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STUDENTS' EPISODIC MEMORIES FOR EVENTS IN GRADE 6 MOTION GEOMETRY LESSONS

by

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To Whom It May Concern;

I am in the final stages of writing my Ph.D. dissertation which includes reference to the Oxford Psychology Series, No. 9, publication by Allan Paivio entitled, Mental Representations, A Dual Coding Approach. If at all possible, I would like your permission to reprint a table and a figure from that publication. The first, Table 4-2, appears on page 57. It is a representation of the orthogonal conceptual relation between symbolic systems and sensorimotor systems with examples of types of modality-sopecific information represented in each subsystem. The second, Figure 4-1, appears on page 67 and is a schematic depiction of the structure of verbal and nonverbal symbolic systems, showing the representational units and their referential (between system) and associative (within system) interconnections as well as connections to input and ouput systems.

I would greatly appreciate it if you would forward written permission for me to include this table and figure in my dissertation to me at the above address.

Yours truly,

Lorne Prupas
Ph.D. Candidate

APPROVAL

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Students' Episodic Memories for Events in Grade 6 Motion Geometry Lessons

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ABSTRACT

Until recently, the role that episodic memories play in learning from classroom instruction has gone largely unexamined. Work by a few psychotherapy and classroom researchers, however, indicates that it is possible to determine personally relevant characteristics of learning events that learners describe as memorable, helpful, and related to semantic memories.

In response to critiques of memory research, the present study includes an investigation of how the mental processing of information, and the metacognitive self-regulation of learning affect memory. The current study explored links among pre-instruction measures of these mental activities, episodic memories from lessons, and learning. All of the 122 Grade 6 participants in the study were administered the Individual Differences Questionnaire (IDQ), a measure of mental coding habits, and the Self-Regulated Learning Questionnaire (SRL), a self-report of metacognitive self-regulation. After each of the three experimental lessons, a posttest and an Episodic Memories Questionnaire (EMQ) were administered. Students' episodic memories were located on videotapes and transcriptions of the lessons.

Part correlations were calculated to investigate relationships among SRL, IDQ, episodic memory reports, and

posttest scores. Contingency tables were scanned to assess association between episodic memories for lesson events and posttest performance on items related to those events. Grounded theory methods were employed to identify a superordinate category of episodic memories reported.

Part correlations between SRL total scores and memory reports were statistically detectable, small, and positive. It was also found that during difficult lessons, metacognitively active students were more likely than others to report episodic memories.

Shortcomings of the present study were noted. Concern about the meaning of the total scale SRL score was issued. It was recommended that the role of spontaneous attention in episodic memory be examined. Also, it was suggested that future large sample studies be done to examine how episodic memories may influence personal, attitudinal, and motivational variables which, in turn, may mediate knowledge construction. Finally, it was recommended that small sample studies be done in order to track in finer detail students' episodic and semantic memories from classroom instruction.

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Finally, thank you Uncle Morris. I'll never forget what you asked me in your thick European accent when I was thirteen-years-old. It was at my Bar Mitzvah. Do you remember, Uncle Morris?

You asked, "So, are you going to become a doctor?"

I did, Uncle Morris. I did.

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CHAPTER ONE: INTRODUCTION

How do episodic (personal, autobiographical) memories mediate knowledge construction during classroom instruction? More specifically, is there a relationship between particular mental activities and the retrieval of episodic memories? Once retrieved, what impact do these episodic memories have on the recall of semantic memories (lesson information and facts)? In short, what attention should teachers give to the episodic memory system in order to improve their instructional effectiveness?

Chapter One of this dissertation provides a rationale for an examination of how episodic memories might mediate learning from classroom instruction. Several arguments are presented in support of such a research effort. Literature reviewed in Chapter Two focuses on mental activities that might be implicated during episodic memory retrieval, the relationship between episodic memory retrieval and recall of semantic memories, and the appropriate venue for the present study. At various points in both chapters, reference is made to literature addressing the larger goal of this investigation, namely, teacher effectiveness.

The Absence of Classroom Research on Episodic Memory

Despite historical interest in episodic memory within psychology generally (Robinson, 1986), the phenomenon has received only minimal attention within educational psychology. Contemporary journals and texts in educational psychology abound with investigations of relationships between semantic memories and teaching and learning processes. Martin (1993) lists several contemporary educational psychology texts with such content (e.g., Dembo, 1991; Gage & Berliner, 1991; Lesgold & Glaser, 1989; Mayer, 1987; Pressley & Levin, 1983a, 1983b), and also points out that those few textbooks that do refer to episodic memory do so in only a cursory fashion (e.g., Dembo, 1991; Gage & Berliner, 1991). They certainly do not address the larger issue of concern in the present investigation, namely, the significance of episodic memories in classroom learning and, ultimately, teacher effectiveness. Other compendiums such as The Handbook of Research on Teaching (Wittrock, 1986) though comprehensive, also have not spoken to how teacher attention to personal memories of students may affect learning from instruction.

The Significance of Episodic Memory Research in Classrooms

Martin (1993) recently called for research that examines how students' episodic memories of classroom teaching might mediate their learning. By episodic memories, Martin refers to students' autobiographical recall of specific instructional events they experience, as opposed to their recollection of semantic or procedural information (factual knowledge) divorced from such experiential context.

As already mentioned, investigations of the mediational role episodic memories may play in classroom learning do not abound in the literature. This is because researchers regularly equate learning with memory, and measure learning outcomes, such as achievement, in terms of a child's memory for facts and information. Resnick (1989) points out the problem with such an approach: "We know that human memory for isolated facts is very limited. Knowledge is retained only when embedded in some organizing structure" (p. 3). It may be that episodic memories form the important facilitative organizing structure to which Resnick is referring.

Several reasons for the surface treatment of the role episodic memories play in classroom learning have been put forward by opponents of such a research effort. These include questions of relevance, controversy over the number and nomenclature of extant memory systems, and debate over the validity of episodic memory research in naturalistic environments. A discussion of, and counterargument for, each of these concerns follows.

<u>Questions of Relevance</u>

<u>Lack of relevance</u>. Educational psychologists have been encouraged by certain prominent researchers not to examine the relationship between episodic memory and classroom learning. Tulving (1983) argues that understanding the

episodic memory system is irrelevant to improving educational practice. Estes (1989) also considers such memories to be less educationally significant than semantic memories for understanding classroom learning and teaching. He states that "most learning that occurs in educational settings has to do with semantic memory and has a cumulative character as distinguished from the memory for discrete events that characterizes episodic memory" (Estes, 1989, p.5). Furthermore, episodic memories suffer from much greater vulnerability to interference than do semantic memories (Tulving, 1983) and, as Slavin (1991) has pointed out, are often difficult to retrieve when one episode gets mixed up with an earlier one--that is, unless something happens to make the episode especially memorable. Nevertheless, the importance of memory to learning has never been questioned (e.g., Gagne, 1989; Horn, 1989; Resnick, 1989).

Relevance. The increasingly popular notion that learning is a multifactor phenomenon (c.f., Iran-Nejad, McKeachie, & Berliner, 1990) suggests an investigation of the different ways memory is implicated in the learning process. Researchers such as Cohen (1989) point out that episodic memories can play a significant role in learning. She argues that such memories can have impact on children's construction and reconstruction of knowledge, particularly during problem solving. Cohen suggests that recall of episodic memories may facilitate problem solving through associative processes. A child may recall problem solving procedures by first remembering the episode in which the procedures were taught and then recalling the procedural knowledge associated with those episodic memories.

The organization and explanation of experience by the self which comes to be known through episodic memory, seems central to processes of learning (Bereiter, 1990; Brewer, 1986; Lapadat & Martin, 1993; Robinson & Swanson, 1990; Zimmerman & Schunk, 1989). For example, Lapadat and Martin (1993) cite the work of Robinson and Swanson (1990) who suggest that through autobiographical memory, individuals are able to construct self-histories that "are central to ongoing processes of self-definition and explanation...(which ultimately) organize experience and desires into meaningful and acceptable patterns" (1990, p. 331).

Similarly, Brewer (1986) suggests that a significant organizing structure in which factual memories are embedded is that of the self, a "complex mental structure that includes the ego, the self-schema, and portions of long-term memory related to the ego-self (e.g., personal memories, generic personal memories, and autobiographical facts)" (Brewer, 1986, p. 27). Self can be conceived as a factor in the phenomenon of learning (e.g., Bereiter, 1990) and is being considered as an overarching organizing structure in which the construction of knowledge occurs (e.g., Resnick, 1989). An exploration of the role episodic memories play in classroom learning could contribute to other efforts aimed at understanding the role self plays in organizing the process of individual knowledge construction.

<u>Number of Memory Systems</u>

There has been much controversy over what constitutes an episodic memory and how, if at all, it differs from other kinds of memory (c.f., Tulving, 1985). Basically, this line of argument puts into question the significance of any research effort on episodic memories if such memories cannot be distinguished from other kinds of memories.

A rationale for the present investigation of episodic memories is based on Tulving's (1985) position that the episodic memory system can be distinguished from at least two other kinds of memory systems. Tulving (1985) cites support for his contention in many quarters (e.g., Hermann, 1982; Herrmann & Harwood, 1980; Kinsbourne & Wood, 1975, 1982; Oakley, 1981; O'Keefe & Nadel, 1978; Olton, 1984; Ruggiero and Flagg, 1976; Shoben, Wescourt, & Smith, 1978; Warrington, 1981; Wood, Ebert, & Kinsbourne, 1982; Wood, Taylor, Penny, Stump, 1980). Tulving cites four reasons for his pluralistic position on memory systems:

a) Generalizations about memory as a whole, generalizations which often give rise to needless and futile arguments, cannot be made. General statements about particular kinds of memory are perfectly possible and would reduce controversy in the memory literature.

b) Memory has become what it is through a long evolutionary process, a process that is seldom linear. One might expect, therefore, that the brain structures and mechanisms which comprise memory would reflect other evolutionary processes.

c) Data from experiments on other psychological functions suggest that there is more than a single memory system. For example, in work by Weiskrantz (1980) and Weiskrantz, Warrington, Sanders, and Marshall (1974) on blindsight, it was reported that people with damage to the visual cortex are blind in a part of their visual field, but still can point accurately to, and discriminate, objects presented to the blind part of their visual field in a forced-choice situation. The implication of such a finding is that different brain mechanisms exist for picking up information about the visual environment.

d) Finally, Tulving argues that it is difficult to believe that all the varieties of learning and memory that appear to be so different can reflect the workings of one and the same underlying set of structures and processes.

Tulving (1985) follows these arguments in support of multiple memory systems by positing a ternary classification of memory in which he distinguishes procedural, semantic, and episodic memories. In addition to the semantic, and episodic memories which have already been described, Tulving asserts the existence of a procedural memory system. This system enables organisms to retain learned connections between stimuli and responses. It is most evident in automatic, unconscious psychomotor behaviour.

Despite these distinctions among the procedural, semantic, and episodic memory systems, it should be noted that Tulving admits to some overlap among them. He describes the three as forming a hierarchical arrangement in which the lowest level, procedural memory, contains semantic memory as its single specialized subsystem, and semantic memory contains episodic memory as its single specialized subsystem. Each higher system has unique capabilities not possessed by the lower systems, but depends on and is supported by the lower systems. This definition suggests that only certain procedural memories can be identified as completely distinct from the other two kinds of memories.

Nomenclature of Memory Systems

Naming the memory system that deals with personal memories figures importantly in the process of distinguishing it from others. There has been much debate over what the system that deals with personal memories should be called. For example, the term "autobiographical memory" has been used interchangeably with "episodic memory." Banaji and Crowder (1989), however, argue that the term "autobiographical memory" really is one of temporary convenience for everyday memory researchers and has connotations that make it inappropriate for everyday memory research. Conway (1991) argues the opposite. He contends that a term such as "episodic memory" has limited utility because of its associations with laboratory studies of memory, whereas the term "autobiographical memory" is linked to ecologically valid research on events meaningful to study participants. Brewer (1986) adds to the classification confusion by positing five different kinds of autobiographical memories, while Mandler (1985) argues for a classification of memory based on automaticity (automatic and non-automatic) and length of term (short and long).

There seems to be no simple way out of this categorization morass. Tulving (1983) endorses the use of the term "episodic" over other possible alternatives. He argues that it does convey a reasonably accurate description of the kind of information or knowledge to which it refers:

> Not only is "episode" one of the synonyms of "occurrence," it is also defined in the dictionary as "an event that is distinct and separate although part of a larger series" ...The relative brevity of the term gives it an advantage over another possible alternative, namely "autobiographical" memory that, despite its historical precedents, further suffers because of its connotation of a literary account of one's life. (p.28)

For the current investigation, the term "episodic memory" will be used for the personal memories being studied.

The Validity of Episodic Memory Research in Natural Environments

So far, arguments have been offered suggesting that episodic memory research is relevant to building understandings of learning and that such a research effort is legitimate in that these memories can be distinguished and named differently from other memories. Still, the question of examining such memories in natural environments such as the classroom has been raised by pundits. However, the concerns expressed have not silenced advocates of natural inquiry.

Over a decade ago, Neisser (1978, p.4) dismissed the importance of findings emanating from memory laboratories by commenting that, "If X is an interesting or socially significant aspect of memory, then psychologists have hardly ever studied X." Martin (1993) follows Neisser in his critique of the potential utility of memory research in the laboratory as it applies to educational psychology. He quotes Slavin (1991) who stated that episodes likely will not be remembered unless "something happens during the episode to make it especially memorable" (p. 139) and concludes that in laboratory settings the likelihood of such occurrences is probably extremely small. Martin attributes the problem to the "kinds of routine, detached information typically embedded in the relatively uninspired tasks most often set by experimenters in such settings" (1993, p. 170).

These attacks on memory research in the laboratory have not gone unnoticed or unrebutted. In their controversial article, Banaji and Crowder (1989) highlight the importance of generalizable findings. They argue that findings from ecologically valid research suffer from low generalizability and that, though of limited external validity, psychology lab findings do not suffer from this shortcoming. They cite several memory studies done in natural settings and point to serious flaws in each. Banaji and Crowder criticize natural investigations on the grounds that: a) their findings are generally not unique and that lab studies usually produce similar findings; and b) the validity of the results from such studies is almost inevitably in question because of serious methodological flaws (e.g., small "n" and lack of attention to confounding variables).

Nonetheless, Banaji and Crowder (1989) provide two strong caveats to their general argument. They discuss Erdelyi and Goldberg's (1979) comment that lack of experimental confirmation for phenomena such as repression could not be a criterion for rejecting the idea of motivated "forgetting." They concede that everyday memory research may yield emergent principles about repressed memory and similar phenomena that cannot be discovered in the lab. Secondly, they imply that principles gleaned from lab research must be tested assiduously for external validity and ought to be examined in more natural settings.

Others, meanwhile, have been critical of Banaji and Crowder's attacks on natural investigations into memory. Ceci and Bronfenbrenner (1991) state that there is substantial counterevidence to the claim that everyday memory research is not worthwhile and that such research is consistently methodologically weak. They argue that the search for principles that govern variation is a necessary scientific endeavour, one that requires the use of both laboratory and real life investigations.

This move toward a balance between laboratory and natural investigation of memory has been echoed recently by Neisser (1988) who is now considerably less severe in his indictment of lab technique for the study of memory. Klatzky (1991), Loftus (1991), Conway (1991), and Tulving

(1991) have all come to the defense of everyday memory stating essentially that the value of such research is in what it can offer to replace reduced control--the availability of data that could not be obtained in a laboratory, suggestions for areas that are worthy of controlled study and, potentially, new phenomena.

Finally, in an article entitled "Continuities between ecological and laboratory approaches to memory," Winograd (1988) further depolarizes the debate by offering descriptions of concerns that are common to the two approaches. He discusses five of these concerns: a) verifiability, b) forgetting functions, c) cue loading versus distinctiveness, d) constructive processes in memory, and e) memorability of events.

Extant Natural Educational Research on Episodic Memories

Another reason to carry on episodic memory research in classrooms is that successful research on episodic memories in other learning environments is currently being conducted and is providing practitioners with valuable information that may enhance their effectiveness.

Psychotherapy Research

For example, examinination of episodic memories in another learning environment, psychotherapy, has proven fruitful. Researchers have been determining qualities of episodic memories from events in psychotherapy that participants consider important. During immediate and six-month follow-up investigations, Martin and Stelmaczonek (1988) found that counselling events identified as important by clients contained dialogue that was deeper, more elaborative, and more conclusion-oriented. In contrast, other dialogue included temporally proximate, but distinct, events that clients did not report (control events). When analyzing memory reports of clients that involved therapist contributions to dialogue, Martin, Paivio, and Labadie (1990) also found that events rated as important could be distinguished from control events. In this study, the same factors identified by Martin and Stelmaczonek (1988) were identified as responsible for this difference, with one addition: therapist discourse from important events was described as clearer than discourse from control events.

Martin, Cummings, and Hallberg (1992) extended this research by exploring the effects of manipulated, elaborative discourse on memories from counselling sessions. They found that in four dyads of experiential psychotherapy, clients tended to report recollections of therapists' intentional metaphors approximately two-thirds of the time, especially when these metaphors were developed collaboratively and repetitively. Clients also rated therapy sessions in which they reported memories of therapists' intentional use of metaphors as more helpful than sessions in which they reported memories of therapeutic events other than therapists' intentional metaphors.

