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Memory retention of mathematical concepts in multiplication in the inquiry-based pantomime instruction

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The purpose of this study was to investigate the effects of memory retention of mathematical concepts in multiplication in the inquiry-based pantomime instructions. Three months later after the pre-test, a comparison was made between traditional class (TC) and class with the inquiry-based pantomime (IP) approach in terms of students retention of mathematical understandings. Results of the study indicated that the IP instructions promoted effective long-term retention of knowledge. We concluded that instructional strategies that promoted active engagement in learning using life examples and drawings produced effective long-term retention of knowledge.

I. Introduction

This investigation examined first grade students' retention of concepts in multiplication when using an inquiry-based Pantomime approach as intervention in elementary school. Posttest and retention test after three months were administered to students both in inquiry-based Pantomime and traditional classes. The results showed that students in the inquiry-based Pantomime class retained higher conceptual knowledge of multiplication and equal proficiency in qualitative/pictorial explanations, when compared with students in the traditional instructional methods. The results of this study lend additional support to the literature of longer mathematics understanding that can occur when teaching with reformative instructional strategies such as inquiry-based teaching, especially in elementary mathematics.

The purpose of this study is to investigate first graders' understanding of concepts in multiplication and contribute to the body of research in the understandingof mathematical concepts. The Principles and Standards for School Mathematics (NCTM, 2000) recommend that pre-kindergarten through grade 2 students "understand situations that entail multiplication and division, such as equal groupings of objects and sharing equally."Thus, students at that age level should be introduced to the operation of multiplication with situations in real life. The understanding of knowledge or knowledge-

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maintenance is an important domain of research that has significant implications for instructional practices and learning goals in education (Bahrick, 2000 Semb & Ellis, 1994). Although memory research has a long history (Ebbinghaus, 1885), mathematics education recently started to address retention-related questions in school mathematics (Garner & Garner, 2001; Kwon, Rasmussen, & Allen, 2005). Specifically, Kwon, et al. (2005) posed central questions regarding retention of mathematical knowledge as (1) Does retention of conceptual understandings differ from retention of procedural understandings? (2) In what ways can educators facilitate students' retention of mathematical understandings and skills for longer period of time? (3) What is the relationship, if any, between instructional approaches and retention of mathematical knowledge?

This study was conducted to compare first graders' understandings of multiplication concept and graphical representation ability for solving multiplication problems between students in inquiry-based Pantomime (IP) and traditional class (TC). Since the study is specifically interested in how different instructional approaches affect the students' retention of mathematical understanding, this research topic reflects the aforementioned question (3) which concerns the effects of instructional approaches to a longer-term retention of mathematical knowledge. Regarding the application of Pantomime approach as an instructional strategy, little is known about the retention of learned knowledge in elementary school mathematics.

II. Theoretical Framework

Enhancing retention of what is taught is a fundamental goal for educators. Educators and scholars conducted numerous research studies over the last half century to determine variables and factors affecting the long-term retention of school knowledge (Bahrick, 1965, 1979; Bloom, 1968; Cain & Willey, 1939; Conway, Cohen, & Stanhope, 1991; Farr, 1987; Hovland, 1940; Keller, 1968; Krueger, 1929 Semb & Ellis, 1994 Wert, 1937). According to Farr (1987), several factors influencing retention include: (1) the content and tasks to be learned, (2) the retention interval, (3) conditions of retrieval, (4) degree of original learning, (5) instructional strategies, and (6) individual differences. Among the variables, this study investigated the effects of (4) degree of original learning and (5) instructional strategies in multiplication learning.

According to Semb and Ellis' (1994) review of 56 psychological research papers on retention of school knowledge, the nature of instructional strategies and degree of original learning are important factors. They concluded that more quantitative than qualitative interactions were not predicted to produce differential forgetting (see more details in Conway, Cohen & Stanhope, 1991; MacKenzie & White, 1982; Specht & Sandlin, 1991; Sturges, Ellis, & Wulfeck, 1981). In other words, no significant differential forgetting was found when the instructional interactionswere quantitative in nature, i.e., giving students more practice or different feedback or a different delivery medium or display. However, when the instructional interactions were qualitatively different (e.g., learning research methods and fieldwork excursion including observing, recording, and answering questions), students actively involved in learning showed less forgetting effects than did those passively involved in learning. The passive learning here included pictures, slides, worked examples, sample test items, and transfer of verbal propositions to maps, diagrams, slides and others.

