knowledge as well as a sense of when and how to
use it because the knowledge was given in a meaningful
life and mathematics with the help of daily life context.

Examples were from our environment. We know all of them
already and we wanted to pay attention to them, we wanted
to use our brains . . . While studying the situations from real
life, we understood when it is useful . . . Because when it is
from daily life, it is more fun and we are interested in much
more and participate more. Since we know something about
daily life, we can compare with daily life. While studying
the situations from real life, we understood when it is useful.
(Student 10)

It was also more logical with the daily life examples. (Student
6)

Students also affirmed that contextualizing the concepts
provided permanent learning because it was meaningful for
them and because they had learned the reasons behind what
they learned. Thus, their learning became more significant for
them.

Since we tried to find truth ourselves, we can keep it in our
mind . . . We comprehended better and they will stay in our
mind in our lifetime. (Student 3)

There was considerable emphasis on visualization provided
by contextualization. Students stated that visualization
convinced them that what they learned was true. That is,
visualization was a kind of proof for them. Furthermore,
student responses included that visualization created an
interest for the lesson.

When you see with your eyes, it is more effective. Since we
saw what we have done in the classroom, we learned better.
(Student 2)

When we saw visually, we were more interested in and easi-
ly caught the crucial points. We will solve the life problems
which we will face in future by the help of it. (Student 8)

We learned by seeing, it was far more than just memorizing.
(Student 11)

Importance of role playing. Students emphasized that they
were more active physically and cognitively in these les-
sions by measuring, forming, discussing, thinking, helping,
doing, explaining, and improvising. They also emphasized
that everyone in the classroom participated in the lessons
by taking on some roles. As students stated, role playing
made them more responsible for the task. Role playing
provided them with better learning, longer remembering,
and more enjoyment. Furthermore, role playing made the
students feel ownership of the problems and made them
feel that they needed stronger power to solve it.

We were scouts in the lesson. We tried to find a way to
get equal heat around the fire. When we formed a perfect
circle, we saw that all of us could get heat. The center was
the fire. For example, in scouting camp, we defined center
as a fireplace, then placed ourselves around the center to get
heat. Briefly, we had to answer the question since it was our
problem. (Student 1)

Everybody was trying to do something. Because everybody
was a different character such as a scout, scout leader, or
engineer. (Student 12)
According to my observations, the students who had not participated in lessons now participated in the activities because everyone had roles. (Student 6)

**Importance of fun.** Some students' responses revealed that the excitement they felt during the drama-based activities also affected their learning. Before the drama-based activities, writing the rules with little or no meaning attached was boring for the students, as they stated. When they compared the drama-based lesson with the regular lesson, they articulated that the latter was duller for them by using phrases such as “sitting boringly” and “sitting like sleeping.” Because it was meaningless to the students, it was also harder for them. Drama-based instruction allowed them to understand the topic through an enthusiastic engagement. As they mentioned, they had fun with the music, daily life examples, role playing, learning by doing, and not being forced to memorize the facts, in particular. An exciting and interesting classroom environment got their attention and enabled them to learn better. They mentioned some reasons for that as follows:

- Absolutely, it was more fun. For example constructing geometric shapes by our hands, arms and ropes was enjoyable. Drawing the shapes by our shoulders, elbows, and nose was enjoyable. When it is enjoyable, we understand better. (Student 4)
- It was entertaining. We learned what we were learning, improvised something. These made the learning enjoyable . . . We did not understand how the time passed. (Student 9)
- Geometry was more fun and easier. With the examples from life, it was more enjoyable. (Student 10)
- Since it was not memorizing, I liked it more. (Student 11)
- Drama was fun and lessons were like enjoyable game for me . . . When we were scouts, the topics were more enjoyable for me and I understood more. (Student 13)

**Impact of working in groups.** Students mentioned that working in groups affected their learning. Group work facilitated their learning responsibility, provided motivation to learn, and enabled them to acquire knowledge by seeing others' behaviors, receiving different ideas, and understanding others' points of view. The social interaction among the students assisted the construction of knowledge. They helped each other and thus learned from each other.