Findings from this research suggest that it is possible to determine characteristics of learning events that learners consider memorable. Equipped with such information, instructors may be better able to intentionally create learning experiences which learners describe as both memorable and helpful.

Classroom Research

The view that episodic memories play a pivotal role in classroom learning (Martin, 1993), receives support from a series of studies of elementary classroom learning conducted by Nuthall and Alton-Lee (1982, 1991). These researchers have recently used qualitative procedures to highlight the significant effect which context has with respect to learning outcomes. Context, they argue, forms children's episodic memories for specific instructional events, memories that persist long after the events in question (Nuthall & Alton-Lee, 1982). Nuthall and Alton-Lee's (1991) work suggests such episodic memories cue semantic memories conveyed in initial classroom lessons.

On the other hand, an exploratory study of high school students' learning from career education videotapes (Lapadat, Martin, & Clarkson, 1993) found only limited support for the hypothesis that episodic memories mediate students' learning from media or lectures, at least in group contexts. As well, in another study of university students' learning from lectures, Lapadat and Martin (1993) found a weak relationship between university students' memory reports of "number of key lecture topics presented" and quiz results at 3 month follow-up for only one of their three experimental lectures. They found no reliable correlations between number of episodic memories reported and learning outcomes.

In commenting on their findings, Lapadat and Martin suggest their results may be due in part to a small subject population that prevented them from using powerful multivariate statistical analyses. Given this limitation in their procedure, these researchers recommend further investigation into the mediational effects which episodic memories may have on learning.

Summary

A number of arguments have been presented as rationale for the continuation of classroom research on episodic memories. Significantly, this kind of research is largely absent from educational psychology and its yield in terms of improving teacher effectiveness has not yet been mined. Such research may provide teachers with keys to assisting students' recall of problem solving procedures or semantic information. Secondly, such research may provide important information to researchers investigating the organizing role that 'self' plays during knowledge construction. Thirdly, it seems that episodic memories are a researchable entity, distinguishable from other kinds of memories. Fourthly, investigations of such memories in natural environments, like classrooms, could provide a much needed complement to abundant laboratory research on memory. Fifthly, promising findings from psychotherapy research were cited as support for episodic memory research in other learning environments such as classrooms. Finally, a shortcoming of extant research on episodic memories in classrooms was mentioned as indicative of the need for improved methodology in research of this kind.

It would seem reasonable, therefore, to investigate the role episodic memories may play in learning. Given the lacuna within educational psychology, it also seems logical that the venue for such research activity be the natural environment of the classroom.

Questions still remain, however, over the grade level of participants and curricular area most appropriate for the present research effort. The former will be dealt with in the chapter on methods. However, rather than address the latter immediately, it may be useful to consider Morton's (1991) critique of investigations of episodic memories in natural environments as well as possible responses to this critique.

Morton (1991) points out that research on memory has suffered from a generally pervasive myopia among memory researchers. He vehemently asserts that memory research is being impeded by its excessively restricted theoretical base. Most significantly, he contends that theories of memory take insufficient account of other mental activities. Literature reviewed in Chapter Two provides information intended to expand the vision of present day memory researchers in exactly this way.

CHAPTER TWO: REVIEW OF LITERATURE

Morton (1991) suggests that any investigation of memory (and, ipso facto, the role memory might play in learning) ought to take into account other mental activities besides memory itself; however, he is not explicit as to what these processes may be. Despite Morton's vagueness, it should be noted that several major themes (to be described later in this chapter) are driving current research activity within cognitive psychology (Ashcraft, 1989). The choice of mental activities appropriate for an investigation of episodic memory can be made on the basis of such themes. In fact, two mental processing activities receiving attention within teacher effectiveness research, and incorporating these several themes, are the dual (verbal and imaginal) coding of information, and the metacognitive self-regulation of learning.

Though it would seem that both these mental activities are necessary for all classroom learning, it can be argued that they are more necessary in certain subject areas than in others. According to extant research, a subject area that calls for both dual coding of information and metacognitive self-regulation of learning is geometry. It is unclear, however, how mental activities such as these affect not only the semantic memory system, but the episodic one as well. For example, does increased mental activity of the kind needed for successful performance in geometry stimulate the recall of episodic memories?

Questions also remain as to the role such episodic memories may play in facilitating lesson learning and, ultimately, in informing teacher practice. On the macroscopic level, what is the relationship between children's recall of episodic memories of classroom events in general and the learning of lesson content? On a more microscopic level, is there a relationship between recall of specific episodes and the learning of lesson content related to those episodes?

An important final concern, particularly in preliminary investigations such as the present one, is that of unexplored possibilities in data gathered. It can be argued that, regardless of findings pertinent to the issues described so far, researchers ought to go beyond the boundaries of traditional verificationist methodologies in order to explore other possibilities within their data.

The following literature review addresses the broad terrain covered by these questions and issues. It begins with a description of important, current themes within cognitive psychology. Next, two mental activities that address most, if not all, of these themes are identified. Theoretical and empirical support for specific understandings of these two mental processes--a dual coding theory of mental represention and a theory of cognitive self-regulation of learning--are presented. The lack of empirical work examining the relationship between either of these two theories and episodic memories is noted. However, available literature linking episodic memory to semantic memory (the latter heretofore generally being of greater concern to the classroom teacher) is reviewed and an argument supporting both macro- and microscopic analyses of this relationship is presented.

Next, examples of studies in which theories of the two mental activities referenced above have been successfully applied in efforts to improve learning from instruction (and, ultimately, teacher effectiveness) are examined. Based on this literature and the nature of the mental activities themselves, an argument is put forward favouring intermediate-level geometry (and motion geometry, in particular) as the experimental subject area for the present investigation.

The chapter concludes with research hypotheses derived from this review of literature and intended to direct the present inquiry. In addition, an exploratory question is posed to supplement the traditional, verificationist approach to research in the social sciences.

Current Themes in Cognitive Psychology

Ashcraft (1989) suggests that seven important themes have arisen within cognitive psychology which are contributing to the ongoing revision of human information processing theory: representation of knowledge, automatic and conscious processing, serial and parallel processing, data-driven versus conceptually driven processes, metacognition, attention, and tacit knowledge and inference. Recently, two mental processing theories have been put forward which, roughly speaking, address all these themes. Dual coding theory of mental representations (Paivio, 1986, 1991) focuses more on the first four of these themes, whereas self-regulated learning theory (Zimmerman, 1990) appears to address the last three. These two theories will now be described in detail.

Dual Coding Theory

Paivio's dual coding theory of mental representation is based on the view that cognition consists of the activity of symbolic representational systems which are specialized for dealing with environmental information in a manner that serves functional or adaptive behavioural goals. The most general assumption in dual coding theory is that there are two classes of phenomena, handled cognitively by separate subsystems: one of these is specialized for the representation and processing of information concerning nonverbal objects and events (the imaginal subsystem), and the other is specialized for dealing with language (the verbal subsystem).

To provide a broader understanding of dual coding theory, a detailed description of the differences (and similarities) between the two subsystems is presented below. Throughout this discussion, the reader should be aware that, despite similarities between the subsystems, Paivio (1986, pp. 140-176) has argued for the independence and additivity of their joint effects.[1]

Structure versus Function

Paivio argues that, theoretically, the two systems are structurally and functionally distinct but, following Palmer (1978), admits that structure and function overlap.

Paivio's research efforts (and the present one, as well) have had a decidedly functional emphasis. His research and the dual coding theory upon which it is based have been criticized on the grounds that they pay insufficient attention to the structure of mental words and images. Paivio bypasses this criticism by emphasizing the difficulty in distinguishing representational structure from representational process. He borrows from Palmer and uses a

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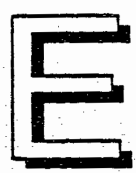
[1] Paivio's theory suggests that strength of dual code mental representation can be ascertained through a summation of verbal and imaginal subscales on any valid and reliable measure intended to assess strength of mental representation within each subsystem.

computational analogy to illustrate his point. He gives two examples. The first concerns the location of cities on a map using multidimensional scaling. Paivio notes that the matrix of distances among cities produced by multidimensional scaling procedures also contains information about the locations of the cities; however, this information can only be extracted by performing the necessary scaling algorithms on the matrix.

The interconnection between structure and function can also be seen with a two-dimensional block letter such as the following.



Ostensibly, the structural entity of this letter is different from a procedure requiring the counting of the inner and outer corners of the letter beginning at the upper right-hand corner and proceeding clockwise. Though the structural entity (the imagined letter E) appears distinct from the counting procedure, Paivio argues that the structure of the E is only revealed by the counting operation. Though it can be revealed by other operations (e.g., drawing the letter), Paivio still maintains that the structure is the drawing procedure. Paivio notes that though it may be theoretically useful to distinguish between structure and function, the two are intimately connected.

Focus on function in investigations of mental representation, Paivio concludes, is legitimate.

<u>Basic Assumptions in Dual Coding Theory</u>

The guiding theoretical assumption about dual coding through symbolic mental representation is that internal (mental) representations have their developmental origin in perceptual, motor, and affective experience, and that they retain these experientially derived characteristics. In this way, representational structures and processes are modality specific rather than amodal. Such an assumption implies that there are continuities between perception and memory, behavioural skills and cognitive skills.

Paivio argues that the verbal-imaginal symbolic distinction is orthogonal to sensorimotor modalities. This allows information to be represented via the same modality in different ways within the two systems. For example, information represented by the visual modality might find expression as visual words within the verbal subsystem, and as visual objects within the imaginal subsystem.

	Symbolic Systems	
Sensorimotor	Verbal	Nonverbal
Visual	Visual words	Visual objects
Auditory	Auditory words	Environmental sounds
Haptic	Writing patterns	"Feel" of objects
Taste	—	Taste memories
Smell	—	Olfactory memories

Table 1. Orthogonal conceptual relation between symbolic systems and sensorimotor systems with examples of types of modality-specific information represented in each subsystem (Paivio, 1986, p.57).

Following Morton (1969), Paivio refers to hypothetical verbal units as "logogens," and uses Attneave's (1974) "iconogen" and "imagen" when referring to hypothetical nonverbal representations. Paivio also distinguishes between unit- and system-level assumptions within dual coding theory. Units of information represented within each subsystem are modality specific, perceptual-motor analogues and are hierarchically organized. Component information in nonverbal units is synchronously organized (thus permitting parallel processing). The example of a synchronously organized imaginal unit that Paivio (1986, p. 60) gives is that of the human face. The face consists of eyes, nose, lips, and other components that themselves consist of smaller parts. As such, the face is organized hierarchically. The perception of the totality, "face," occurs through the synchronous organization (i.e., parallel processing) of this hierarchy of imagens. According to Paivio, when one is looking at "faces," one sees the gestalt. One does not see eyes, nose, lips, etc., and then see a face, unless one is looking specifically at those subunits and not the entire unit.

Logogens are processed differently. They differ from imagens in internal structure so that smaller units are organized into larger ones in a sequential or successive fashion. The sequential processing of logogens is best exemplified in the case of auditory-motor representations that correspond to heard or spoken language. Phonemic units are organized into syllables, syllables into words, and so on. According to Paivio, smaller phonemic units must first be processed and represented before larger ones.

Paivio describes system-level assumptions involving relations among representational units within and between verbal and imaginal subsystems. He puts forward four assumptions: first, he suggests that though the systems are functionally independent, they are interconnected. One system can trigger activity in the other.

Secondly, he notes that different levels of processing are possible both within and between systems. Representational processing refers to the relatively direct activation of verbal representations by linguistic stimuli, and of non-verbal representations by nonlinguistic stimuli. Referential processing refers to the activation of the nonverbal system by verbal stimuli, or the verbal system by nonverbal stimuli. Associative processing refers to the activation of representations within either system by other representations within the same system.

Thirdly, there is differential specialization for synchronous and sequential (parallel or serial) processing, not only within units but between them as well. Verbal transformations presumably operate in a sequential fashion, whereas imaginal transformations operate in a synchronous way. Fourthly, there is both automatic and conscious processing in the two subsystems.

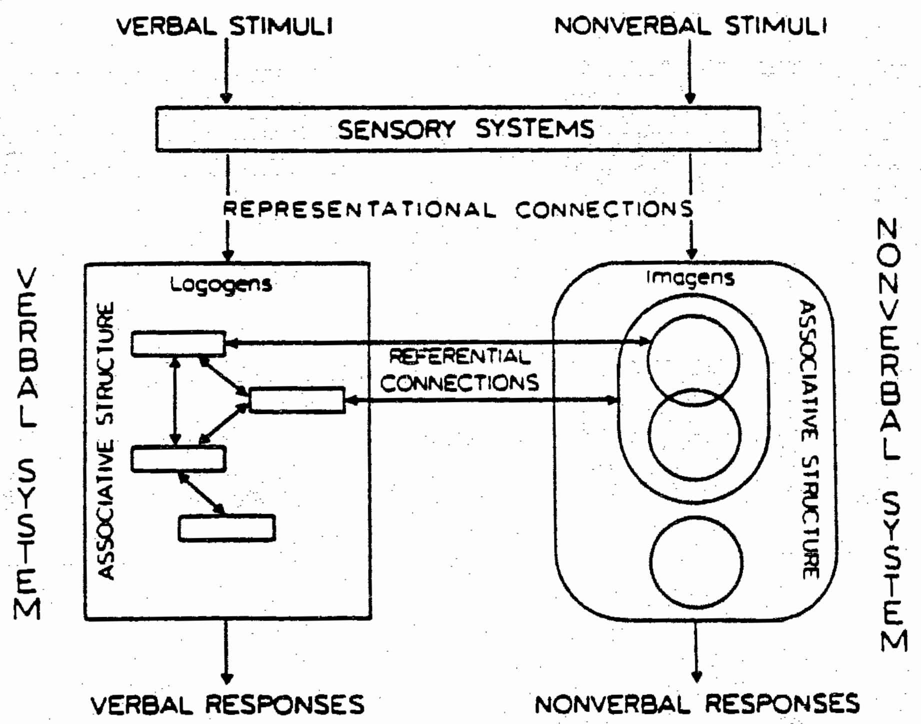


Figure 1. Schematic depiction of the structure of verbal and nonverbal symbolic systems, showing the representational units and their referential (between system) and associative (within system) interconnections as well as connections to input and output systems. The referentially unconnected units correspond to abstract-word logogens and "nameless" imagens respectively (Paivio, 1986, p. 67).

Paivio holds that such mechanisms do not include a separate executive or controller, but instead consist entirely of the probabilistic activation of particular representations determined by the significance of environmental stimuli or previously activated representations. Paivio's vagueness about what shapes the probability function is deliberate and intended to forestall such misinterpretations as the idea that what is encoded is a detailed and faithful reproduction of the episodic information.

Such a view is at odds both with the notion of executive control in the process-oriented version of information processing theory, and the implicit assumption of executive control in self-regulated learning theory (to be described shortly). Paivio does, however, argue that incoming verbal and nonverbal information is organized through constructive processes which operate on the input structure.

In addition to describing unit- and system-level assumptions in his theory, Paivio highlights the mnemonic functions of the two subsystems. He points out that the impact of both imaginal and verbal mediational processes on memory has attracted the attention of researchers for decades. The implication has always been that both systems play important roles in the encoding, storage, and retrieval of episodic information, although they operate in different ways.

Empirical Evidence

Verbal versus imaginal processes. Paivio evaluates evidence for dual coding theory through analyses of research on individual differences in cognitive abilities and symbolic habits. He cites research by Guilford (1967), Pellegrino and Goldman (1983), Carroll (1983), Di Vesta, Ingersoll, and Sunshine (1971), Forisha (1975), and Paivio and Cohen (1979) to support his contention that the verbal and imaginal systems are distinct. Guilford's (1967) factor analytic research is an example of the kind of empirical support cited by Paivio. Guilford found that most of the structure of intellect (SI) tests which used verbal materials and processing fell under symbolic and semantic content categories, whereas most of the nonverbal tests fell into figural categories. Paivio does admit, however, that while other factor-analytic data are consistent with the dual coding distinction between symbolic (verbal-nonverbal) and sensory modalities, a clear factorial separation along both dimensions remains to be demonstrated within a single study.

Evidence for structures and processes posited in dual coding theory. Support for other aspects of dual coding theory has been limited, and requires further research. The degree to which the three levels of processing (representational, referential, and associative) are distinct, for example, remains unclear. Tests aimed at differentiating imaginal and verbal organization, and transformation in synchronous versus sequential terms, have also produced inconclusive results. Researchers such as Das, Kirby, and Jarman (1975) have proposed an alternative model of cognitive abilities in which the distinction between simultaneous and successive synthesis is not tied to the verbal-imaginal one. In short, linking synchronous processing with the imaginal subsystem, and sequential processing with the verbal subsystem, requires further empirical and conceptual support.

In short, evidence appears to exist that supports overall distinctions between verbal and imaginal representational systems (Paivio, 1986). However, more conclusive evidence is still required for various structures and processes posited in the theory.

Evidence in episodic memory. Despite these empirical shortcomings, Paivio provides other evidence for dual coding representation and processes. His examinations of episodic memories (as defined by Tulving, 1972) lend support for: "a) distinctiveness (modality specificity) of verbal and nonverbal memory codes; b) the independence and additivity of their joint effects in some tasks; c) differences in the way that complex verbal and nonverbal information is organized in storage, and d) retrieval differences associated with the organizational distinctions and task demands" (Paivio, 1986, p. 148). The latter two points refer to the general synchronous processing of the nonverbal representational system, as opposed to the sequential processing in the verbal system as revealed in episodic memories.