Active learning environments in our study are defined as students engage in creating meaningful mathematical ideas to represent terms and symbols of mathematicsand having discourse to solve problems with minimal assistance from the teacher. Usually, these learning environments are described as inquiry-based. Cobb, Wood, Yackel, and McNeal (1992) argued that "Students who participated in an inquiry mathematics tradition typically experience understanding when they can create and manipulate objects in ways that they can explain and, when necessary, justify" (p.598). In this type of instructional approach, students are afforded many opportunities to actively engage in the learning process generating conceptual understanding. As Bae (2002) and Bae and Park (2004) argued, an inquiry-based Pantomime Mathematics Education (PME) offers students ample opportunity to create and explain mathematical ideas including symbols and equations of mathematics so that they can construct meaning and develop a deeper understanding of how mathematical concepts work. The key point of this instructional method is that students create meaningful mathematical ideas to represent the concept that is introduced in class and draw pictures of them. In this process called 'mathematizing,' symbols, equations, and termscan be better understood when students build them from the bottom up through a process of suitably guided reinvention (Bae, 2002 Bae and Park (2004). Drawing pictures for meaningful representation of mathematical concepts invites clarification and exploration of students' understanding of concepts. This process can generate a deeper understanding of students' knowledge and beliefs.

III. Pantomime Mathematics Education (PME)

The inquiry-based Pantomime Mathematics Education (PME) basically cycles 8 steps that start with an example from realistic daily life(see Appendix 1 for an example). Students are first given one or twoopportunities to watch a Pantomime play that shows how mathematical concept works (if you do the Pantomime twice with different symbol, then it would become 11 steps all together). Students then draw pictures of what they watched and label them in meaningful symbols and equations from the scratch. After a small group discussion about each of the reasons, students label it with a meaningful mathematical term and elaborate it with group members (community) to fit into formalized mathematical principles and theorems.

Confirming the students'creative ideas fitting the concepts, students are challenged to solve story problems so that they can understand how it works in real life. Students are also asked to create a story problem by using the learned concept. Anytime when students do not understand the mathematical concept, then you may want to go back to a step in whichstudents were having difficulty. Since the instructional strategies and degree of original learning variables are closely related in nature, meaning of the instructional strategies used in this study is operationally defined as inquiry-based Pantomime instruction (IP) including all level of interactions occurring in the classrooms including student-to-student, teacher-to student, group-to-group, etc.

An example of the PME model (Bae, 2002 Bae and Park, 2004) is as follows: PME is a model for teaching and learning mathematics in math education. Figure 1 presents the facets of PME that connect each facet of the model. These components with arrows demonstrate a flow of an inquiry-based PME instruction from the beginning to the end.

Facet1. Real World: To teach a mathematical concept and method, students are offered real situations to tap into, which are related to the concept being taught within a unit of lesson. (1) Intuition as a component within the Real World facet comes forth as a first reaction when children saw Pantomime. The importance of intuition has been emphasized by mathematics educators. However, there is a tendency that intuitive attitude often comes to an end with a subjective knowledge. Although it is deemed subjective, intuition helps students in learning mathematical concept. (2) Concrete Operational Activities are an important component in PME. Elementary school children often understand mathematical concept by observing in real situations or by using concrete or semi-concrete manipulatives because they are in the concrete operational stage of development. So teachers should be able to provide real world situations in which the students can observe directly from or they can perform concrete manipulatives.

Facet 2. Model: Mathematics is originally based on the real world. However, the real world itself is not the concept to teach in mathematics education. As a prior stage to understanding ofabstract mathematical terms, a model is a simple figure or an equation that corresponds to real situations. An equation may not find a correspondence to intuition or operational activities in forming a model.

Facet 3. Taken-as-Shared (Agreement): Mathematical concepts include both processes and results rather than only results. In the process of obtaining mathematical concepts in mathematics education, one selects one perspective out of many perspectives to abstract definition of a concept. Definition is an outcome of formation of a mathematical concept in the field of mathematics education. More children-friendly term "agreement" replaces a rigorous mathematical definition. This agreement consists of symbols and terms. Symbols are mathematical representation of figures and equations that the children came up with. Terms represent the group of symbols.