- We learned to work together. Everyone in a group had a duty, so that we have learned responsibility. (Student 7)
- Everybody was helping each other. I taught my friend something and they taught something to me, too. We transferred knowledge to each other. . . . You [we] were also observing the others while you [we] were doing something in the lesson. By this way we have learned. (Student 9)
- **Impact of communication.** Drama-based activities brought the necessities of communication. Engaging in discussion and negotiation within or between groups in all phases of the lesson brought some advantages. For example, when the students were preparing an improvisation in their groups, they had to exchange their ideas, criticize others’ ideas, and negotiate their roles and presentation. Moreover, to alleviate a conflict posed by the dramatic moments, they suggested solutions, discussed the similarities and differences of all suggested solutions, criticized others’ solutions, and justified and tried convincing others to accept their own solution. Students became aware of what they were studying. They reflected on and clarified their thinking about mathematical ideas and situations. In this way, a concept at an intuitive level became a concept at a reflective level.

In the past, we wrote in our notebooks at our desks. Now we are talking since we need to solve the problem together. We are discussing related with the topics, in order to answer the questions and solve the problems . . . When we were doing so, everyone could freely express his or her ideas. We were happy when we found the things and expressed our ideas. Everyone explained their opinion, discussed something even in breaks. (Student 1)

While everyone worked alone in the past, we were now discussing together. We concentrated on some issues and talked about them. We could explain our opinions freely. (Student 3)

- For example, while studying with the straws and ropes, we were talking with our friends. We discussed it, our thinking developed. This made me learn better. (Student 2)
- In lessons, we had to explain something. Participation and expression of ideas were necessary in every lesson. (Student 7)

**Discussion**

The present findings confirm that drama-based instruction has a statistically significant effect on students' achievements with angles and polygons and with circles and cylinders, in comparison with traditional teaching. The large effect sizes (η²) measured for the POSTAPA and POSTCCCA also indicate the practical significance of the results related to achievement. This present finding supports the findings of previous studies (Omniewski, 1999; Saab, 1987), which provided evidence of the efficiency of drama-based instruction in facilitating an explicit understanding of mathematics concepts.

The significant difference in achievement was partly attributable to the capability of drama-based instruction to enable EG students to contextualize geometric concepts in real-world situations by acting as a character (role playing) in those real-world situations. This was likely to have facilitated their better understanding of the concepts taught by providing meaningful learning, as shown in better performing better than their CG counterparts. Contextualization and improvisation also provided visualization that is important for assimilating abstract geometric knowledge (Battista, 1994; Bishop, 1989; Hershkowitz, 1989). Visualization convinced them that what they were learning was true. In other words, visualization served as proof for them. The familiarity with the context of the problem could also have promoted the better performance of students in the EG because their understanding of the mathematical situation was enhanced (Civil, 1998; Presmeg, 1998). For
example, learning the concept of circles by improvising the camp setting of scouts around a fire provided an underlying structure for discussing circles in the context of a camp setting as well as for imagining circles.

The present findings also appear to suggest that working in groups had a positive effect on the EG students’ performance. Students generally worked in groups in most of the lessons (e.g., forming shapes, preparing a television program concerning adjacent and vertical angles); working in groups provided motivation to learn and enabled them to acquire knowledge by seeing others’ behaviors, receiving different ideas, and understanding others’ points of view. As students helped each other, they learned from each other. Consistent with the literature, it is clear that because students worked in groups in most of the lessons, the communication skills were developed automatically (Barnes, 1998). Students had to communicate in groups when determining the roles of the group members, discussing the flow of the improvisation, and trying to overcome dramatic moments. Because the social interaction that Vygotsky (1930/1978) emphasized leads to changes in students’ thoughts and enables development of minds (Daniels, 1996), students in the EG became better negotiators and communicators and were better able to express their own opinions and ideas. Communication allows students opportunities to talk about their ideas, get feedback for their thinking, and hear others’ points of view. Talking about geometry makes it more alive and more personal, thus lightening students’ interest (Wragg & Brown, 1995).

The students who experienced drama-based instruction were better at retention of achievement than were the students exposed to traditional teaching. The medium to large effect sizes calculated indicate the practical significance of the result related to the retention of achievement. This result is consistent with the result of Omniewski (1999), who found positive effects of the drama-based instruction on retention of mathematics achievement. The publications on theoretical aspects of drama also emphasized that drama-based instruction supports the retention of mathematical concepts (Annarella, 1992; Kelner, 1993; Southwell, 1999). This finding was also validated by students’ interview responses that indicated that drama-based instruction promoted long-lasting learning. As students stated, seeing the reasons behind what they were learning and feeling the necessity of learning personally made their learning long lasting. Retention in mathematics achievement can be provided in two ways: meaningful learning and connections that show children how mathematical ideas are related (Reys, Suydam, Lindquist, & Smith, 1998). These two requirements were satisfied by drama-based instruction, which ensured that meaningful learning as the contextualization of geometric concepts in real-world situations is easier and more logical, interesting, and familiar for students. In the activities, they related geometric concepts to real life and made connections between them.