Summary

Paivio's dual coding theory of mental representation assumes nonverbal objects and events are handled by a subsystem that is separate (at least functionally) from the one specialized for dealing with language. Though Paivio posits a range of unit- and system-level differences between the two subsystems, his strongest empirical evidence comes from Guildford's work on the structure of intellect. In this research, factor analytic procedures revealed that verbal materials and processing fell into one content category, whereas nonverbal tests fell into another. Such findings support the argument for the independence and additivity of effects of the two subsystems.

Self-Regulated Learning

What follows is a description of self-regulated learning theory. This theory accounts for academic achievement through an emphasis on "a) how students select, organize, or create advantageous learning environments for themselves, and b) how they plan and control the form and amount of their own instruction" (Zimmerman, 1990). Students who display self-regulatory behaviours appear to respond and benefit more from instruction than those who do not.

The following review has three broad goals. First, the reader is acquainted with the three major foci of research on self-regulated learning. Next, empirical evidence in support of the theory is provided and a rationale for an examination of one of the major foci in the current study, metacognition, is provided. Finally, controversy over the level of metacognitive analysis, small- or large-grained, that is most appropriate for the present investigation is described. The view that metacognition be viewed as a disposition with large-grain components is presented. For present purposes, the breakdown of metacognitive self-regulation into even large-grain components is questioned.

<u>Foci of Research on Self-Regulated Learning</u>

Zimmerman (1990) summarizes findings from research into the components of self-regulated learning. First, good self-regulators tend to be metacognitively active learners who possess statable and stable knowledge about their own cognitive processes. They are able to regulate such cognitive activity (Palincsar & Brown, 1987). They "plan, set goals, organize, self-monitor, and self-evaluate at various points during the process of acquisition" (Zimmerman, 1990, p. 4-5). Essentially, these learners track the effectiveness of their learning methods or strategies and react to this feedback in a variety of ways, ranging from covert changes in self-perception to overt changes in behaviour, such as altering the use of a learning strategy.

Secondly, self-regulators display high motivation during learning. They are self-starters who are effortful and persistent during learning and report high self-efficacy and intrinsic task interest. The role of motivation in learning has been highlighted by researchers with theoretical orientations ranging from behavioural to phenomenological.

Thirdly, self-regulators actively alter the environment in order to optimize their learning potential. In behavioural terms this means that they select, structure, and create environments which support their efforts to learn efficiently.

Empirical Evidence

Zimmerman and Martinez-Pons (1988) developed a structured interview procedure to determine the kinds of self-regulated learning strategies high school students used in a number of contexts. From these interviews they identified 14 such strategies, including: self-evaluation, organization and transformation, goal setting and planning, information seeking, record keeping, self-monitoring, environmental structuring, self-consequences, rehearsing and memorizing, seeking social assistance, and reviewing. In the same study, Zimmerman and Martinez-Pons (1988) analyzed high school teachers' ratings of observable learning strategies their students used during instruction. Factor analyses revealed that the self-regulated learning factor accounted for 80% of the variance in these ratings.

Zimmerman and Martinez-Pons (1988) also found that students' achievement track (high academic vs. lower tracks) could be predicted with 93% accuracy via discriminant function analyses using their weighted strategy totals across learning contexts. Others have also found that self-regulated learning strategies appear to be related to performance on memory tasks. For example, in their study of metamemory and memory performance on a sort recall task with fifth and seventh graders, Kurtz and Weinert (1989) used causal modeling to show strength of metacognitive knowledge to be a good predictor of performance.

Zimmerman (1990), nonetheless, cites studies which demonstrate that strategy knowledge is not sufficient for actual strategy implementation. It seems that awareness of learning and performance outcomes is critical to continued strategy use. Still, developmental data (e.g., Moynahan, 1978) suggest that monitoring learning outcomes is a complex metacognitive activity which involves directed attention and sophisticated reasoning processes. Adults are more likely to exhibit such attention and reasoning than children.

It does appear, however, that children can productively self-monitor their use of learning strategies. Harris' (1990) review of self-monitoring during reading and writing indicates that grade 3 children can use self-feedback to enhance reading comprehension, and to foster their continued use of the strategy itself. Zimmerman (1990) reports that Sawyer, Graham, and Harris (1989) had similar findings with grade six, learning disabled children using a written composition strategy.

The Significance of Metacognition

Though many other researchers have attended to metacognitive, motivational, and behavioural factors affecting self-regulation, there are four reasons why special attention is being paid to learners' metacognition in a classroom setting in the present study: First, as already mentioned, metacognition is one of the seven major themes in cognitive psychology that currently are informing revisions to information processing theory. Secondly, a focus on metacognition fits within contemporary interest in students' reports of their attention, understanding, and use of cognitive strategies to learn from instruction (Peterson, Swing, Braverman, & Buss, 1982; Peterson, Swing, Stark, and Waas, 1984). Thirdly, there is a need for more ecologically valid studies of metacognition, as most of the research until the mid-1980's occurred largely in laboratory settings (c.f., Brown, Bransford, Ferrara, & Campione, 1983; Yussen, 1985). Findings from such research may or may not pertain to students' learning in the classroom (e.g., Peterson, 1988). Fourthly, as Howard (1989) points out, the metacognitive processes in which students engage to acquire and manipulate subject matter content, and the appraisals they make in learning about self and task, have significant influence on learning outcomes.

Level of Analysis of Metacognitive Processes

Research has been conducted to determine the kind of metacognitive engagement which is optimal for different learning tasks. Howard-Rose and Winne (in press), for example, attempted to validate Corno and Mandinach's (1983) model of cognitive engagement used for different learning tasks. The model proposed by Corno and Mandinach describes four forms of cognitive engagement (recipience, resource management, task focus, and comprehensive engagement). Each of these forms of engagement is differentiated in terms of high or low usage of both self-regulated acquisition and transformation processes.[2] Acquisition processes are theoretically assumed to comprise attending, rehearsing, monitoring, and strategic planning components; whereas transformation processes are assumed to include selecting, connecting, and tactical planning.

Findings from the Howard-Rose and Winne study have relevance to the current inquiry, in that they questionned the level of analysis currently in vogue in research on metacognition. In particular, the lack of coherence among small-grain measures to assess different forms of engagement suggests that such microscopic analyses might not be relevant to understanding metacognition during specific kinds of instructional events. The authors, instead, propose an alternative view of metacognition during learning--that it be viewed not as a set of discrete, small-grain strategies but rather, as a "disposition" with two large-grain components. They came to these conclusions following their study of a heterogeneous group of 33 high school students who completed six academic tasks, each designed to elicit primarily one of the forms of cognitive

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[2] Corno and Mandinach's (1983) four forms of engagement include: a) comprehensive engagement which calls for high use of both acquisition and transformation processes; b) task focus which entails high use of transformation processes but low use of acquisition processes; c) resource management which calls for low use of transformation processes but high use of acquisition processes; and d) recipience, which entails low use of both transformation and acquisition processes.

engagement. Metacognitive self-regulation was assessed through a) a global reflection about cognition applied to academic tasks (the Self-Regulated Learning Scale, Corno, Collins, & Capper, 1982); b) task-specific reflections about cognitions, which students reported immediately following each task; and c) on-the-fly traces of discrete cognitive events, which students recorded in the midst of working on a task.

Results of this study provide only minimal empirical support for the self-regulated learning model proposed by Corno and Mandinach. Coherence among measures of self-regulated learning processes, supposedly associated with tasks emphasizing particular kinds of engagement, was not achieved. Only some components of acquisition processes, (as measured by metacognitive questionnaires) showed a pattern of <u>mild</u> positive correlations among themselves. No other analyses provided convergent or divergent validation for acquisition and transformation processes.

Citing other research, Howard-Rose and Winne point out that component cognitive processes probably occur interactively and unfold in rapid succession, if not simultaneously. As a result, there are limitations on learners' abilities to monitor and report accurately on their cognitive processing. In the end, Howard-Rose and Winne report a lack of empirical evidence for the Corno and

Mandinach model and, with reference to the complexity of cognitive processing, call into question the level of analysis appropriate for measurement of metacognitive self-regulation. Though they favour a description of metacognitive self-regulation as a disposition comprising two large-grained components, their findings and arguments cast doubt on even this grain-level of analysis. One possible implication of their study is that the size of grain of metacognitive analysis be determined, at least in part, through an examination of local data and findings from factor analytic procedures.

Summary

The preceding review of self-regulated learning theory began with a description of research findings that students who cognitively plan and monitor their learning are likely to respond and benefit more from instruction than those who do not. Three foci of research in this area were presented. Empirical evidence showing that self-regulated learning processes can be identified, and that self-regulation is related to achievement and performance on memory tasks, was also given. It was noted that, in situations where cognitive strategies have been employed, awareness of learning outcomes promotes their continued use.

Four reasons for special attention to metacognitive self-regulation were then put forward. Controversy in the research over the grain of analysis for such metacognitive activity was identified. It was suggested that, despite some researchers' recommendation that metacognition be viewed as a disposition with possibly two large-grained components, the determination of level of analysis be left to empirical determinations through factor analyses of local data.

Relationships Among Episodic and Semantic Memories, Dual Coding, and Metacognitive Self-Regulation

Literature reviewed so far has provided a rationale for an examination of the role episodic memories play in learning from classroom instruction and has suggested that both dual coding and metacognitive self-regulation are mental activities deserving attention in an examination of memory (including episodic memory). The following section reviews relationships among episodic and semantic memories, dual coding, and metacognitive self-regulation. More specifically, it examines available research on relationships between a) the two selected mental activities and episodic memories for events in classrooms, b) episodic memories (possibly resulting from such mental activities) and semantic memories (lesson information and facts) and c) the two selected mental activities and semantic memories.

Dual Coding and Episodic Memory

There appear to be no published studies in which Paivio's dual coding theory has been applied to research on episodic memories in classrooms.

Literature review procedures. A comprehensive review of literature was done in an attempt to discover such studies. Three procedures were followed: First, an ERIC search for journal articles published since 1966 was done using "memory," "learning," and "educational research" as keyword descriptors. From this search, 249 articles were identified as possibly relevant to an investigation of episodic memories in elementary school classrooms. Abstracts for each of these articles were examined for application of dual coding theory in natural classroom inquiry.

Secondly, the list of references in Ashcraft's (1989) text on memory and cognition, Human Memory and Cognition, was reviewed and any journal which might contain articles related to the operationalization of dual coding theory in classroom research was identified. (See Appendix A for a the list of 44 journals reviewed.) Articles in issues in the past 5 years for all these journals were examined for relevance to the present literature review.

Thirdly, a computerized Social Science and Citation Index search was done with "Paivio, A." as the search term.

Though articles in the past 10 years of research were examined through this process, only 84 citations resulted from this search. Each of these was also examined for pertinence to the current inquiry. Finally, the 116 references in Paivio's (1991) most recent iteration of dual coding theory were scanned.

Metacognitive Self-Regulated Learning and Episodic Memory

No greater success was had at discovering studies examining the relationship between metacognitive self-regulated learning and episodic memories for events in classroom lessons.

Literature review procedures. Similar literature review procedures were performed to those followed for applications of dual coding theory. First, an ERIC search for journal articles published from 1966 to the present was done using "memory," "long term memory," "educational research," and "metacognition" as descriptors. From this search, 132 articles were identified as having possible bearing on the topic. Secondly, the past 5 years of journal issues gleaned from Ashcraft's (1989) text on memory and cognition were reviewed.

No studies were uncovered through these search procedures which addressed both metacognitive self-regulated learning and episodic memories for events in classrooms.

Empirical Evidence for the Relationship between Episodic and Semantic Memories

There would be no point in doing a study on episodic memory intended to inform teacher practice unless a link were made between such memories and the ones about which teachers typically are most concerned, semantic memories of lesson content. When the rationale for an examination of the role episodic memories may play in classroom learning was presented in Chapter One, the little extant research in which this relationship has been examined was reviewed. The reader is reminded of the promising findings in the Nuthall and Alton-Lee (1982, 1991) studies in elementary school classrooms in which it was found that episodic memories: a) persisted long after a specific instructional event, and b) cued semantic memories.

Unfortunately, Lapadat, Martin, and Clarkson (1993) and Lapadat and Martin (1993) found only limited support for the mediational role episodic memories may play in learning. However, neither study was conducted with a large subject population from a natural context. The former was conducted using a small group format. The latter employed a small subject population.

Given the promising findings in the work of Nuthall and Alton-Lee, it may be too soon to dismiss a research effort intended to investigate the link between episodic and semantic memories. As well, lack of similar findings in the research of Lapadat, Martin, and Clarkson (1993) and Lapadat and Martin (1993) may be due to methodological concerns.

The Role of Dual Coding in Enhancing Semantic Memories from Classroom Lessons

Literature in which the role dual coding may play in enhancing semantic memories from instruction was examined. First, studies investigating dual coding and university students' learning from instruction are reviewed. Then, studies in which high school students comprise the subject population are considered. Next, a study examining the role of dual coding in elementary school students' performance in mathematics is presented. This last study involves a domain that has received a fair amount of attention in the literature examining the role metacognitive self-regulation plays in enhancing semantic memories from intermediate-level mathematics lessons. Finally, implications for instruction from the literature reviewed are summarized.

One already referenced, unpublished study of episodic memory has also investigated how dual coding contributes to semantic memories from classroom lessons. In Lapadat and Martin's (1993) examination of university students' episodic memories for lectures in an undergraduate educational psychology class, it was found (through quizzes administered both immediately after lectures and at three month follow-up sessions) that students learned more from visually presented lecture topics than from exclusively verbally presented ones. They also noted the significance of an individual difference variable. Students with strong imaginal processing habits tended to report more memories of episodes from lectures than students with strong verbal processing habits.

Mayer and Anderson (1991) conducted two experiments with mechanically naive college students, specifically intended as an experimental test of Paivio's dual coding theory. Participants viewed animations depicting the operation of a bicycle tire pump, which included a verbal description given before or during the animation. The "words-with-pictures" group outperformed the "words-before-pictures" group in post-tests of creative problem solving. In a follow-up this same group outperformed groups who saw animation without words, heard words without animation, or received no training.

Two additional studies looked at the use of visual aids in learning from instruction at the secondary level. Winn and Sutherland (1989) referenced dual coding theory in their study of the effects of varied kinds of visual information presented to high school students, on tasks requiring them to remember a map or a diagram. A town's amenities and an electronic circuit system were presented to the one hundred and seventy-eight participants in one of two visual formats. In the more graphic visual format, elements were shown either as labelled drawings in which standard electrical symbols were used to represent circuitry information or icons representing the location of various services on maps for tourists. In the less graphic visual format, the location of symbols on both the circuitry diagram and the map remained the same as in the more graphic format; however, squares were used instead of standard electrical symbols or typical tourist map icons.

Participants either had to recall the names or the locations of elements. These researchers found that low ability subjects were less accurate in their recall when they saw squares than when they saw drawings, but that there was no difference for high ability participants.

Raphael and Wahlstrom (1989) reviewed the influence of instructional aids on mathematics achievement in 103 Ontario grade eight classrooms. They did not specifically reference dual coding theory in this review; however, the aids they examined were concrete and visual (i.e., imaginal, according to Paivio's dual coding theory). Though these researchers examined other areas of mathematics, of particular interest was their finding that student achievement in geometry was related to the occasional use of a variety of visual and highly concrete aids (e.g., geoboards, paper cutouts, models of solids, folded paper, mirrors or translucent reflectors, flims and filmstrips, and kits for construction) in addition to the ones typically associated with geometry instruction.

One study was found in which dual coding in learning from instruction at the elementary level was referenced. Lee and Dobson (1977) examined the role mental imagery plays in rule induction processes during intermediate-level math instruction. They instructed small groups of grade 4 (and combined grade 5-6) students who first had to learn two linear function rules (e.g., a x F = S) under one of seven conditions. Experimental conditions varied in terms of pointing and visual cues. Their control group received verbal instructions only. Subsequent to instruction, participants were taught a complex rule as a transfer task. These researchers found that those subjects trained with visual cues abstracted a rule from rule instances, and expressed it in symbols more easily than did others. Visual cues were particularly facilitative of transfer, whereas pointing, though having an initial short-term effect during acquisition, appeared to retard transfer.

Summary. These studies differed in terms of age of participants, as well as domains of knowledge and kinds of learning tested. For these reasons, generalizations from the findings are limited. They do, however, pose questions about the relationship between visual and verbal lesson information on the one hand, and the learning of instructional content on the other. It seems that at least under certain instructional conditions: a) visual aids are more facilitative of learning than no visual aids; b) certain kinds of visual aids may be more helpful than other kinds, particularly with low ability students; and c) optimal learning may occur when visual aids are used in conjunction with verbal information.

Dual coding theory formed a backdrop for each of these studies to some extent. What is generally lacking in most of them is attention to individual differences in coding habits described in the theory. Only the Lapadat and Martin (1993) study employed an individual difference measure of verbal and imaginal mental representation habits (Paivio's Individual Differences Questionnaire). Aside from this study, the ones reviewed here focused essentially on the role visual and concrete aids play in learning without examining differences in how individuals might cognitively process such stimuli.