Facet 4. Method: Mathematical concepts one agreed may cause some inconvenience when applied to solve all of the problems in real life. We need to create a method (theorem, property, and formula) that helps us eliminate inconvenience so that we can utilize it readily, simply, conveniently, and swiftly. Teachers should beable to offer time for students to discover methods that overcome the pain coming from their experience with difficult, complex, inconvenient, and slow process. Students ought to be encouraged for the discovery of the method.

Note: When applying this model to teaching mathematics, some step may be skipped based on situations (e.g., students' level of learning). In some cases, an operational activity can also be omitted.

Facet 5. Conforming Mathematical Concept: Conforming mathematical concepts start with one's intuition and operational activities in the real world. Have students draw figures and write equation that corresponds to intuition and operational activities. Write symbols that correspond to the figure and equation, and then come up with agreed terms that represent the symbols.

In backward process, have them draw figures and write equations corresponding to a new symbol. Have the students write sentences using the symbol. Finally, students are to write a beautiful sentence that talks about a beautiful story in mind using the symbol.

Flow of a PME lesson

The Pantomime Approach in mathematics education (published on the U.S. Newspaper, Pantagraph, Oct. 15, 2004) is one way to teach mathematics with operational thought-provoking activities in which a teacher gets students motivated and interested in the topicby using a vehicle such as costume, cognitively conflicting demonstration, and sounds or video clips. Pantomime draws pupils' attention to his/her mathematical presentation and helps students build up the conceptual understanding of mathematical concept. The flow of teaching using Pantomime Approach is as follows:

1. [Real life situations]

The teacher acts in pantomime (silent performance) demonstrating mathematical concepts using operational manipulatives. The teacher

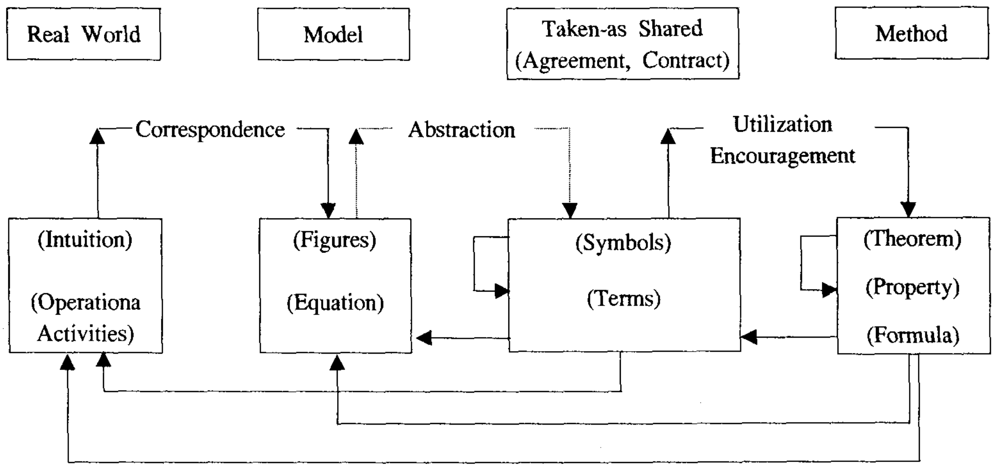


Figure 1. Model of Mathematics Education Teaching and Learning

should be able to offer real situations that are related to the concept, and that are familiar to the students. This stage provokes students'intuition about the demonstrated mathematics concept and engages the students in the thought-process of math concept formation by stimulating their interests and curiosity. The teacher only gives a cue by saying, "Start" when the pantomime begins and "Finish" when it is done.

2. [Model]

Students are now asked to draw figures in correspondence to what they watched from the pantomime and write an equation for the figures. The stage of PME model often shows students' primitive understanding of mathematical concepts. They are modeling their intuitive thoughts and ideas about the demonstrated concept.

3. [Symbols]

Students are then asked to come up with an idea to express what they observed and drew into a symbol with a term. Students are asked with questions such as, "What symbol would you like to use for what you drew and how would you name [Term] it and why?" This stage often shows a variety of ideas and creative expressions of students. Students discuss in a group and brainstorm and share what they come up with the whole class. This is the stage where all the students should agree and take it as shared, which is the way the mathematical concepts are formed.