Long-lasting learning can be attributed to active involvement by role playing. Students emphasized that they were more active physically and cognitively in role playing. By role playing, they felt that they were the authority and the responsible person in problem solving. Thus, they were constructors of their own personal knowledge, as suggested by constructivism, rather than receivers and repeaters of given knowledge. Only in this way is learning more meaningful, applicable, and memorable (Davis, Maher, & Noddings, 1993).

Findings of the present study added empirical support for the statistically significant effect of drama-based instruction on attitudes toward geometry. The medium effect size that we calculated indicates the practical significance of this result. The results of the study related to attitude are similar to the finding of Üstündağ (1997) and Kamen (1992) that attitude toward content area significantly increased through the use of drama-based instruction. As students indicated, they realized the importance of geometry in their daily life, gained confidence by engaging in activities, and became motivated to complete the lessons. Each of these outcomes may be a cause of the increase in attitudes.

Positive effect in attitude toward geometry is explicable by the fun that students had during the drama-based lessons. This method made students understand the topic through enthusiastic engagement. Some students mentioned the enjoyable time they had during activities. They implied that they willingly participated in the lessons. The exciting and interesting classroom environment got students’ attention and allowed them to learn better. Consistent with Freeman (2000) and Kamen (1992), students enjoyed participating in drama-based instructed lessons. As the literature suggested, the development of positive attitudes toward mathematics links to the direct involvement of students in activities (Bergeson, Fiton, & Bylsma, 2000).

The analysis failed to detect a statistically significant difference in mathematics attitudes and Van Hiele geometric thinking levels between groups, whereas the medium effect sizes calculated for the POSTMAS and the large effect sizes calculated for the POSTVHL indicate the practical significance of the results related to the mathematics attitudes and the Van Hiele geometric thinking levels.

We attribute the results related to the geometric thinking level to the longer period of time that was necessary for students to make significant gains in Van Hiele levels. Previous studies (Johnson, 2002; Van Hiele & Geldof, 1984) have indicated that it takes time for students to raise their Van Hiele levels; perhaps in the present study, the treatment period was not enough for the significant change to occur. However, the communication needed in the drama-based instruction provided a platform on which the students and teacher worked at the same Van Hiele geometric level of understanding about the geometric concepts. Alternatively, because the treatment was mainly on geometric topics, it may not be enough to make noteworthy changes to students’ attitudes toward mathematics.
Recommendations

Replication of the present study with different grades and mathematics topics is recommended to determine whether drama-based instruction is an effective teaching method for a wider range of age groups regardless of the implementer and concepts taught. Further, some characteristics of this treatment are not specific to drama-based instruction (e.g., contextualizing the problems in real-world situations, group work, communication). All these aspects can be seen in some other constructivist teaching methods. Drama-based instruction involves not only those somewhat common characteristics, but also some aspects that are unique such as role playing and improvisation. Therefore, some studies can be conducted to compare drama-based instruction with other methods that require contextualization or group work. Such comparison would illuminate whether these results are specific to drama-based instruction. For example, a study aiming to compare drama-based instruction with problem-based instruction or cooperative learning of geometry would be fruitful.

To prepare teachers to use drama-based instruction effectively in a classroom environment, in-service and preservice teacher training programs should involve courses about its benefits and help teachers gain knowledge and skills about preparation for and implementation of drama-based lessons. Furthermore, curriculum developers and authors of mathematics education books should give examples of drama-based lessons.

REFERENCES


March/April 2009 [Vol. 102(No. 4)] 285


APPENDIX
Specimen Questions from the Achievement Tests

Angles and Polygons Achievement Test Questions
1. What are the positions of three lines being in a plane with respect to each other? Draw and explain.
8. a. Which of the following figures are polygons? Why?
   b. Which of the following figures are nonpolygons? Why!

Circle and Cylinder Achievement Test Questions
12. If a bicycle tire goes 180 cm in a one round turn, what is the diameter of that tire?
15. We want to construct a box in the shape of a right cylinder with 1 meter diameter and 2 meters altitude.
   a. How much paper do we need to form its lid?
   b. How much paper do we need to form its lateral surface?
   c. How much paper do we need to form all parts of cylinder?
   d. This box is filled with how much water? (\( \pi = 3 \))