The Role of Metacognition in Enhancing Semantic Memories of Lessons

Pressley, Burkell, Cariglia-Bull, Lysynchuk, McGoldrick, Schneider, Snyder, Symons, and Woloshyn (1990) have reviewed recent studies in which metacognition facilitated learning. An area to which they devote much attention is the relationship between metacognitive strategies and the learning of problem-solving procedures in intermediate-level mathematics. To provide a flavour for this research, summaries of three studies reviewed by these researchers are presented below. The studies reported support the argument that metacognitive activity is positively correlated with academic performance in regular intermediate-level classrooms.

Peterson, Swing, and Stoiber (1986) trained 15 fourth-grade teachers to teach strategies for solving mathematical word problems. The strategies included defining and describing the problems, comparing different mathematical operations and problems, thinking of reasons for solution procedures, and summarizing. Fiften control group teachers were given instruction in effective classroom time management procedures.

After five months of regular mathematics instruction in which experimental and control conditions were implemented, posttests showed that the thinking skills intervention was effective in high-ability classes but not in lower-ability classes. Examinations of findings within high-ability classes indicated that higher ability students within these classes benefited more from the control condition (time intervention) than the thinking skills intervention. On the other hand, lower-ability students within these same classes benefited more from the thinking skills treatment. Peterson et al. interpreted their findings to suggest that a fairly high level of average math ability is needed to implement thinking skills treatment effectively in a class; however, once implemented, benefit will accrue more to the lower-ability students within that class.

Charles and Lester (1984) do not report performance differences among students of different aptitudes who were given metacognitive instruction for problem solving in mathematics. These researchers assigned approximately equal numbers of 23 grade five and 23 grade 7 teachers to a thinking strategies or a control condition. In the thinking strategies condition, teachers were trained in how to instruct students in the use of metacognitive strategies during problem solving. Metacognitive instruction included learning a problem solving guide with self-prompts to paraphrase problems, draw diagrams, make lists, use concrete objects, find important information, monitor task difficulty, and check work. After 23 weeks of regular mathematics instruction in which the treatment groups received additional thinking skills training, the researchers reported that strategy training had beneficial effects. It improved performance in understanding problems, developing a plan to solve problems, and to a lesser extent, in generating correct results.

Finally, Lee (1982) also found that metacognitive strategy instruction substantially improved the posttest mathematical problem-solving performance of 16 average achieving grade 4 students. Following Polya[3] (1957), Lee instructed students in self-questioning to identify questions, indicate relationships among items involved in the problem, draw pictures and charts, look for special cases and patterns, make and implement a plan, and verify if the obtained answer appears reasonable.

The instruction group had 20 problem-solving sessions of approximately 45 minutes each over a period of nine weeks, while the non-instruction group attended regular classes. Though the small sample size precluded quantitative analysis, there were substantial differences in the number of problems solved by the instruction versus no-instruction groups on both post-instruction and delayed post-instruction tests.

Summary. Several studies have been reviewed in which the role metacognitive activity plays in enhancing semantic memories of lesson-related content was investigated. Though

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3 Polya (1957) is regularly referred to as the grandfather of the movement to provide strategy instruction in mathematical problem solving. He proposed the following four stages in the solution of a problem: a) understanding the problem, b) devising a plan, c) carrying out the plan, and d) looking back.

one (Peterson et al., 1986) identified a treatment by ability interaction, the others did not. Generally speaking, the studies reviewed here suggest that, regardless of ability, the use of metacognitive strategies during intermediate-level mathematical problem solving improves performance.

A Case for Intermediate-Level Motion Geometry as the Experimental Subject Area

Literature relevant to the choice of the subject area most appropriate for the present investigation is now reviewed. Recall the argument at the outset of this chapter that certain subject areas may call for both mental activities--dual coding and metacognitive self-regulation--simultaneously for successful learning within those subject areas. Hence, the search for the "right" subject area entailed a review of studies that investigated, and found, a relationship between both of these mental activities and semantic memories for lesson-appropriate content.

Intermediate level motion geometry (grade 6) was selected as the experimental subject area for the present study. The rationale for selection of this experimental subject area, based on conclusions from findings in literature reviewed so far, is as follows.

Educational psychologists ought to investigate the heretofore largely unexamined mediational role episodic memories may play in classroom learning. However, such an inquiry would be shortsighted were it not to consider other mental activities, aside from memory process itself. Two such mental activities that address most currently important themes in cognitive psychology are: the dual coding of information during mental representation, and the metacognitive self-regulation of learning.

Some studies have examined the role dual coding can play in learning from classroom instruction. These studies generally have supported Paivio's discussion of the facilitative effect of visual (imaginal) aids in learning from classroom instruction. One conclusion from such studies is that optimal learning may occur when visual aids are used in conjunction with verbal information. Other studies have shown how instruction in metacognitive self-regulation has improved performance in areas such as intermediate-level mathematical problem solving.

Intermediate-level motion geometry seems an appropriate vehicle of instruction in the present research in that successful performance in that subject area likely calls for the dual coding of information, and metacognitive self-regulation. It would seem that motion geometry calls for both the coding of verbal information (e.g., instructions and explanations given by the teacher, on worksheets, and on tests), as well as visual (imaginal) information (e.g., different geometric shapes). It would also seem that problem solving tasks within a mathematical subject such as motion geometry call for the metacognitive management of procedural routines. As such, motion geometry is likely a subject area in which the relationship between both dual coding of information and metacognitive self-regulation of learning, and other variables, such as episodic memories, is available for examination.

Elliott, MacLean, and Jorden (1968) have written the following about geometry in general, and motion geometry in particular:

> Geometry is the natural language of spatial concepts and of the space relationships so common in the real world as to be taken for granted. Geometry plays a basic role in physical science and engineering, and some role in nearly every other subject or profession. Geometry has strong aesthetic connections; the visual arts employ actual geometric expression. Geometry can give pleasure and stimulus for both aesthetic and intellectual reasons...
>
> Motion geometry...deals with ideas that come very naturally to children--for example, symmetry. A child is probably aware of the symmetry of a butterfly before the concept of distance has become fully clarified. Much of the work with motion geometry appeals to the artistic side of children--for example, the classification of ornamental patterns by their symmetry interests--and is accessible to children in Grades 4 to 6, while continuing to hold interest of much older students.
>
> Motion geometry leads to the ideas of vectors and matrices. The essential point about vectors and matrices is that they bring out algebraic properties of geometry and (like co-ordinate geometry) makes possible the application of algebraic techniques to geometrical problems. (p. 5)

This description of motion geometry highlights its highly visual properties as well as the procedural understandings which the subject requires. As such, the description also reinforces the likely importance of dual coding and metacognitive self-regulation for successful performance in motion geometry.

Research Hypotheses

We now come to an articulation of the two sets of hypotheses and one exploratory question intended to guide the present study. Following Morton (1991), *individual difference hypotheses* were put forward to test implications from literature reviewed on the relationship between other mental activities and episodic memories. Findings from that literature suggest that certain subject areas, such as motion geometry, likely call for dual coding and metacognitive self-regulation. The first set of hypotheses was generated to test whether, for individual participants, relationships between these two mental activities and episodic memories can be found to exist, at least during motion geometry lessons.

Additional *mediational hypotheses* were written in order to examine whether episodic memories are important to the semantic memories of lesson content (learning of information and facts). Two such hypotheses were generated. The first is intended to examine the microscopic relationship between memories for specific classroom events, and knowledge of information conveyed during those events. The other examines the more macroscopic relationship between overall memory for classroom events, and knowledge of lesson content.

Finally, the *exploratory question* was written in response to the need to go beyond the limitations of traditional verificationist methodology, particularly in a relatively new area of investigation. The goal of this question is to open exploration to the range of possible meanings in the data gathered.

<u>Individual Difference Hypotheses</u>

1. In intermediate-level motion geometry, there is a relationship between certain mental activities and individual students' episodic memories for classroom events.

1a. Specifically, students with both strong verbal and imaginal mental representation habits will report more memories of instructional events in intermediate-level motion geometry lessons than students with other combinations of these habits.

This hypothesis follows on the implication in empirical studies reviewed that more attention be paid to individual differences in the use of dual coding in examinations of classroom learning. It also follows on Paivio's (1986, 1991) claim that verbal and imaginal mental representation subsystems, though functionally independent, are interconnected. Paivio asserts the additivity of their joint effects in a variety of tasks, including memory ones. It also follows on Morton's recommendations.

1b. Students who report extensive metacognitive self-regulation of learning in intermediate-level motion geometry lessons in general are likely to report more remembered instructional events than those who do not.

This hypothesis follows Zimmerman's (1990) contention that metacognitive self-regulation is associated with better management of and performance on learning tasks (Zimmerman, 1990). It again follows from Morton's recommendations.

Mediational Hypotheses

1. If students report recalling particular instructional episodes, they are more likely to possess greater domain knowledge of the content associated with the particular episodes reported, than students who do not report remembering those particular episodes.

2. If students report recall of more instructional episodes, they are more likely to possess greater domain knowledge of lesson content than students who report recall of fewer instructional episodes.

These two hypotheses were generated for the following reasons. Martin (1993) and Lapadat and Martin (1993) suggested that correlations between episodic memory measures (either for content related to specific posttest items or in general) would provide support for the mediational hypothesis that episodic memories facilitate learning of declarative/procedural information. Lapadat and Martin's test of this hypothesis was not supported in their study of university students' episodic recall from university lectures. However, there was at least one methodological shortcoming in that study. They had a small sample size. Furthermore, theirs' was an examination of a fairly sophisticated group of learners. In addition, Nuthall and Alton-Lee (1982, 1991) have established links between episodic and semantic memories for elementary school students during classroom instruction.

The possibility still exists, therefore, that episodic memories do mediate learning with younger students. The two mediational hypotheses stated here continue the line of investigation of Nuthall, Alton-Lee, and Martin and Lapadat. The present inquiry involves a young, large, Canadian, public school population.

Exploratory Question

Is it possible to learn anything about the kinds of classroom events which children remember, through exploratory classification and analyses of those events?

Shortcomings of strictly verificationist approaches to inquiry in the social sciences have been described by Glaser (1978) and Glaser and Strauss (1967). In particular, the verificationist approach de-emphasizes grounded, "bottom-up" data analysis. An exploratory investigation employing a grounded approach would allow for the exploration of unanticipated patterns or trends in the data obtained.

Summary

The chapter began with a description of major themes in cognitive psychology today. Next, two mental activities--dual coding and cognitive self-regulation--that incorporate most of these themes were highlighted.

Paivio's dual coding theory of mental representation was then presented. Empirical evidence supporting structural and functional distinctions between verbal and imaginal mental subsystems was put forward. It was noted, however, that other structures and processes posited within dual coding theory require more empirical substantiation than currently is available.

A form of cognitive self-regulation, metacognitive self-regulation, was then described based on Zimmerman's overview of the self-regulated learning literature. A rationale was then presented for special attention to the role of metacognitive self-regulation during classroom learning. An argument was given suggesting that the determination of the grain-size for analysis of metacognitive activity probably ought to be left to findings from factor analytic work on local data.

Five other sets of literature were then reviewed. No published literature was found in which either Paivio's dual coding theory or Zimmerman's description of metacognitive activity had been applied to classroom research on episodic memory. Still, it was argued that a study of the role episodic memory plays in classroom learning is important. Literature in which the relationship between the episodic and semantic memory systems has been found, such as in work of Nuthall and Alton-Lee, was referenced in support of this argument.

It was also noted in two other literatures reviewed that dual coding of information and metacognitive self-regulation have been found to be significant in learning from classroom instruction. Research on the relationship between dual coding and semantic memory highlighted the fact that optimal learning may occur when visual aids are used in conjunction with verbal information. Particular attention was paid to literature showing the positive effect of metacognitive instruction on performance in intermediate-level mathematics classes.

A case was then made for motion geometry as the experimental subject area in the present investigation.

Motion geometry is a visually rich area within mathematics. As such, it likely calls for dual coding of information. Motion geometry also entails problem solving and, as a result, performance in this subject area is probably enhanced by metacognitive self-regulation.

Based on the literature reviewed, the chapter ended with a description of, and rationale for, four research hypotheses and one exploratory question.

CHAPTER THREE: METHODS

Overview

The focus of this study was on episodic memory. The individual difference hypotheses that were formulated address two relationships of interest, based on previous theoretical and empirical work on coding and metacognitive self-regulation. The first hypothesis posits a relationship between strength of mental representation habits and episodic memories for events in lessons. The second suggests that there is a relationship between metacognitive self-regulation and such episodic memories.

Prior to delivery of the experimental lessons, the researcher/teacher administered two measures to assess individual differences in strength of mental representation habits and metacognitive self-regulation. Three experimental lessons were taught and students were asked to report whatever episodic memories they had for events in these lessons on an Episodic Memories Questionnaire (Appendix S). The number of episodic memories each participant reported within each lesson was then calculated and relationships between this report count and the two individual difference variables were then determined.

Mediational hypotheses were put forward to examine whether students recalling particular episodes were likely to know more lesson content related to those episodes, and to investigate whether students who tended to report more episodic memories in general also tended to do better on post-lesson quizzes. To test these hypotheses, two procedures were followed. First, students completed posttests after each experimental lesson. Secondly, lesson transcripts were analyzed for content specifically related to each posttest item. The relationship between memory reports related to episodes containing posttest content and performance on items related to that content was assessed. Also, the relationship between memory reports and overall posttest performance was calculated.

Finally, procedures following grounded theory methodology were employed to examine the content of episodic memories reported. Cards containing student reports of episodic memories for each remembered event were created. These cards were then sorted and categorized.

What follows is a detailed description of methodology used to examine the hypotheses and exploratory question.

The Study

Pilot Study

A pilot study was conducted to determine whether measures and procedures proposed for the main study a) were practical, and b) would provide the data required to respond to the research questions. With two exceptions, methods implemented in the pilot met these two criteria.

During the pilot it was discovered that students needed practice and feedback on how to fill out the episodic memories questionnaires before actually using them during the experimental lessons. It was also found that lesson one contained too much content for the allotted instructional time. As a result, this lesson was reduced in length. See Appendix B for more detail on the pilot study.

Sample and Setting

One hundred and twenty-two children (58 females and 64 males), from a pool of 145, volunteered (Appendix C) and received parental permission (Appendix D) to participate in the main study. All participants were from five different grade six classrooms, in four different schools, in the same large, urban school district in which the pilot study was conducted.

Two of the schools in the study are considered by district officials to be in lower-middle class/working class neighbourhoods, while the other two are thought to be situated in more middle to upper-middle class neighbourhoods.[1]

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[1] Informal descriptions of socioeconomic status of neighborhoods for each school were obtained from school district officials (Assistant Superintendent of Schools and District Resource Personnel) as well as school principals in each of the four schools in the study. One criterion for school selection was that a range of socioeconomic stati be represented in the participant population.

Participants in the study were taught three lessons in motion geometry from the required grade six mathematics text. The content covered in the experimental lessons forms part of a spiral intermediate-level curriculum that begins in grade four. Spiral curricula involve repeated but more complicated exposure to concepts with each successive grade. It should be noted, however, that some apparently less essential mathematics curriculum (such as geometry) often goes untouched throughout the intermediate programme.[2] Elaboration on actual content of these lessons appears later in this chapter as well as in Appendix I.

The principal investigator, a researcher/teacher, taught all experimental lessons, while the regular classroom teacher observed at the back of the classroom. The principal investigator has a diploma in special education and is certified to teach in the B.C. public school system. He has 12 years of experience as a teacher/instructor at the elementary, secondary, college, and university levels. He quickly obtained entry to schools by approaching officials in his former school district.

<u>Pre-Instruction Measures</u>

Prior to instruction, participants completed four questionnaires and pre-tests. These included the Self-

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[2] Teachers in the experimental classrooms reported that geometry was an area in the curriculum that often was overlooked at all levels of the intermediate programme.

Regulated Learning Scale (SRL, Corno, Collins & Capper, 1982, Appendix E), The Individual Differences Questionnaire for Grade 6 Students (IDQ, Specht, 1992, Appendix F), and two teacher-prepared tests of prior knowledge of the content to be taught (Appendix G).

It was decided that administration of the SRL should precede that of the IDQ. The IDQ is a self-report measure of imaginal and verbal mental representation habits. The SRL measures the extent to which individuals are active metacognitive self-regulators. There was concern that, if the order of administration were reversed, attention to and report of mental representation habits might cause individuals to focus unduly on their cognitive processes. It was thought that such an increased focus might contaminate or sensitize students' subsequent reports of metacognitive self-regulation.

It was also decided that two tests of prior knowledge be administered. The first was a test requiring participants to draw slides, flips, turns; and, in certain instances, identify slide rules and turn angles[3] (Appendix

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[3] A slide rule or a slide arrow is used to indicate how an image is to be slid (moved) from a starting to an ending position. The rule indicates the actual distance and direction of the slide. The arrow visually portrays this distance and direction.

A flip image is the mirror of an image over a line (the flip line). Points on the original and flip images are equidistant from the flip line.

G). The second was a multiple-choice test of knowledge about the same content but required participants to circle correct responses printed on the test form (Appendix G) rather than draw them. For example, in the multiple-choice test, individuals were asked to identify whether an image was the flip of another image. In the first test, participants were asked to draw the actual flip image of another image. The multiple-choice test followed the test of drawing so that declarative and procedural knowledge, embedded in the printed answers on the former, would not inflate scores on the latter.