The above processes 1-3 show the process of how students come to understand a mathematical concept. Once the students came to conceptual understanding, they should be able to apply in their real life situations. So the stage of [Method] follows in teaching.

4. [Method]

Now students are asked to use the understood concept in real life situations. In this stage, all that matters is a method in teaching since the students already understood a math concept. Method here means practicing it and how to use it in real life situations in a way that is easier, more convenient, faster, and more precise. So students are asked to come up with a story problem that applies the learned concepts into real life so that they can appreciate the meaning of it and make sense to them. This stage helps the students understand the concept completely. This whole process takes less than 10 minutes and repeats as needed.

IV. Methods

Participants and the context- Participants were first grade students from two different classrooms at the same Midwestern US schools. For the purpose of selection of homogenous group in the school, we used two factors: First, two classes that had no intervention program on multiplication. Second, multiplication was not part of the school curriculum for the first graders. Therefore, participants just started their semester with no exposure to multiplication. It stands to reason that two groups are homogeneous for this purpose of research. The sample selection was arranged by the school principal who knew about this project. One class was assigned as the traditional class (TC) and the other asthe inquiry-based Pantomime (IP) class. Each of the classes met once a week for six weeks and each lesson lasted 45 minutes. The topic was an understanding of multiplication. No specific textbook was used in either class.

In TC class, multiplication was taught in a traditional lecture-type format in which the teacher explained the concept using a story book that entails multiplication application. After the concept was taught, the teacher gave the students a story problem and then they practiced problem solving. The instructor of the TC class had sevenyears of teaching experience at the elementary level.

In IP class, the teacher taught the concept of multiplication utilizing an inquiry-based Pantomime Mathematics Education (PME) approach using manipulatives (Bae, 2002 Bae and Park, 2004; Journal Star, 2004; Pantagraph, 2004). PME is one way to teach mathematics with operational thought-provoking activities in which the teacher in a unique costume draws pupils' attention to his/her mathematical presentation and helps students build up conceptual understanding. The flow of teaching multiplication using the Pantomime approach entails the aforementioned four stages - (1) Real life situations- (2) Model- (3) Terms and symbols- and (4) Method.

Data Collection- (1) Quantitative data source was collected from three tests including pretest, post-test, and retention test. The pretest was given before the intervention of Pantomime approach to both TC and IP classes. The posttest was administered to both the same groups of TC and IP classes after the intervention of multiplication with Pantomime was completed. The posttest consisted of 10 multiplication problems that required answers specifically including writing an equation, answer, and drawing (only five problems asked for drawing) (Appendix 2). The same items as the posttest were re-administered to the same students for the retention test three months later to test for the effects of the group. Two experts of math education coded the answers for the two tests and compared for cross-checking. (2) Qualitative data were collected from three classroom observations and twelve interviews of students from each class during and after the intervention to confirm their conceptual understanding, which were all audio-recorded and transcribed by the third person. The ten test items were developed by the researcher and the teachers, and were with the validity .93and the test-retest reliability .81. Students'IDs were anonymous for the tests.

For the purpose of data analysis, two modalities of analysis were used to examine students' conceptual understanding (1) Conceptual knowledge of multiplication (CKM) and (2) Qualitative/Pictorial explanations (QPE). Two coders were trained by the researcher to analyze students' answers from the tests until they felt comfortable. For example, "After the picnic, 3 boys each picked up 2 soda cans to recycle. How many cans did the boys recycle all together? Write an equation and draw a picture that best represents the problem." The right answer should be an equation of 2x3=6 with an appropriate drawing. The coders analyzed tenproblems that require a writing of the equation for CKM scoring and five problems (these five overlapped and asked for drawing additionally) that require pictorial explanations (for QPE scoring). So the total scores are 10 for equation (CKM)and 5 for pictorial explanation (QPE).

V. Results and Conclusions

Both the TC and the IP classes took the pretest before the treatment and the results were no significantly different(CKM Scores: Mean of TC=1.14 (SD=2.77), M of IP=1.47 (SD=2.32), t=0.36, p=.72; QPE scores: M of TC=2.86 (SD=1.62), M of IP=2.47 (SD=1.36), t=1.82, p=.42), indicating that they had comparable level of knowledge of multiplication. Participants' scores reflected such a low scores since this was the pretest where they had no multiplication curriculum before. Both posttest and retention test were examined, and in-depth interviews were conducted to investigate student's conceptual understanding.