SRL. The SRL, first developed by Corno, Collins, and Capper (1982), was recently used by Howard (1989) in her Ph.D. dissertation on variations in cognitive engagement as evidence of metacognitive self-regulation during learning. The scale used by Howard contains the same 20 items used by Corno et al. (1982), asking students to rate the extent to which they use the various metacognitive components of acquisition and transformation skills in their classroom learning. Response options for each item on that scale are "usually," "often," "sometimes," "almost never," and "don't know."[4]

A turn image results when an image is turned clockwise or counterclockwise about a point (the turn centre) by an indicated part of a complete revolution (the turn angle).

[4] Howard (1989) does not give a description of SRL scaling procedures she used.

Psychometric information is not available from the initial report of the development of the SRL (Corno, 1992), but data on both its reliability and validity appear in Howard's (1989) research. Howard used Guttman's reliability coefficients to calculate internal consistency for the acquisition, transformation, and total scale[5] scores of the SRL. She reported the largest of the six coefficients generated through Guttman's formulae on the grounds that the true reliability of a scale will not be smaller than the largest of the six coefficients (Guttman, 1945). Howard reports a .84 Guttman reliability for the 13 items of the acquisition scale, a .48 reliability for the 7 items of the transformation scale, and a .91 overall reliability for the total scale.

For the present research, minor changes were made to the version of the SRL used by Howard (1989). First, response categories were reduced from 5 to 4. The "don't know" category was eliminated in an attempt to force

[5] Howard (1989, p. 6) described four acquisition and three transformation processes as metacognitive components measured by the SRL The acquisition processes included rehearsal (repeating information to oneself), monitoring (self-checking of general level of understanding systematically), attention (receiving and tracking incoming stimuli), strategic planning (overviewing tasks, assessing goals, and seeking outside resources when needed). The transformation processes included connecting (searching for familiar knowledge and linking familiar knowledge to incoming information), selectivity (discriminating among stimuli and distinguishing relevant from irrelevant information) and tactical planning (organizing a task sequence or performance routine).

participant choice and obtain more useable data.[6] Secondly, the Corno et al. (1982) version of the SRL made no distinction between cognitive self-regulation within different subject domains, but rather was a "generic" measure. To remedy this shortcoming, all items on the SRL were amended to point specifically to cognitive self-regulation within grade six geometry lessons. This was done by changing the first sentence in the original set of directions from, "Below are some questions about things you may think about or do to help you learn in school." to "Below are some questions about things you may think about or do to help you learn <u>during a math class in which you're working with shapes</u>." This phrase was also added to each item of the original SRL to direct participants' attention to their metacognitive performance in geometry, not simply in school in general.

In her study, Howard used the original version of the SRL with grade 12 students. In order to ensure that the current version of the SRL was readable by grade 6 students, it was piloted with two such students, one a student of high academic ability, and the other a learning disabled student.

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6 Scoring for SRL items was as follows:
"Usually" was scored "4." "Often" was scored "3." "Sometimes" was scored "2." "Almost never" was scored "1." Items 14 and 18, which were worded negatively, were reverse scored. For these two items, "usually" was scored "1," "often" was scored "2," sometimes was scored "3" and almost never was scored "4."

Neither had difficulty comprehending the instrument, and neither had recommendations on wording changes necessary for the instrument to be more understandable to their peers. The questionnaire was also read to participants during administration, to reduce the impact of poor reading ability on results.

IDQ. The original version of the IDQ designed by Paivio (1971) contains 86 items. It was used to measure imaginal and verbal thinking habits and skills in university students. Paivio and Harshman (1983) investigated the structure of the test in a series of item factor analyses in two samples of university students with 300 or more participants. When analyses were restricted to two factors, they found that the solutions were essentially identical across samples, and the factors corresponded well with the original (theoretically defined) verbal and imaginal scales. Solutions with up to six factors also were shown to be replicable.

Employing Paivio's blueprint, Specht (1992) created a modified version of the IDQ which is usable with grade 6 students. Thirty items were selected from Paivio and Harshman's (1983) six-factor solution of their 86-item pool. These 30 items corresponded to the 15 verbal and 15 imaginal items in the original scale which loaded with coefficients greater than .30 on the good verbal expression and fluency, or habitual use of imaginal representations factors respectively. Since Paivio and Harshman used their scale with university students, Specht (1992) edited items to make them readable at the grade 6 level.

Specht confirmed Paivio and Harshman's two factor solution for data she gathered from 214 grade 6 students from 8 schools in a mid-sized Ontario city. She found factor loadings similar to those of Paivio and Harshman on 25 of the 30 items and obtained Cronbach's alphas of .79 for the 13-item verbal scale, and .77 for the 12-item imaginal scale. (Only 25 of the original 30 items were included in her subscale construction, since she eliminated items that loaded higher than .30 on more than one factor, or loaded on the opposite factor than that suggested by Paivio and Harshman.)

Replication of Specht's validation procedures was done to ensure that the same verbal and imaginal factors appeared in data from the current sample (using the 30 item pool rewritten at the grade 6 reading level). The wordings used by Specht (Appendix F) were used in the present research after pilot testing for readability with the same two high ability and learning disabled grade 6 students who responded to the SRL. Again, to reduce the impact of poor reading ability on test results, directions and test items were read to participants while they were responding.

Tests of prior knowledge. Two tests of prior knowledge (Appendix G) were developed to reflect the following learning objectives for each lesson:

a) By the end of the lesson on slides (session 3, Appendix I), it was intended that students would be able to identify the slide rule for a given slide arrow and use tracing paper, pencil, and ruler to slide both triangular and non-triangular shapes.

b) By the end of the lesson on flips (session 4, Appendix I), it was intended that students would be able to use tracing paper to flip both triangular and non-triangular shapes over a flip line.

c) By the end of the lesson on turns (session 5, Appendix I), it was intended that students would be able to identify turn angles using clocks, identify the turn angles of turned images, and use tracing paper to turn both triangular and non-triangular shapes.

Both tests of prior knowledge provided assessments of the extent to which participants had already mastered the intended learning outcomes. See Appendix H for a breakdown of the number of items on each test, to assess each learning outcome.

Measures Collected During Instruction

Worksheets. Three worksheets (see Appendices J, K, and L) were created to assist students in learning the lesson material. See Appendix M for a breakdown of the knowledge covered in each of the three worksheets.[7]

Post-Instruction Measures

Quizzes. At the end of each lesson, students were tested on their knowledge of lesson content. Whereas students were expected to draw geometric forms in worksheet exercises, quizzes followed a multiple choice format. (See Appendices N, O, and P for samples of these quizzes. Appendix Q contains a breakdown of the knowledge covered in each of the three quizzes.)

Episodic memories questionnaire. The E.M.Q. (Appendix S) asked students to report salient episodic memories of classroom events. Participants were asked to think back to the lesson of the day and to report all they could remember from that lesson as well as the events that "stood out" for them the most. They were told to close their eyes for one minute and run a videotape of the lesson they just experienced for their "mind's eye." Then they were asked to report as much as they could recall, including exact quotes, in response to the "list" question on the E.M.Q. They were reminded that they could report anything and, if they so chose, their reports did not have to relate to actual lesson

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[7] As noted in the description of lesson content (Appendix I), students were given a limited amount of time to complete the worksheets so that other lesson material and experimental procedures could be covered. As a result, most students did not complete the lesson worksheets.

content. From the responses to the list question, they were then asked to select the three memories that stood out for them the most.

The two retrieval questions were: a) make a list of specific words you heard or events you saw during the lesson; and b) select one thing you remember that stood out most for you during today's lesson. The second question was repeated twice.

Curriculum Taught

The 3 lessons taught during this study were selected from the chapter on motion geometry in Journeys in Math 6 (Connelly, Marsh, Sarkissian, Calkins, Hope, O'Shea, Sharp, Taschuk, Tossell, 1987). Students were taught the basic concepts of sliding, flipping, and turning images. Lesson 1 dealt with "slides," lesson 2 with "flips," and lesson 3 with "turns." Though lessons differed in content, procedures were similar across all lessons. After a teacher demonstration of the core concept using some concrete material (e.g., sliding an actual object, the "image," across a piece of flip chart graph paper), generally students were taught 3 to 4 important pieces of vocabulary. Students would then do some "hands on" activity to improve their understanding of the key concepts. Next, they would watch the teacher demonstrate the "tracing paper method" for sliding/flipping/turning first triangular and then non-triangular shapes. Students completed worksheets after each tracing paper procedure was taught.

At various points during the lesson, either the teacher or the students (when solicited by the teacher to do so) would generate "real world" images of the core concept being taught. As an illustration, some examples elicited from the students for a slide were: a skier going down a hill, someone going up an escalator, and a train crossing a bridge.

Shortly after the second worksheet was completed, students completed a quiz of their knowledge of the lesson content taught. After this test they were asked to fill out the E.M.Q. (Appendix S).

Style of Instruction

"Recitation style" instruction was used for the purposes of the study. The recitation mode has been described by Bellack, Hyman, Smith, and Kliebard (1966) as a structured method of teaching in which the whole class attends to instruction delivered by the teacher, and dialogue is characterized by a question-response-react cycle. Only classrooms where teachers used the recitation mode of teaching in their lessons were considered for inclusion in the study.

Lessons followed the general cycle of instruction described by Clark, Gage, Marx, Peterson, Stayrook, and Winne (1979) in their study of teacher structuring, soliciting, and reacting. An overview of material to be covered in a lesson segment was followed by a didactic presentation of actual lesson content. The teacher then solicited questions about lesson content from students and reacted to these questions by further clarifying lesson material. Students then worked individually on exercises which reinforced their learning of that segment of lesson content. This cycle was repeated several times during the lesson until all lesson segments had been covered.

The researcher/teacher was responsible for teaching all lessons in all 5 experimental classrooms. All lessons were videotaped.

Description of Lesson Procedures

A summary of in-class procedures, as well as a precise description of these procedures with time allotments, appears in Appendix I.

Coding and Scoring

Episodic Memories Included in the Data Analysis

Participants had the opportunity to provide episodic memories in response to the "list" and three "salience" questions on the E.M.Q. (see Appendix S). The list question is a request for participants to report whatever words or events they could remember from the lesson. The salience questions constitute probes to solicit student prioritizations of the events from their responses to the list question, in terms of what stood out for them the most.

All events reported in both the list and salience questions were considered potential episodic memories and were evaluated according to rules implied by Tulving's (1983) theoretical view on the nature of episodic memories, as well as his more formal description of these memories (Tulving, 1985). Tulving suggests that episodic memories can be "unitized" in terms of events or episodes. A complex event may comprise a series of simpler events, sometimes called episodes. Episodic memories of events have beginning and end points, and always involve the rememberer, either as one of the actors or as an observer.

Though each event in episodic memory refers to a particular instant, date, or period of time, the referent is not chronological or calendar time. It is the rememberer's personally experienced time. It is not the mere dating of a fact in the past. It is the dating of the fact in the <u>rememberer's</u> past.

The following rules were developed for scoring episodic memories on the E.M.Q., based on Tulving's theorizing and practical considerations delineated by Martin, Paivio, and Labadie (1990) in their methodology for locating important events in psychotherapy.

1. The episode had to be locatable at only one spot <u>within</u> the lesson transcript or lesson videotape. A reported episode that occurred more than once during the lesson (e.g., "Jimmy was asked to hold the tracing paper for Mr. Prupas.") and could not be located by other information provided by the rememberer was eliminated from data analysis.

2. Memories of episodes prior to the start of the day's motion geometry lesson were not included in the analysis.

3. Both simple episodes (e.g., "Mr. Prupas said good morning to me.") and more complex events (e.g., "When we first learned all the steps in how to use tracing paper to slide a triangle.") were included in the analysis.

4. Memories of the entire lesson (e.g., "We did a lesson on turn images.") were excluded from data analysis. Though no time limit was set on the length of episodes or more complex events, generally, simple episodes lasted a few seconds (e.g., "When Randy said slide image instead of turn image). More complex events usually lasted anywhere from 2-8 minutes.

5. The start and end points of complex events (e.g., reference to the first time all the steps in the procedure to slide a triangle were described) followed guidelines established by Martin, Paivio, and Labadie (1990). The core statement or activity of the event being referenced was

located within the lesson transcript. Boundaries on the time of the "event" were expanded to include the context before and after this referenced core statement or activity. The beginning or end of the event was demarcated by a teacher or student talking turn (uninterrupted speech). The beginning or end of the event was also demarcated by a shift in topic or activity.

6. If an episode was reported in response to both the salience and list questions, or more than once in the list questions, it was counted only once.

7. Rememberers did not have to reference themselves explicitly in the recollection for it to be considered an episodic memory. It was assumed that individuals were providing personal memories from their own past in response to the retrieval questions. So, for example, a memory of "the test" which was locatable but without a personal reference was included.

A check on the reliability with which episodic memories were selected was performed by a research assistant.[8] The research assistant is a practicing learning assistance teacher with 17 years of teaching experience in B.C. public schools at both the elementary and secondary level. She has completed a number of graduate courses in reading and

[6] Hill, Greenwald, Reed, Charles, O'Farrell, and Carter (1981) suggest that judges for reliability checks be undergraduate or graduate students with high grade point averages.

special education. The research assistant studied the guidelines for scoring the episodic memories (as listed above) and, with the primary investigator, practiced coding samples of memory reports from the pilot study. She then reviewed all memories on lesson transcripts and highlighted ones she thought were not episodic. She classified as episodic 558 of the 605 originally coded as such by the principal investigator. Using procedures described by Lapadat and Martin (1993), the research assistant and principal investigator discussed those 47 events about which they disagreed. After this discussion, the two decided to eliminate 21 of the 47 memories not identified as episodic by the research assistant, leaving a total of 584 episodic memories for further data analysis. Disagreements were generally over whether an item was too vague to be locatable within the transcript (for example, "We learned the steps in how to flip a triangle" after discussion was deemed to be too vague whereas, "When we first learned the steps in how to flip a triangle" was not).

Scoring of the SRL and IDQ. Total SRL score and two subscale scores, derived from the two factor solution for the IDQ (Appendix W), were used in data analysis procedures. Further discussion of score selection procedures for the SRL and IDQ appear below in sections on factor analysis and tests of reliability.

Grade point average (GPA). GPA was included in order to partial out the correlation between previous academic achievement and reports of episodic memories from the correlations of primary interest. GPA was calculated by averaging a participant's grade 5 permanent school record grades in language arts, mathematics, science, and social studies. Other subject areas were not included in the calculation of GPA because generally they were not available on the permanent record (see Appendix U for the GPA letter-to-number grade conversion key).

Coding of transcripts for test related content. As already mentioned in the statement of hypotheses for this study, others have suggested that an understanding of the way episodic memories mediate learning requires an examination of the correlations between such memories and performance on posttest measures. A rough idea of this relationship can be obtained by calculating the correlation between the total number of episodic memories reported and performance on quizzes.

A more precise description of this relationship involves an analysis of both episodic memories and quiz items in terms of the actual declarative/procedural knowledge they encompass. To do this, it is necessary to analyse lesson events (as depicted through lesson transcripts) in terms of the to-be-tested knowledge they cover.

Hence, in the present study, lesson transcripts were marked for content related to specific knowledge areas tested on the quizzes. Occasionally, lesson segments addressed more than one knowledge area at a given time. These areas of transcripts were therefore marked accordingly, showing the combination of posttest declarative and procedural knowledge areas they covered (see Appendix R for a breakdown of the posttest knowledge areas covered within each lesson).

Analysis of transcripts for knowledge areas in the posttest was done based on "talking turns." Simply stated, any uninterrupted speech event, no matter how long,[9] was coded as a "talking turn." Talking turns were coded as containing content related to a) a specific learning outcome tested on the quiz, b) a combination of specific learning outcomes tested on the quiz, c) management or lesson procedures not tested on the quiz, d) a combination of a and c, or b and c. A description of the use of combination codes for lesson content related to a mix of learning outcomes (b) follows shortly.

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9 Single words were often coded as talking turns. Such words (e.g., "right" or "correct") were usually coded similarly to contiguous talking turns if the gist of the sequence of talking turns related to the same test related content.

Combination coding (a and c, or b and c) often occurred during lesson transitions and were always given to researcher/teacher talking turns. For example, it was generally the case that the researcher/teacher ended a lesson segment related to a specific learning outcome and then made a lesson transition statement not related to any particular learning outcome all within one talking turn. Such a talking turn would be given a combination code (a and c or b and c).

In lesson one, explanations of <u>how</u> to produce a slide arrow from a slide rule and vice versa, to slide a triangular shape, and to slide a non-triangular shape, were each identified as relating to different intended learning outcomes. In lesson two, the same was true of explanations of how to flip triangular and non-triangular shapes. How to determine turns on clocks, turn angles for turned images, and turns for triangular and non-triangular shapes, were all distinguished from one another in terms of intended learning outcomes and were given separate codes in lesson three.

Descriptions of slide, flip, and turn vocabulary were given combination codes in each of their respective lessons. This was done because understanding of vocabulary was considered prerequisite for learning of motion geometry procedures in any of the lessons.

Similarly, lesson content in which "real world" examples of slides, flips, or turns were discussed was not tested with unique quiz items. "Real world" examples are ones drawn from or evident in the student's out-of-school experience, though they may be ones talked about in school. As it was assumed that these discussions contributed to a global understanding of the procedures involved in sliding, flipping, or turning different kinds of images, as well as in labelling those procedures, they were given the same combination code used for coding vocabulary.