First, the results of posttest for the two different instructional strategies compared on the two modalities indicated that students in the IP group (N=22)scored significantly higher than the TC group (N=24) on the qualitative/pictorial explanation task (IP: M=2.95 (SD=1.53); TC: M=1.13 (SD=1.51), t=4.08, p=.001), but no significant differences were found on the conceptual knowledge of multiplication task. A possible explanation might be that the teacher in the TC group did not teach how to draw a picture to explain the multiplication problem. Instead, the TC teacher gave verbal instructionswithout using manipulatives or drawings. On the other hand, the IP group learned how to represent pictorially the multiplication problem by brainstorming in a group. However, the students in both groups learned the concept of multiplication and how write an equation of the multiplication.

Second, the retention of the TC (N=23) and IP groups (N=22) was compared to test for the effects of two different instructional strategies. The IP group showed retention of conceptual knowledge of multiplication (CKM) at a significantly higher rate that did the TC group (IP: M=3.00 (SD=4.15); TC: M=.35 (SD=1.11), t=2.96, p=.005). The big difference of SDs between the posttest and the retentiontest in the IP group is fundamentally caused by the variance of students' scores between the time intervals. In other words, most students must have understood the multiplication at the time of instruction and yet a few students must have forgotten it after three months later. Eleven students responded correctly in the IP group whereas only three students had the correct answer in the TC group. There was, however, no difference between the two groups on the qualitative/pictorial explanation task. Interestingly, the IP group retained the conceptual knowledge of multiplication more than did the TC group. We believe that the IP group's inquiry oriented Pantomime approach contributed to this result, that the students were offered opportunities to create ideas about how to represent the mathematical operation of multiplication and how to write symbol and term in a brainstorming group. As mentioned previously in the methodology section, students in the IP group routinely exchanged explanations and justifications for their ideas with pictorial explanations. This type of instruction helps students to come to conceptual understanding.

Third, in-depth interviews were basically designed to investigate students' conceptual understanding of multiplication. For most of the first grade students, the meaning of multiplication is:

$$mn := \sum_{k=1}^{n} m$$

This is mathematical shorthand for, "Add m to itself n times" (m and n are whole numbers).

Students in the TC group typically had misconceptions about multiplication. One example is as follows (A letter "I" stands for Interviewer and "S" for student):

I: I am going to ask you a couple of questions about 3x2.
I: Did you learn multiplication before?
S1: Yes.
I: Where did you learn it?
S1: (in) Our class.
I: Did you learn it at home?
S1: No.
I: Would you tell me what 3X2 makes?
S1: 6
I: Now, would you tell me what this means?
S1: Um, 3 is how many times you have 2.
I: Could you write it into addition?
S1: Yes.
I: How?
S1: 2+2+2

This student learned multiplication only from the traditional class. As indicated in the above, however, this first grade student had misconception that was very resistant to change. As shown in the following interview, students' conceptions of multiplication were seemingly in a state of flux. This was evident when they attempt to illustrate a real life application of multiplication with drawing:

I: O.K. what does 2X3 mean?
S2: It means that you take the two and you can either change this into three in front, if it is easier for you, oh if you wan to do it like that two times three, because that is two times- you have to do the second number in the group, the first number is the group, and the second number is what you would put in the group.
I: Hum.
S2: And it is easier for me to have the bigger number first, so three times two is just three groups of two.
I: O.K. Could you give me a life example that represents two times three (2X3)?
S2: Yes. There is (are) two cars, with three people in each car. If there are three people in each car you add the three's together for six, because there are three people in two cars, and that equals six.
I: O.K. Now could you draw a picture that represents three times two?
S2: Can I draw the people as dots?
I: That is fine.
S2: There are three cars, with two in each one?
I: Is that what this means.
S2: Three times two (3X2) means that you take three groups, and you have two in each group. You have three cars, with two in each one-that still equals six.

This student's conception was tentative about the given problem (the meaning of 2X3). Yet, the student reformulated it 3X2, which was more familiar and comfortable to him. But it was still a misconception (see "three groups of two"). In the process of conceptualization, the students were just confused with the multiplier (the number of people) that operates on the multiplicand (the number of cars) to produce the answer. When asked to provide a life example, the student showed a misconception. Drawings also showed the same misconception. All in all, one of twelve interviewees had a correct understanding of multiplication and two had a mixed understanding in the TC group whereas five of twelve interviewees had a correct understanding and three had a mixed understanding in the IP group.