An exception to this coding rule occurred when "real world" knowledge was used to instruct students in specific knowledge that was posttested. A discussion of how the movement of skateboards can represent a slide arrow with a specific slide rule, was coded as covering "slide rule and arrow" knowledge.

Content coding reliability was determined by having a trained coder (the same research assistant described previously) recode a randomly selected one-third of all lesson transcripts (two from lesson one, two from lesson two and one from lesson three).[10] Moderate content coding reliability was indicated by Kappa statistics of .71, .66,

[10] The check for reliability of transcript coding differed from that for identification of episodic memories. This is because the Kappa statistic can be calculated when there are two or more categories over which coders can agree or disagree. For the episodic memory reliability check, the research assistant had to examine memories that had all been classified the same way by the primary investigator, i.e., as episodic.

and .63 for each of the three lessons. An average Kappa of .67 was obtained for a combination of all three lessons.[11]

Data Analysis Procedures

Descriptive Statistics

Initially, descriptive statistics were produced describing participants' prior knowledge of the curriculum taught, GPA, quiz scores, and the quantity of their episodic memories from classroom lessons. Descriptive statistics of SRL and IDQ data were calculated following factor analysis and reliability procedures.

Factor Analysis of SRL and IDQ Data

The three steps outlined in the SPSS/PC+ Statistics 4.0 manual for factor analysis were performed on data from both measures. First, the appropriateness of the factor model for the data was established. Next, the factor extraction procedure was determined. Finally, factor loadings were calculated, following the selection of a rotation procedure which produced the best solution.

To determine the appropriateness of the factor model, three steps were followed: First, the correlation matrix for all items was examined for items with only minimal correlation (less than .10) with all other individual items. Then, the Kaiser-Meyer-Olkin (KMO) measure of sampling

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[11] See Hill, Greenwald, Reed, Charles, O'Farrell, and Carter (1981) for a description of this statistic, which represents percent agreement adjusted by expected chance agreement.

adequacy was calculated. A low KMO indicates that a factor analysis may not be advisable. Thirdly, anti-image correlations (negatives of partial correlation coefficients) were calculated.[12] Factor analysis procedures should not be followed if the proportion of large anti-image correlations is high.

After it was determined that factor analysis could proceed for each of the sets of the SRL and the IDQ data, the optimal number of factors to be extracted was determined. To do this, a scree analysis was performed. The scree procedure plots eigenvalues (variance associated with each factor) for each factor. It is often superior to other methods of factor specification when there are minor factors, and the interest is in locating only major common factors (Linn, 1968; Tucker, Koopman, & Linn, 1969). Typically the scree plot shows a break between the steep slope of the large factors and the gradual trailing off of the "factorial litter or scree." Cattell (1965a, 1965b) suggested the rule that factoring cease at the point where the eigenvalues begin to form this scree. The only caveat to using the scree procedure is that it may not be

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[12] If variables share common factors, the partial correlation coefficients between pairs of variables should be small when the linear effects of the other variables are eliminated. The partial correlations are then estimates of the correlations between the unique factors and should be close to zero when factor analysis assumptions are met. The negative of the partial correlation coefficient is called the anti-image correlation.

appropriate when there is more than one major break in the eigenvalue graph (Kaiser, 1970), something which was not the case in either of the current factor analyses.

Once the number of factors to be extracted was determined for each data set, principal axis factoring with varimax rotation was performed. The number of factors extracted using the scree procedure was forced into the varimax rotation. The varimax was selected over the oblimin rotation for both analyses as it produced better factor solutions than the latter method. The varimax: a) produced more factor loadings above .30 (a cut-off of .30 was selected following Paivio and Harshman, 1983); and b) provided solutions where fewer items showed similar loadings on both factors.

Tests of Reliability

Cronbach's alpha was calculated for SRL and IDQ subscales (created from factor analysis[13]) and total scale scores. Results from both factor analysis and reliability procedures were used to determine whether subscale or total scale scores would be used in further data analyses.

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[13] SRL and IDQ subscales were created from items with the higher factor loading in the two-factor solutions that reached the minimum cut-off of .30. As a result of this procedure, two subscales both with 9 items were created from the SRL data; two subscales with 14 and 11 items were created from the IDQ data.

Calculation of Part Correlation Coefficients

Part correlation coefficients[14] were created through regression procedures in order to determine the unique correlation between any one predictor variable and the outcome measure. In tests of the individual difference hypotheses, the predictor variables were the overall scores of the IDQ verbal and imaginal subscales,[15] SRL total scores, and GPA. The outcome measures were based on reports of episodic memories. In tests of the mediational hypotheses, the independent variables were reports of episodic memories and GPA. The outcome measures were quiz scores. Regression procedures were followed both within and across lessons.

Card Sort of Episodic Memories

A grounded approach (Glaser, 1978; Glaser & Strauss, 1967; Strauss & Corbin, 1990) was followed to generate categories for the episodic memories identified for inclusion in data analysis through the above procedure. A card sort task was developed and performed by both the

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14 The part correlation coefficient is the correlation between Y and X_i when the linear effects of the other independent variables have been removed from X_i. The part correlation coefficient is not to be confused with the partial correlation coefficient which is the correlation between the ith independent variable and the dependent variable when the linear effects of the other independent variables have been removed from both X_i and Y.

15 IDQ overall scores were obtained by adding scores on the imaginal and verbal subscales identified through factor analysis procedures.

primary investigator and the research assistant (as described previously). Cards for remembered events were printed (one card was printed for each remembered event, regardless of the number of times that event was referred to in students' episodic memories). The cards were then sorted according to categories of the sorter's own choosing (see Appendix T for instructions given to the research assistant).

The following criteria were suggested as guidelines in the creation of major categories (Glaser, 1978). The category had to:

a) be central,

b) reoccur frequently,

c) take more time to saturate than other categories,

d) relate meaningfully and easily to other categories,

e) have clear and compelling implications for formal theory.

A check on the card sort was done by the research assistant who both reclassified cards and reworded categories created by the primary investigator. Final classifications and category labels were determined through discussion between the primary investigator and the research assistant.

Search for a Core Category of Episodic Memories

Once major categories had been identified, an attempt was made to define a core, superordinate category (c.f., Strauss and Corbin, 1990, p. 253). To do this, major categories were examined for a common factor from a list of those possibly involved in episodic memory process (to be described in Chapter Five).

CHAPTER FOUR: RESULTS

Preliminary Data Analyses

Descriptive Statistics for Tests of Prior Knowledge and Reports of Episodic Memories

Table 2 provides descriptive statistics for both tests of prior knowledge. A 2-tailed *t*-test[1] for paired observations measuring differences between the means of scores on these two tests showed that students performed detectably better on the multiple-choice test than on the drawing test (t=9.86, d.f.=112, p<.01).

Despite the better performance of students on the multiple-choice test, it cannot be concluded that, overall, students performed well on either of these tests. On average, students answered 8.8% of test items on the drawing test and 23.9% of test items on the multiple-choice test correctly. Average percent correct for both forms was 16.3%. Though the content of the prescribed Grade 6 mathematics text, Journeys in Math 6, forms part of a spiral curriculum in which concepts such as those taught in motion geometry may be covered in earlier grades, students either did not learn or did not retain much of what they learned from previous instruction on motion geometry concepts. Informal discussions with grade 6 classroom teachers and

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[1] Scores were converted to a common scale by dividing them by the maximum possible score for their respective scales prior to the *t*-tests.

supervisors of intermediate-level student teachers revealed that motion geometry is considered less important than other topics in grade 6 mathematics and often is forsaken due to limited instructional time.

Table 2.
Descriptive Statistics for Tests of Prior Knowledge

	M	MD*	SD	Max.	Min.
Drawing test Max. Poss. Score=13 n=113	1.01	0.00	1.58	8	0
Mult. ch. test Max. Poss. Score=11 n=114	2.63	2.00	2.31	8	0

*MD is the abbreviation for "median."

Table 3 gives the descriptive statistics for the number of episodic memories reported both within and across the three lessons. On average, participants reported between 1.5 to 2.0 memories per lesson, a report rate somewhat higher than the 1.1 rate obtained in the add-on lesson[2] of the pilot study. In no lesson did participants report detectably more memories than in any other lesson. Two-tailed *t*-tests for paired observations found no detectable difference in the quantity of memories reported in lessons one and two (t=.35, *d.f.*=110, p<.73), lessons one and three (t=1.19, *d.f.*=112, p<.24), or lessons two and three (t=1.26, *d.f.*=110, p<.21).

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2 See Appendix B for a description of this add-on lesson.

Table 3.
Descriptive Statististics for Episodic Memories

	M	MD	SD	Max.	Min.
Lesson 1 kurtosis=-.012 skew=.814 Sum=190 n=118	1.61	1.00	1.53	6	0
Lesson 2 kurtosis=-.275 skew=.535 Sum=186 n=113	1.65	2.00	1.26	5	0
Lesson 3 kurtosis=3.393[3] skew=1.367 Sum=208 n=116	1.79	2.00	1.45	8	0
All Lessons kurtosis=-.525 skew=.388 Sum=552 n=109	5.06	5.00	3.28	14	0

Factor Analyses of the SRL and IDQ

Appropriateness of the factor model. All calculations indicated that the factor model was appropriate for both the SRL and IDQ data. The average minimum correlation[4] was .37

[3] For data on kurtosis and skew, only this kurtosis is particularly large. Stevens (1986) notes that in distributions that are leptokurtic, the actual alpha is less than the nominal alpha. For such distributions, actual power exceeds nominal power.

[4] Factor analysis procedures are inappropriate if correlations among items, on average, tend to be small (i.e., no discernible factors present). To assess whether the correlations between items were in fact small, the correlations between a given item and all other items were scanned. The lowest correlation in this set of correlations was noted. After correlations for all items had been examined, an "average minimum correlation" was calculated

(*s.d.* .10) for the SRL and .38 (*s.d.* .09) for the IDQ. If the correlations between variables are small, it is unlikely that they share common factors; however, this does not appear to be the case for these data.

Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy were also in the acceptable middling range (Kaiser, 1974) for both measures. The KMO was .76 for the SRL and .70 for the IDQ. Finally, anti-image correlations were small for both SRL and IDQ data and, as such, allowed for factor analyses. For the SRL, 24.2% of anti-image correlations were greater than .09 while for the IDQ, 16.8% were greater than .09.

Factor extraction. Scree analysis showed a two factor solution to be the best for both measures, the SRL and IDQ. For the SRL, the two factors derived from the analysis had eigenvalues of 4.482 and 1.928. Though there were 6 other eigenvalues greater than 1.000 (ranging from 1.302 to 1.072), these formed the scree of the plot and were therefore not considered of major importance. For the IDQ, the two factors had eigenvalues of 5.267 and 3.170. For these data there were 8 other eigenvalues greater than 1.000 (ranging from 1.925 to 1.011); but again, these factors formed the scree of the plot and were not extracted for further analysis.

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for these "lowest correlations" for items in both the SRL and IDQ data.

Rotation. Varimax rotation of a solution constrained to two factors following principal axis factoring produced the best discrimination among items loading on the two factors for both SRL and IDQ data. (See Appendix V for SRL factor loadings; Appendix W for IDQ factor loadings.)

SRL and IDQ Subscale Construction

Following Paivio and Harshman's (1983) factor analysis procedures, the higher of the two factor loadings for both SRL and IDQ data determined the subscale in which an item was included, so long as the factor loading reached a minimum of .30. Items where neither factor loading reached this cut-off were not used for subscale analyses. As a result, the subscales created for the SRL had 9 items each, while the two created for the IDQ had 14 and 11 items. (Boldened items in Appendices U and V show factor loadings used to determine subscale construction.)

Tests of reliability. A series of three reliability analyses were performed on SRL and IDQ data. Cronbach's alphas were calculated for each subscale identified in the factor analysis and for total scale scores. SRL subscales had alphas of .75 and .59. Cronbach's alpha for the SRL total scale score was .79. IDQ subscales had standardized alphas of .80 each, while the IDQ total scale was .83.

SRL. It was decided that subscales on the SRL would not be used in further data analysis procedures. Alphas for these subscales were lower than the total scale standardized alpha. These results corroborate Howard's (1989) Guttman reliability analyses of her SRL data.[5]

It should be noted, however, that Cronbach's alpha is expected to diminish when scale length is shortened. Another reason for using the SRL total scale score in the present data analysis over individual subscale scores was mentioned in Chapther Three. Howard-Rose and Winne's (in press) validity checks and concern about small-grain cognitive process analysis put into question the grain-level appropriate for any investigation of metacognitive self-regulation. Though Howard-Rose and Winne recommended continued assessment of two metacognitive processes, acquisition and transformation, the low alpha on one of the subscales in the present data and the high alpha for the SRL total score suggested that the latter be used in other data analysis as a global measure of metacognitive self-regulation activity.

IDQ. It was decided that subscales of the IDQ would be used in other analyses. Factor extraction procedures on IDQ data in the present study corroborated Specht's two factor solution. Similar to Specht, only 25 of the original 30

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[5] As mentioned in Chapter Three, Howard reports a .84 Guttman reliability for the 13 items of the acquisition scale, a .48 reliability for the 7 items on the transformation scale, and a .91 overall reliability for the total scale.

items on the IDQ in this study were included in subscale construction but, as described previously, items included in subscales were not identical to those included by Specht. Asterisked items in Appendix V indicate items that were included in both Specht's work and in this work in the same verbal and imaginal subscales.

In addition, standardized alphas were high for the two subscales created from the two factor solution and were virtually equal to the total scale alpha. As well, the Pearson _r_ of .274 (n=109, p<.01) for the two subscales was not large.

Descriptive Statistics for SRL Total, IDQ Subscale, IDQ Overall, and GPA Scores

Table 4 provides the descriptive statistics for measures, aside from quantity of episodic memories reported, that were used to investigate the individual difference hypotheses. No comparable data exist on the use of the SRL with a grade 6 population. Both Corno et al. (1982) and Howard-Rose and Winne (in press) used the measure with high school students. Despite a few differences in IDQ verbal and imaginal subscale construction, findings for the IDQ in the present study support Specht's (1992) findings with a pool of 209 grade 6 students in central Canada. Specht found that, on average, participants scored higher on the imaginal scale (M=8.88) than on the verbal scale (M=7.12).

Though not quite as striking, similar results were found in the present study. The mean of the imaginal scale scores was 7.79 whereas it was 7.16 for the verbal subscale. Two-tailed t-tests for paired observations showed this difference to be detectable (t=6.32, d.f.=108, p<.01). Specht's IDQ overall mean of 16.00 was 0.97 higher than the mean of 15.03 in the present data. Strength of mental representation appeared somewhat greater in her sample than in the present one.

GPA data are mildly surprising. The average student GPA was 2.63, (C+ in terms of a letter grade). This mean GPA is only .07 below the B- letter grade equivalent. Perhaps this high[6] mean GPA is a result of high grading practices in schools; however, it is more likely that the reason for such a high mean for participants in this study is that students in three of the five experimental classrooms came from schools located in a fairly affluent suburban area. It may be that students from these classrooms come from homes where schools and education receive much support, and where there is substantial 'press' for achievement.

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6 A practicing grade six classroom teacher as well as an elementary school psychologist both reported that, on average, grade six students achieve a 2.00 GPA (C in terms of a letter grade).

Table 4.
Descriptive Statistics for Individual Difference Variables.

	M	MD	SD	Max.	Min.
SRL Total n=118 Max. Poss. Score=80	50.84	50.50	8.29	71	26
IDQ Verbal n=113 Max. Poss. Score=14	7.16	7.00	3.62	14	0
IDQ Imaginal n=115 Max. Poss. Score=11	7.79	8.00	2.86	11	0
IDQ Overall n=109 Max. Poss. Score=25	15.03	15.00	5.25	25	3
GPA n=112 Max. Poss. Score=4.33	2.63	2.50	.75	4.00	1.25

Descriptive Statistics for Lesson Quizzes

Table 5 reports the mean scores for each of the three quizzes and the mean total score for all three quizzes. Two-tailed t-tests for paired observations between means showed that students performed detectably better on quizzes for lessons two and three, when compared with lesson one (t=10.72, d.f.=110, p<.01; t=7.65, d.f.=112; p<.01), and better on lesson two when compared with lesson three (t=5.57, d.f.=111, p<.01). In other words, students performed best on the lesson two quiz and worst on the lesson one quiz. It can be concluded that the degree to which learning objectives were achieved was detectably different across the three lessons.

Data from both tests of prior knowledge were combined[7] as were data from all three post-lesson quizzes. A two-tailed *t*-test for paired observations between means revealed that students performed detectably better on post-lesson quizzes than on tests of prior knowledge (t=21.52, d.f.=102, p<.01). In other words, it appears that students were detectably more knowledgeable with respect to intended learning outcomes following instruction than before it.

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[7] To combine data on tests of prior knowledge, first the two tests of prior knowledge were converted to a common scale. Then the mean for the two common scale prior knowledge scores was obtained. A similar procedure was followed for scores on the post-lesson quizzes. First, quiz scores were converted to the same common scale used for the tests of prior knowledge. Then the mean for all three common scale post-lesson quiz scores was calculated. Finally, the *t*-tests for paired observations was calculated for the average common scale prior knowledge and quiz scores.

Table 5.
Average and Total Quiz Scores Immediately After Experimental Lessons

	M	MD	SD	Max.	Min.
Lesson 1 n=117 Max. Poss. Score=10	4.32	4.00	3.11	10	0
Lesson 2 n=113 Max. Poss. Score=10	7.52	8.00	2.88	10	0
Lesson 3 n=116 Max. Poss. Score=11	6.63	7.00	3.35	11	0
All Lessons n=109 Max. Poss. Score=31	18.31	18.00	7.60	31	0

Tests of Individual Difference Hypotheses

Part correlations derived from regression analysis procedures were used to test the two individual difference hypotheses, namely: a) whether students with both strong verbal and imaginal mental representation habits would report more memories of instructional events than students with other combinations of these habits; and b) whether students who report extensive metacognitive self-regulation of learning in math lessons are likely to report more remembered instructional events than those who report less self-regulation.

In order to investigate these hypotheses, first, part correlations were calculated to determine the unique relationship between SRL total scores and the quantity of reports of episodic memory. The same was done to determine the unique relationship between the IDQ overall scores and the quantity of episodic memories reported. GPA was included in the calculation of these part correlations to determine whether SRL and IDQ overall scores correlated detectably more with reports of episodic memories than a standard measure of prior achievement.[8]

Table 6 provides the results of these calculations. No part correlation between the IDQ overall score and the outcome measure (with both GPA and SRL total scores partialled out) reached a level of detectability. In two of the three lessons, as well as in the cross-lesson analysis, part correlations between SRL scores and episodic memory

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[8] Pearson r correlations with p-levels calculated for 2-tailed significance were computed among all variables. These correlations appear in Appendix X. Almost all Pearson r correlations between GPA and other variables were detectable. GPA was detectably correlated with IDQ overall (r=.296, n=100, p<.01), memories for lesson one (r=.494, n=112, p<.01), memories for lesson two (r=.245, n=112, p<.01), memories for lesson three (r=.270, n=112, p<.01), memories for all lessons (r=.435, n=112, p<.01), lesson one quiz results (r=.482, n=109, p<.01), lesson two quiz results (r=.500, n=105, p<.01), lesson three quiz results (r=.556, n=107, p<.01), and quiz results for all lessons (r=.631, n=100, p<.01). The only variable used in testing the individual difference hypotheses which did not have a detectable Pearson r correlation with GPA was the SRL Total Score (r=-.079, n=108, p=.415). Given the detectable correlations between GPA and most other variables, a decision was made to calculate part correlation coefficients between the predictor variables used to test the individual difference hypotheses and number of episodic memories (outcome variable). In that way, linear effects of GPA would be removed from both the predictor variables.

count did reach detectable levels. In lesson one, the part correlation was .28. In lesson three, it was .22, and across all three lessons it was .26. All part correlations between GPA and episodic memory count (with IDQ overall and SRL total scores partialled out) were detectable. In lesson one this part correlation was .49, in lesson two .20, in lesson three .28, and across lessons it was .42.

Within-lesson and across-lesson analyses provide the same profile of results, with only one small exception in lesson two. The profile is illustrative of the fact that the relationship between past academic achievement and number of episodic memories reported is the strongest of the three relationships examined. Following the categorization scheme for effect sizes proposed by Cohen[9] there is generally a negligible, undetectable, negative relationship between IDQ overall scores and reports of episodic memories. On the other hand, except in three instances, there is a small, detectable, positive relationship between both SRL total scores and GPA, and memory reports. In lesson two the

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[9] Cohen (1977) attempted to address the issue of interpreting effect size estimates. He suggested some general definitions for negligible, small, medium, and large effect sizes in the social sciences. Cohen labelled an effect size negligible if r was less than .10. He considered an r between .10 and .29 as small, one between .30 and .49 as medium, and one greater than .50 as large. Cohen also noted that many effects sought in psychological research are likely to be small because of the attenuation in validity of the measures employed and the subtlety of the issue frequently involved.

positive relationship between SRL total scores and memory report is negligible and undetectable. In lesson one and across all lessons, the positive relationship between GPA and memory report is medium.

These findings do not support the first hypothesis. There were no detectable relationships between overall strength of verbal and imaginal mental representation, and quantity of episodic memories reported. The findings do, however, support the second hypothesis. There appears to be a small, positive relationship between reports of metacognitive self-regulation and episodic memories. This is so even when the linear effects of past achievement on episodic memories are removed.

Table 6.
Part Correlations for IDQ Overall, SRL Total and GPA with Quantity of Episodic Memories

	IDQ Sum	SRL	GPA
Lesson 1			
r	-.09	**.28**	**.49**
n	96	96	96
sig. of t	.28	<.001	<.001
Lesson 2			
r	-.06	.09	**.20**
n	96	96	96
sig. of t	.55	.35	.05
Lesson 3			
r	-.06	**.22**	**.28**
n	96	96	96
sig. of t	.53	.03	.01
All Lessons			
r	-.09	**.26**	**.42**
n	96	96	96
sig. of t	.32	<.001	<.001

Part correlations with a significance of t > .05 are boldened.
R Square between predictor and outcome variables was .30 in lesson 1, .04 in lesson 2, .11 in lesson 3, and .23 across all 3 lessons. Low R Squares in two of the three lessons indicate that interpretations should be read with caution.

Why is it that the present data do not support the contention that strength of mental representation is positively related to report of episodic memories, but do support a relationship between metacognitive self-regulation and such reports? Are these findings generalizable or valid only for these data? Why is it that the part correlation of GPA with reports of memories figured so prominently in the first lesson and across all three lessons? Why is it that the relationship between reports of metacognitive self-regulation and episodic memories were negligible and undetectable in the second lesson while it was small and detectable everywhere else?

These questions will be addressed in Chapter Five, where factors that probably affect individual lesson difficulty, as well as methodological and conceptual issues will be discussed. Before moving on to that discussion, however, results pertaining to the mediational hypotheses and exploratory investigations are presented.

Tests of the Mediational Hypotheses

Tables in Appendix Y summarize the data used to test whether a student who recalls particular instructional episodes is more likely to possess greater content knowledge associated with those episodes than students not recalling those episodes. As stated in Chapter Three, quiz items were grouped according to the learning objectives they were used to assess. Students were then assigned subtest scores (ordinate) based on their performance on the cluster of posttest items addressing each learning objective. Content in lesson transcripts was then evaluated and coded in terms of the learning objective addressed. One frequency plot was created for each learning objective and one plot was created for content related to the combination of all learning objectives within lessons. Scores on the abscissa indicate the number of events, related to a learning objective (or combination of learning objectives) that students remembered.

Andrews, Klem, Davidson, O'Malley, and Rodgers (1981) recommend the use of the Pearson chi-square to measure association between two such nominal variables.[10] However, Siegel (1956) points out that in contingency tables with degrees of freedom greater than 1, the chi-square test should only be used if fewer than 20 per cent of the cells have an expected frequency of less than 5 and if no cell has an expected frequency of less than 1. None of the contigency tables with degrees of freedom larger than 1 met both these conditions. A chi-square analysis was performed on the one 2 x 2 table (frequency plot of number of events reported and number of items correct related to turning a triangle, lesson 3). The chi-square of .097 for this table did not indicate a detectable association between variables on the abscissa and ordinate.

As the chi-square statistic could not be computed for the other 11 contingency tables, a visual scanning procedure was employed in order to detect any evidence that students who recalled particular instructional episodes are more

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[10] Andrews, Klem, Davidson, O'Malley, and Rodgers (1981) suggest that a Pearson chi-square analysis is appropriate in examinations of association between two nominal variables when: a) at least one is not a 2-point scale, b) no distinction between the dependent and independent variable is being made, and c) the statistic is to be based on the number of cases in each category.

likely to know more content associated with those episodes. A positive relationship between number of events related to specific declarative/procedural knowledge that a student reported, and the number of quiz items testing that knowledge, would have been indicated by trends of frequency counts increasing steadily from the lower left quadrant of each plot to the upper right quadrant. None of the plots show this trend. The hypothesis, therefore, remains unsupported. Possible reasons for this finding will be discussed in Chapter Five. The reader is reminded that the eye is easily fooled and interpretations based on visual scanning ought to be read with caution.

The Relationship between Quantity of Reported Episodes and Performance on Quizzes

Table 7 provides the part correlation coefficients calculated to test the hypothesis that if students reported more instructional episodes, they were more likely to possess greater declarative/procedural knowledge of lesson content than students reporting fewer instructional episodes. In all instances, once linear effects of GPA on quiz scores had been removed, part correlations between memory report and quiz scores were generally undetectable.[11]

[11] As already mentioned, all Pearson r correlations between GPA and quiz results both within and across lessons were detectable (Appendix X). Part correlations between report counts of episodic memories and quiz results were calculated to determine the relationships between these two variables once the linear effects of GPA had been partialled out.

On the other hand, both within and across lessons, part correlations between GPA and quiz scores with episodic memory report count partialled out, were detectable. In lessons one and two, part correlations of .36 and .45 respectively, were medium in size, whereas in lesson three and across lessons, part correlations of .52 for both were large. GPA was clearly more substantially and detectably correlated with quiz scores than was report of episodic memories. Again, these findings will be discussed in Chapter Five.

Table 7
Part Correlations for Quantity of Reported Episodes and GPA with Quiz Scores

	Episodic Memories	GPA
Lesson 1		
r	.13	.36
sig. of t	.13	<.001
n	105	105
Lesson 2		
r	.05	.45
sig. of t	.56	<.001
n	101	101
Lesson 3		
r	.05	.52
sig. of t	.52	<.001
n	104	104
All Lessons		
r	.07	.52
sig. of t	.36	<.001
n	96	96

R Square between predictor and outcome variables was .25 in lesson 1, .25 in lesson 2, .31 in lesson 3 and .40 across the three lessons.

Exploratory Question

The exploratory question was posed in order to find out whether it was possible to learn anything about the kinds of classroom events that children report remembering. A card sort task was used to consider this question. From the 584 episodic memories reported, 265 cards were created. These cards were categorized and the categorization of each card was discussed with a research assistant. In the end, the following categories of events that students reported from the three motion geometry lessons were determined:

1. lesson materials or aids, including their distribution or use (59 cards, 22.3% of total);
2. content related to learning objectives (42 cards, 15.8% of total);
3. specific attention to others' participation including distribution/collection of materials, assisting teacher, being called to board, requesting information (34 cards, 12.8% of total);
4. own participation in class (32 cards, 12.1% of total);
5. concrete examples illustrative of concept presented (27 cards, 10.2% of total);
6. teacher structuring and pacing of lesson (15 cards, 5.7% of total);
7. other student's (students') error or difficulty, display of difficulty (14 cards, 5.3% of total);
8. teacher providing rememberer with help or individual attention (6 cards, 2.3% of total);
9. teacher error or difficulty (5 cards, 1.9% of total);
10. own error or difficulty (5 cards, 1.9% of total);
11. unclassified (26 cards, 9.8% of total).

It should be noted that card totals and percentages do not necessarily reflect the number of times to which a particular event was referred. Occasionally, one card was written for an event referred to several times by the participants.[12]

Search for a Core Category of Episodic Memories

The list of other factors possibly involved in episodic memory process (see Chapter Five) was applied to each of these major categories. Factors considered (from available data) as possibly core were: stimulus intensity, affective value, novelty, surprise, oddity, and conflict. The roles that stimulus consistency with expectation, interest, and conceptual change might play in episodic memory process were

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[12] The following is a frequency count of the actual number of episodic memories for each category created during the card sort:
1. report of lesson materials or aids including their distribution or use (169 memories, 28.9% of total);
2. report of content related to learning objectives (77 memories, 13.2% of total);
3. report of specific attention to others' participation including distribution/collection of materials, assisting teacher, being called to board, requesting information (85 memories, 14.6% of total);
4. report of own participation in class (44 memories, 7.5% of total);
5. report of concrete examples illustrative of concept presented (61 memories, 10.4% of total);
6. teacher structuring and pacing of lesson (27 memories, 4.6% of total);
7. report of other student's (students') error or difficulty, display of difficulty (32 memories, 5.5% of total);
8. report of teacher providing rememberer with help or individual attention (13 memories, 2.2% of total);
9. report of teacher error or difficulty (25 memories, 4.3% of total);
10. report of own error or difficulty (12 memories, 2.1% of total);
11. unclassified (39 memories, 6.7% of total).

also considered. These attempts to identify a core category underlying <u>all</u> major categories were unsuccessful.

However, a superordinate category described by Hidi (1990) may be at the root of much episodic memory. Hidi suggested that the "energetic" variable, i.e., an umbrella of personal, attitudinal, and motivational factors ought to be considered in present-day attempts to better understand cognition and information processing (including memory processes). More will be said about the superordinate variable in the following chapter.

CHAPTER FIVE: DISCUSSION

Overview

This chapter begins with a brief review of the major findings of the study. Descriptive statistics are interpreted further and particular attention is paid to comparisons with related investigations. This is followed by a discussion of results that speak to the individual difference hypotheses. The interaction between posttest scores, report of episodic memory, and metacognitive self-regulation is highlighted here, and comment about the source and significance of this interaction is offered.

Next, discussion of results from tests of the mediational hypotheses is presented. It is suggested that a future research focus on the mediational effects of largely involuntary attention on semantic memory might prove fruitful. It is also suggested that factors predominant in extant literature on conceptual change might be contemplated in other investigations of episodic memory in classroom teaching and learning.

A rationale for consideration of the energetic variable as possibly driving much of episodic memory performance is then presented.

The question of alternative methodologies appropriate for the exploration of episodic memories is raised again towards the end of the chapter. One particular approach that combines qualitative/quantitative and small n methods, described by Nuthall and Alton-Lee (1991), is delineated. The chapter ends with concluding remarks about a salient finding within the study, and a review of recommendations for future research on episodic memories of students in classrooms.

Review of Major Findings

Once prior achievement, as measured by students' GPAs, was partialled out, results of this study supported only one of the two individual difference hypotheses. A positive, detectable, and generally small correlation was found to exist between participants' reports of metacognitive self-regulation and their reports of episodic memories from lessons. On the other hand, the hypothesis that strength of mental representation was correlated with reports of episodic memories was not affirmed.

Results also did not support either of the mediational hypotheses. No relationship was found between students' reports of episodic memories of particular instructional episodes and performance on quiz items testing content taught during those episodes. Furthermore, once GPA was partialled out, no relationship was found between students' overall reporting of memories from instructional episodes and their performance on quizzes testing the declarative/procedural knowledge, both within and across lessons.

Exploratory investigations revealed ten major categories of memories reported by students. About half of these related to lesson materials, content, and examples. The other half focused on the student's own, peer, or teacher activities, including lesson involvement, display of difficulty or error, and lesson management (usually structuring on the part of the teacher).

Descriptive Statistics

Prior knowledge. Examination of descriptive statistics provided some interesting findings. First, students had only minimal prior knowledge of the motion geometry concepts to be taught in the experimental lessons. The average of their combined scores on both tests of prior knowledge was 16.3%. Hence, it can be assumed that knowledge of the curriculum could not have influenced either of the mental activities or performance on posttests.

Reports of episodic memories. Secondly, students on average reported between 1.5 to 2.0 memories per lesson. This figure is somewhat higher than the 1.1 memories per lesson statistic obtained in the add-on lesson in the pilot study. This may be because students in the main study reviewed how to fill out the EMQ prior to each experimental lesson, whereas students in the pilot learned and practiced the procedures only once. In the main study, counts of mean memory report increased across lessons, a finding possibly attributable to practice effects.

No comparable EMQ data exist with a similar aged population. However, Lapadat, Martin, and Clarkson (1993) did examine high school students' episodic memories from two career guidance videotapes about the career of an auto technician. The mean number of such memories was 3.0 for data aggregated across videotapes. As well, in a study of university students' episodic memories from lectures, Lapadat and Martin (1993) found, on average, that students reported 3.7 memories per lesson. It appears that students in higher grades tend to report more episodic memories from learning events than those in lower grades. This simply may be because older students are better than younger ones, both at cognitively processing the demands of an EMQ and in writing responses.

In neither study do these researchers report the amount of time participants had to fill out their EMQ's; however Lapadat (1993) indicated that in the study of university students, participants generally were given less than the ten minutes afforded students in the present study to complete the memory questionnaires. It seems, therefore, that university students provide more episodic memories in a shorter period of time than grade six students.

<u>SRL findings</u>. No comparable SRL data with a similar aged population exists. However, Corno et al. (1982), in their study of metacognitive self-regulation among high school students in inner city summer school writing and reading classes, provide pre-treatment SRL means from which an overall mean was calculated. This overall mean of 48.75 was lower than that of 50.84 obtained for the grade six students from regular session, suburban classrooms in the present study. Older students grouped specifically for summer school remedial help in reading and writing reported less metacognitive self-regulation than younger ones in a regular classroom. Howard (1989) does not provide data by which an overall SRL pre-treatment mean can be calculated.

<u>IDQ findings</u>. The profile of IDQ scores matched the one obtained by Specht (1992) in her study of a similar aged population in central Canada. Though her IDQ scores were somewhat higher than those obtained here, as in the present study, she found that IDQ imaginal subscale scores were higher than IDQ verbal subscale scores. Means for subscale and IDQ sum scores from both samples were all within one point of each other. Minimal differences among IDQ subscale and sum scores between samples may reflect the small differences in how scales were constructed from factor analysis procedures.