In conclusion, students' participation in the IP class produced a positive retention of conceptual knowledge of multiplication as seen in student responses to CKM and QPE tasks compared to students' retention in its TC counterpart. Especially, as indicated in the interviews, students had a common resisting misconception. Their explanations of life example and drawings also showed unchanged of it.

Students in the IP class were required as a step to use some sort of life example and pictorial visualization (see (4) Method in the methodology section), and we hypothesized that retention of pictorial images may be longer term than retention of semantic content. A study by Bahrick, Bahrick, and Wittlinger (1975) lends support to this possibility; they found that participants retained the images of faces at a much higher rate than names over a 25-year period. This interpretation is comparable with the perspective that active learning experience assisted students in generating meaning for content being learned (Wittrock, 1974). The results of our study indicated that instructional strategies that promotedmore active engagement in learning using life examples and drawings produced effective long-term retention of knowledge. The inquiry-based pantomime approach can draw students' attention and stimulate their mathematical thought by letting them draw pictures, representing with symbols, and making word problems aligned with other representations. This approach is dynamic in that students continuously need to represent their mathematical ideas and communicate each other, which leads better memory retentions of mathematical concepts.

Long-term retention of school knowledge has been an issue in education across the subject areas in termsof affecting factors. One of the critical factors is an instructional strategy. In mathematics, there are few studies which consider how to promote longer retention of conceptual knowledge in students. This studyaimed to investigate the effects of actively involved learning environment compared to the traditional class. The results of this study will add to the research area of retention of school knowledge in mathematics. In addition, inquiry-based pantomime approach needsto practice in various levels and areas.

References

Bahrick, H. P. (2000). Long-term Maintenance of Knowledge, p. 347-378. In E. Tulving, & F. I. M. Craik (Eds.), *Oxford Handbook of Memory*. England: Oxford University Press.

Bahrick, H.P. (1979). Maintenance of Knowledge: Questions about Memory We forgot to Ask. *Journal of Experimental Psychology*: General, 108, 296-308.

Bahrick, H.P. (1965). The Ebb of Retention. *Psychological Review*, 72, 60-73.

Bahrick, H.P., Bahrick, O.P., & Wittlinger, R.P. (1975). Fifty Years of Memories for Names and Faces: A Cross-sectional Approach. *Journal of Experimental Psychology*: General, 104, 54-75.

Bae, J. (2002). Enhancing Children's Understanding of Mathematical Concepts Using Pantomime. Paper Presented at the Annual Meeting of NCTM, Las Vegas.

Bae, J., and Park, M. (2004). *Teaching and learning mathematics in Korea*. Paper presented at the 10th Annual Meeting of International Congress on Mathematical Education, Copenhagen, Denmark

Bloom, B.S. (1968). *Taxonomy of Educational Objectives*. New York: David McKay Co.

Cain, L.F., & Willey, R. (1939). The Effect of Spaced Learning on the Curve of Retention. *Journal of Experimental Psychology,* 25, 209-214.

Cobb, P.., Wood, T., Yackel, E., & McNeal, B. (1992). Characteristics of Classroom Mathematics Tradition: An Interactional Analysis. *American Educational Research Journal,* 29, 573-604.

Conway, M.A., Cohen, G., & Stanhope, N. (1991). On the Very Long-term Memory of Knowledge Acquired Through formal Education: Twelve Years of Cognitive Psychology. *Journal of Experimental Psychology*: General 120, 395-409.

Ebbinghaus, H. (1885). *On Memory* (H.A. Ruger & C. E. Bussenius, Trans.) New York: Teachers' College, 1913. Paperback edition, New York: Dover, 1964.

Farr, M.J. (1987). *The Long-term Retention of Knowledge and Skills: A Cognitive and Instructional Perspective.* New York: Sprinter-Verlag.

Garner, B., & Garner, L. (2001). Retention of Concepts and Skills in Traditional and Reformed Applied Calculus. *Mathematics Education Research Journal,* 13, 165-184.

Hovland, E.I. (1940). Experimental Studies in Rote Learning Theory: VI. Comparisons of Retention Following Learning to Same Criterion by Massed and Distributed Practice. *Journal of Experimental Psychology*, 26, 568-587.

Journal Star, The. 2004. October, 15. *Pantomime Math*. A local newspaper; McClean County, Peoria/Bloomington/Normal, IL

Keller, F.S. (1968). Good-bye, Teacher …. *Journal of Applied Behavior Analysis*, 1, 79-89.

Krueger, W.C.F. (1929). The Effect of Overlearning on Retention. *Journal of Experimental Psychology,* 12, 71-78.

Kwon, O. N., Rasmussen, C., & Allen, K. (2005). Students' Retention of Mathematical Knowledge and Skills in Differential Equations. *School Science and Mathematics,* 105(5), 227-236.

MacKenzie, A.A., & White, R.T. (1982). Fieldwork in Geography and Long-term Memory. *American Educational Research Journal,* 19, 623-632.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics.* Reston, VA: Author.

Pantagraph, The. 2004. October, 15. *A Clown for Math.* A local newspaper; McClean County, Peoria/Bloomington/Normal, IL

Semb, G. B., & Ellis, J. A. (1994). Knowledge Taught in School: What is Remembered? *Review of Educational Research,* 64(2), 253-286.

Specht, L.B., & Sandlin, P.K. (1991). The Differential Effects of Experiential Learning Activities and Traditional Lecture Classes in Accounting. *Simulation and Gaming,* 22, 196-210.

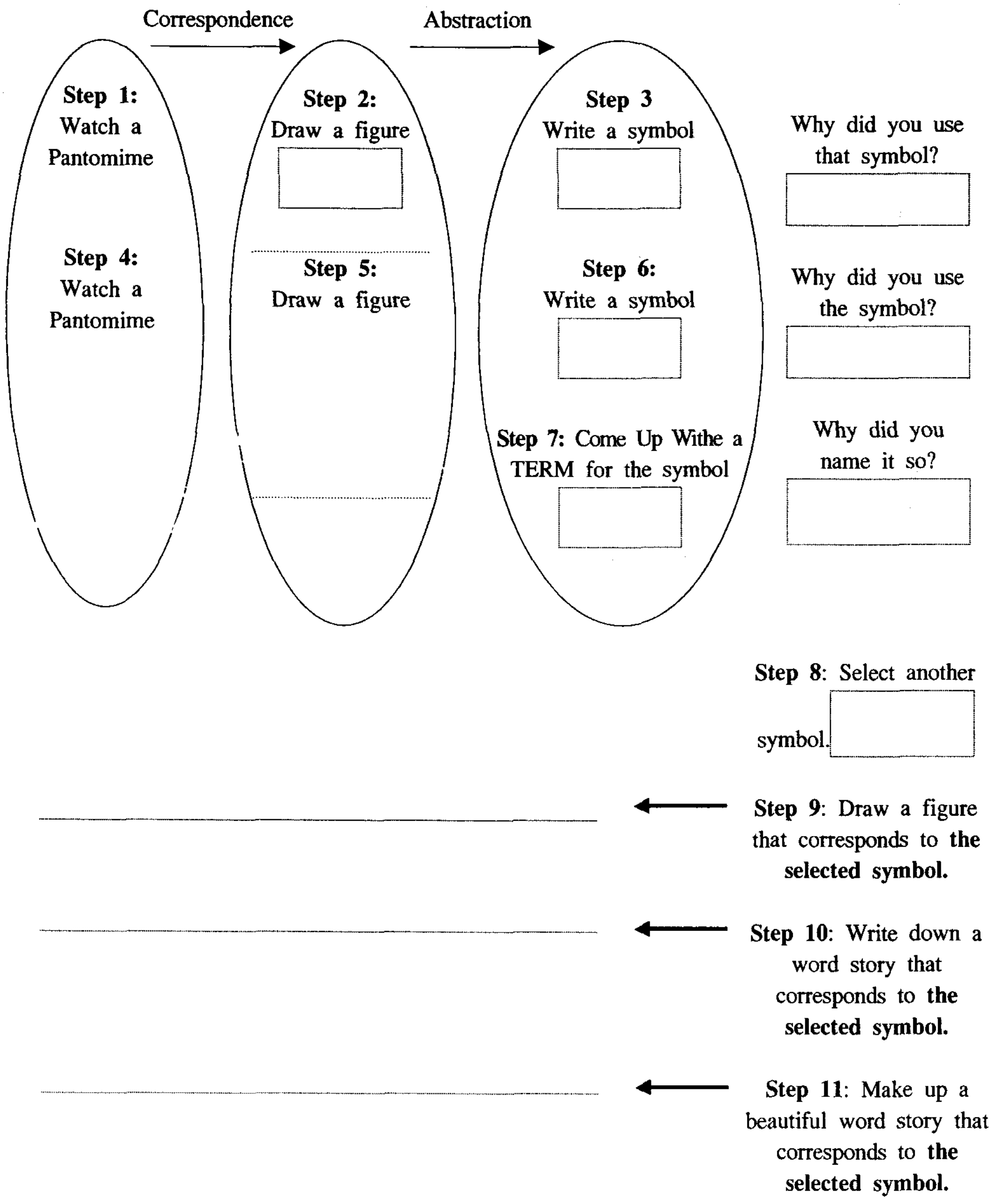
Sturges, P.T., Ellis, J.A., & Wulfeck, W.H. (1981). *Effects of Performance-oriented text upon Long-term Retention of Factual Material* (Tech. Rep. NPRDC TR-81-22). San Diego: Navy Personnel Research and Development Center.

Wert, J.E. (1937). Twin Examination Assumptions. *Journal of Higher Education,* 8, 136-140.

Wittrock, M.C. (1974). Learning As a Generative Process. *Educational Psychology,* 11, 87-95.

Appendix 1. An example of Pantomime

[Pantomime] Watch pantomime, draw a figure, write a symbol, and come up with a term for the symbol.Select another symbol, draw a figure that corresponds to the symbol, write down a word story that corresponds to the selected symbol, and make up a beautiful word story that corresponds to that symbol.



Appendix 2. Test Instrument

1. 3 children took 5 crackers each. How many crackers are there? Write an equation and answer.
2. Kevin had 2 weeks of field trip. It is 8 days per week. How many days did Kevin have for his field trip? Write an equation and answer.
3. Jane bought 2 packs of gum. There are 4 sticks of gum per pack. How many sticks of gum did she buy? Write an equation and answer.
4. Sarah has 3 bags of marbles. Each bag had 8 marbles in it. How many marbles does she have in all? Write an equation and answer.
5. After the picnic, 4 boys each picked up 3 soda cans to recycle. How many cans did the boys recycle in all? Write an equation and answer.
6. Ashley bought 2 rows of 6 eggs. How many eggs did Ashley buy? Write an equation and answer. Draw a picture.
7. There are 3 rows of window panes. Each row has 4 panes. How many panes are there in all? Write an equation and answer. Draw a picture.
8. The marching band has 4 rows with 5 players in each row. How many players are in the band? Write an equation and answer.
9. One carton of soup cans has 4 rows of cans. Each row has 8 cans. How many cans are there in all? Write an equation and answer. Draw a picture.
10. The sheet has 6 rows of stamps. There are 5 stamps in each row. How many stamps are there in all? Write an equation and answer. Draw a picture.

탐구 중심 판토마임 교수에서 곱셈 개념의 기억의 보존

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본 연구는 초등학교에서의 탐구 중심 펜토마임 접근법을 이용할 때 곱셈의 개념에 대한 학생들의 기억의 보존에 관하여 조사를 하였다. 사전시험을 실시한 후 전통적으로 지도한 반과 펜토마임 접근법으로 지도한 반을 3개월 후에 어떻게 달라졌는지 알아보았다. 이연구 결과 펜토마임 접근 방법을 사용한 반이 전통적인 지도 방법을 이용한 반보다 곱셈의 개념을 보다 더 잘 기억하였고 수량적/기하적 설명을 하는데 있어서는 전통적인 지도 방법을 이용한 반과 비슷하였다. 이 연구는 특별히 초등학교 수준에서 탐구 지향적인 교수법과 같은 다양한 교수 전략을 사용할 때 수학적 개념의 이해의 유지에 어떤 영향을 주는지에 대한 시사점을 제공하였다.

* key words : memory retention(기억 보존), multiplication(곱셈), inquiry-base approach (탐구 중심적 접근), pantomime(펜토마임).

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