GPA and quiz results. Two other descriptive statistics of note emerged from the data analyses conducted. First, students in this sample appear to have relatively high GPA's, a finding possibly attributable to the middle to upper-middle class socioeconomic status of the families from which at least three-fifths of the participants came. Such a finding limits the generalizability of the results to other populations. Secondly, when results of post-lesson quizzes were compared with tests of prior knowledge, students were detectably more knowledgeable about the intended learning outcomes after instruction than they were before it.[1] Nonetheless, there were detectable differences in amount of procedural/declarative knowledge (as measured in the posttests) evident across individual lessons. For some reason, students displayed detectably more content appropriate knowledge in lesson two than in any other lesson, and detectably less knowledge in lesson one than any other lesson. These differences are now addressed.

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[1] The effect size for the difference between common scale prior knowledge and post-lesson test averages was 2.08. On average, the percentage change from pre- to posttest was 42.4%.

Individual Difference Hypotheses

Inter- and Cross-Lesson Findings

Though inter-lesson differences were not observed in terms of strength of mental representation habits, three facts about SRL, GPA, quiz results, and episodic memory report counts stand out, particularly with regard to the second lesson. First, students performed best on that lesson's quiz. Secondly, lesson two was the only lesson in which the part correlation for SRL and episodic memory report counts was not detectable. Thirdly, in that lesson a small part correlation of .20 was found to exist between GPA and memory report counts, with I.D.Q overall and SRL scores partialled out.

It seems that lesson two was the easiest of the three lessons. For one thing, students were introduced to motion geometry concepts for the first time that year in the first experimental lesson, not in the second one. As well, it was the shortest in length (see Appendix I) and had the fewest intended learning outcomes of the three lessons (see Appendices M and Q). It appears that in this, the easiest lesson, SRL scores were not related to episodic memory report counts whereas GPA scores were.

Lesson one appears to have been the most difficult of the three lessons. In this lesson students were exposed to motion geometry concepts and experimental lesson procedures (including videotaping) for the first time. It was also the longest of the three lessons (see Appendix I). In this, the apparently hardest lesson, detectable part correlations were found between both SRL and GPA scores, and episodic memory report counts. The part correlation between GPA and episodic memory count was medium-sized; the one between SRL and cpisodic memory count was small.

Lesson three was probably the lesson of medium difficulty. Though it did have one more intended learning outcome than the ostensibly hardest lesson, by the time students encountered lesson three content, they had already had some exposure to motion geometry concepts. As well, the length of this lesson was mid-way between that of the hardest and easiest lessons. In this lesson of medium difficulty, part correlations between both SRL and GPA scores, and episodic memory reports were both small and approximately equal.

Two conclusions may be drawn from these observations. First, regardless of lesson difficulty, it appears that the better a student's past academic record, the greater the likelihood s/he will report episodic memories. Such a student may have a generally rich knowledge base and elaborate cognitive structures that enable her/him to encode episodes more readily than other students.

Secondly, there seems to be an interaction between lesson difficulty, report of metacognitive self-regulation, and report of episodic memories. Students who plan, set goals, organize, self-monitor and self-evaluate during difficult lessons are more likely to report episodic memories than less metacognitively sophisticated students.

Memories of good metacognitive self-regulators. What exactly might be happening to cause good metacognitive self-regulators to report more episodic memories in difficult lessons than in easy ones? The argument about to be presented will be embellished later in the chapter when other factors that may be related to episodic memories of classroom instruction are described. The basic argument is this: During difficult lessons, awareness of obstacles to knowledge construction is registered by metacognitive self-regulators. Such awareness may be particularly apparent to better self-regulators who notice when they are having difficulty learning and realize that they have to overcome this difficulty. Heightened attention to difficult learning events may mark such events as salient episodic memories for these learners.

The same may not be true for individuals who report less metacognitive self-regulation. Such individuals may remain passive in the face of difficult lesson content and not attend to the difficulty, nor employ strategies to overcome it. For these learners, lack of heightened attention to these situations may produce few salient episodic memories of them.

Shortcomings of SRL findings. Two concerns with the SRL findings remain. One relates to the validity of the scale itself, the other pertains to the lower or undetectable part correlations between SRL scores and episodic memory report counts in easier lessons. First, concern over the validity and reliability of subscales comprising acquisition and transformation processes within the SRL measure has already been stated (Howard-Rose and Winne, in press). A total scale score was used in the present analysis, in keeping with Howard-Rose and Winne's recommendation to focus on large-grain metacognitive analysis, and in response to factor analyses and tests of scale reliability. The total scale score was found to be more reliable than either subscale score obtained through factor analysis procedures and detectably more reliable than one of the subscale scores for the SRL data in the present study. Still, concern over the meaning of the total scale has been expressed in various quarters (Corno, 1992; Martin, 1992).[2] In fact, such a global measure of metacognitive activity may be measuring many things.

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[2] During a brief consultation at the 1992 Annual Meeting of the American Educational Research Association, Corno questioned the usefulness of the SRL in identifying microscopic metacognitive processes. As well, Martin

Secondly, it seems necessary to consider why it is that the relationship between metacognitive self-regulation and episodic memory report counts is less prominent in easier lessons than in harder ones, yet students still report episodic memories from the former. In fact, they reported as many memories from easier lessons as from the hardest one. A focus on the voluntary, intentional, and deliberate nature of metacognition in the pursuit of explicating episodic memory reports may be telling only part of the story.

The role of spontaneous attention. Hidi (1990) describes another kind of attention that may be at work with respect to these results. She remarks that the construct of spontaneous attention, though not in vogue, is not new and cites Dewey (1913), Berlyne (1960) and Kahneman (1973) in an argument distinguishing the governance of voluntary and involuntary attention. In particular, Kahneman points out that momentary intentions rule voluntary attention, whereas enduring dispositions direct involuntary attention. Kahneman suggests, for example, that novel objects, ideas, and events, objects in sudden motion, and conversation in which one's own name is mentioned, are likely to draw spontaneous attention. It may be that easier lessons demand

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pointed out that the subscales created through factor analysis procedures could not be readily classified in terms of metacognitive self-regulation processes assessed.

less voluntary attention, leaving the stimulus selection arena wide open to involuntary attention. Aspects of stimulus selection during spontaneous attention, including those described by Kahneman, that have potential bearing on the report of episodic memories will be discussed shortly.

IDQ. The IDQ findings corroborate some of the findings of Lapadat and Martin (1993) in their study of university students' episodic memories from lectures. In that study, Lapadat and Martin described strength of mental representation habits in terms of an interaction score that was the product of scores on the original IDQ verbal and imaginal subscales. They found no correlation between this interaction score and any of their memory measures.

Mediational Hypotheses

Several reasons were presented in Chapter One as to why it is important to examine the relationship between reports of episodic memories with semantic memories of lessons as measured by quiz scores. First, it was pointed out that little has been done to examine how such memories might affect learning in natural classroom contexts. Secondly, a primary focus on human memory for isolated facts has ignored the organizing structures in which those facts are embedded. Researchers (Brewer, 1986; Lapadat and Martin, 1993; Robinson and Swanson, 1990) are now theorizing about the role episodic memories may play in self-definition, a definition that is intimately linked to the organization of experience into meaningful patterns. Thirdly, it was noted that some researchers (e.g., Cohen, 1989) have been quite specific in arguing for an examination of the role episodic memories might play in improving learning abilities such as problem solving. Finally, it was pointed out that a few initial attempts (Lapadat, Martin, & Clarkson, 1993; Lapadat & Martin, 1993; Martin, Cummings, & Hallberg, 1992; Martin & Stelmaczonek, 1988; Nuthall & Alton-Lee, 1982, 1991) to research such memories in learning environments (be they classroom or otherwise), have met with some success.

Though the rationale for conducting such an investigation was sound, the lack of findings supporting the mediational hypotheses suggest that perhaps commentators such as Estes are right. Estes (1989, p. 5) states that "most learning that occurs in educational settings has to do with semantic memory and has a cumulative character as distinguished from the memory for discrete events that characterizes episodic memory."

Nonetheless, it may be premature to discard the mediational hypotheses based on a single, large sample study. Smaller scale qualitative studies that take better account of contextual variables (c.f., Nuthall & Alton-Lee, 1991) may uncover individual differences in relationships between episodic and semantic memories that did not surface here. On the other hand, future research efforts may also take advantage of path analysis procedures appropriate for large sample studies in attempts to uncover important attitudinal, personal, or motivational variables that mediate the relationship between episodic and semantic memories.

The idea of the mediating role such variables might play may be illustrated by a story recounted to me by my friend, Bruce. Over dinner one evening, Bruce recounted that, despite his degree in Russian and music from the University of California, Berkeley, he had not always been a successful student. In fact, he had a slow start in his elementary schooling. However, an important event occurred while he was in grade three that transformed him from an underachiever to a highly successful student.

It happened during Miss Tilo's science lesson on how a liquid can solidify. During the first week of school that year, Miss Tilo had all the children in her class pass around a container of thick cream. Everyone got a chance to shake the container. Everyone was included. Everyone contributed to the magic of the metamorphosis. Something that was liquid became a jar of delicious whipping cream.

Bruce apparently responded very favorably to that lesson. He couldn't quite put into words how the lesson had affected him, but I got the impression that for the first time in his school career, Bruce had become extremely excited about a bit of classroom learning.

Clearly, this episodic memory is a strong one for Bruce. For one thing, it has lasted almost 40 years. For another, Bruce describes it as an important marker in his life, the turning point when school suddenly became interesting and even exciting. In the end, Bruce did not go on to become a scientist. He did, however, become a teacher. Who knows the extent to which this eye-opening experience in Miss Tilo's class affected Bruce's subsequent vocational choice?

It seems to me that an interesting investigation might be of the many ways anecdotes like the one Bruce recounted affect people's learning and, ultimately, their lives. Perhaps what is significant in episodic memories is not a direct relationship they may have with procedural/declarative knowledge. Their significance may lie in how they influence personal, attitudinal, and motivational variables, variables which in turn mediate semantic memories in classrooms.

Other Factors

Hidi (1990) distinguishes between voluntary selective and involuntary attention. Factors that fit in both categories will be offered as clues to better understanding the role episodic memories may play in classroom learning.

Interpretation of findings from the exploratory investigation using these factors will follow this discussion.

Several prominent researchers have recognized the restricted nature of a purely cognitive focus in building understandings about learning and memory (e.g., Bereiter, 1985, 1990; Berlyne, 1960; Brown, Collins, & Duguid, 1989; Csikszentmihalyi, 1975, 1988; Larson, 1988; Piaget, 1981; Pintrich, Marx, & Boyle, in press; van Dijk & Kintsch, 1983). These researchers have called for a more broadly based conception of cognition and information processing, which Hidi (1990) refers to as "energetic" factors, i.e., personal, attitudinal, motivational ones, to complement the rational and structural constructs predominant in cognitive psychology.

What follows is a description of a range of these variables cited by memory and learning theorists and researchers as deserving of further attention.

<u>Stimulus Selection</u>

Using traditional laboratory studies to support his argument, Berlyne (1960) lists nine collative factors that may affect stimulus selection, the stimuli to which individuals attend and which they are most likely to remember. The collative factors he describes include stimulus intensity, serial-position, novelty, surprise, oddity, and conflict. As well, he suggests that individuals' motivational states, dispositions toward, and understandings of memory task requirements are also important determinants of remembering.

Affect

Bower (1981) posits an associative network theory in which he argues that emotion serves as a memory unit that can enter into associations with coincident events. Activation of this emotion unit aids retrieval of events associated with it, and primes emotional themes for use in free association, fantasies, and perceptual categorization.

Consistency of Information with Expectation

Results of the Pezdek, Whetstone, Reynolds, Askari, and Dougherty (1989) study of undergraduate students' recall of items in two different settings suggest that information inconsistent with expectation is more likely to be recalled than information consistent with expectation.

Schema Relevance

In their discussion, Pezdek et al. (1989) differentiate their findings on consistency with expectation from those on schema relevance. Firstly, they point out that both Maki (1987) and Mandler (1984) have argued that consistency with expectation and schema relevance[3] are orthogonal qualities.

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3 Schema relevance refers to the relatedness of new information to knowledge stored in memory which is organised as a set of knowledge structures, or schemas. Schemas

They then go on to cite Goodman's (1980) research in which schema relevance was manipulated. In that study, researchers found that high-relevance items were better recalled than low-relevance ones, but low-relevance items were better recognized.

Interest

Following Bartlett (1932), Hidi (1990) stresses the importance interest plays in remembering. Hidi focuses her attention on two factors that contribute to interest. One is very similar to Berlyne's collative variables of novelty, surprisingness, and unexpected events and/or ideas. The other is more content bound and includes universally interesting concepts, human activity, intensity factors, and life themes.

Physiological Responses

Hidi also references numerous studies in which collative variables, such as interest (or lack thereof), are associated with a variety of physiological responses. It seems, for example, that interest may affect electrical activity in speech musculature (Sokolov, 1972), as well as pupil dilation and heart rate (Libby, Lacey, & Lacey, 1973). Berlyne (1960, 1974) went so far as to suggest that collative variables such as interest may not actually affect

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represent general knowledge about objects, situations, events, or actions acquired from past experience.

behaviours such as recall directly, but may do so only indirectly through physiological arousal.

Conceptual Change

The call for elaboration of standard cognitive psychology research practice is being heard in other quarters. Of note, Pintrich, Marx, and Boyle (in press) have called for an understanding of conceptual change that includes personal, motivational, and contextual variables. Though these latter day constructivists do not explicitly address the role that memory, and specifically, episodic memory plays in learning or conceptual change, they highlight a number of personal and contextual factors they feel will extend understandings of knowledge construction processes. These same processes may be implicated in episodic memory performance.

The factors delineated by these researchers appear in Table 19.

Table 19
Classrcom Contextual, Motivational, and Cognitive Factors Related to the Process of Conceptual Change[4]

Classroom Contextual Factors
Task Structures
Authority Structures
Evaluation Structures
Classroom Management
Teacher Modeling
Teacher Scaffolding

Motivational Factors
Mastery Goals
Epistemic Beliefs
Personal Interest
Utility Value
Importance
Self-efficacy
Control Beliefs

Cognitive Factors
Selective Attention
Activation of Prior Knowledge
Deeper Processing
Problem Finding and Solving
Metacognitive Evaluation and Control
Volitional Control and Regulation

Conditions for Conceptual Change
Dissatisfaction
Intelligibility
Plausibility
Fruitfulness

Exploratory Investigation

There were three major thrusts in this study. The first addressed the relationship between two mental activities and reports of episodic memories in classroom lessons. The second thrust focused on how such episodic

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4 In: Pintrich, P. R., Marx, R. W., and Boyle, R. (1993). Beyond "cold" conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. Review of Educational Research. Permission for citation and quote was obtained from the authors.

memories mediate classroom learning. Finally, an exploratory question was posed to understand better the kind of episodic memories children in grade six motion geometry lessons report.

The "Energetic" Variable's Role in Episodic Memory Performance

Hidi (1990) points out that the umbrella term, energetic variable, derives from Piaget's (1981) theorizing. Piaget emphasized that all behaviour has cognitive as well as positively and negatively valenced affective components. He argued that intellectual functioning depends on the energizing role that affectivity (regardless of valence) plays, and he used the term "energetic" to describe this dimension of the human information processing system. It may be that the energetic variable underlies several, if not all, of the major categories that were identified in the search for a core, superordinate category.

For example, it may be that personal factors (in that rememberers were referencing themselves or others in their memories) were implicated in seven of the ten classifiable major categories. As well, the energetic variable may have been at play in the three other major categories. For example, students often made reference to lesson materials. One such lesson material which they frequently remembered was the posttest. One can guess that most students do not like such tests. Their reports of the test may be related to their attitude toward them. Another major category, student report of concrete examples illustrative of concepts presented, may also be rooted in a core energetic variable. Most of these concrete examples were unusual and were drawn from out-of-school personal experiences students in grade six are likely to have (e.g., skateboarding, watching circus tightrope walkers, making snow angels).

The energetic variable may even underlie many reports of content related to learning objectives, the third "non-personal" major category. For example, a memory such as, "You told us what people usually do wrong when sliding images," may have been reported by rememberers fearful of making mistakes. "When we were working on the diamond you said that we were having difficulties because we were forgetting to extend the arrow," may also have been reported due to the energetic variable. Some rememberers may be motivated not to forget important detail necessary for mastery of lesson content.

The label "energetic" variable is conceivably a very good one. It can be assumed that some factor (perhaps personal, attitudinal, or motivational) is energizing rememberers to recall and report specific episodes. Incontrovertible evidence supporting this variable as the core category of all episodic memories reported could not be found in the present study. Still, it is a category deserving attention in future studies of episodic memories in classrooms.

The Question of Methodology

As already mentioned in discussions of findings from both individual difference and mediational hypotheses, qualitative analyses with a small samples or n=1 might be better at identifying the episodic memories individual children have of classroom lessons, why such memories are encoded and retrieved, and how such memories are implicated in knowledge construction related to curriculum content. This recommendation was made, for example, by Lapadat and Martin in their report of university students' episodic memories from lectures. These researchers commented that

> the usual advantage of quantitative analysis, generalizability to similar students studying similar content, might be outweighed by the disadvantage of not being able to capture the highly complex and idiosyncratic personal nature of individual participants' episodic memories" (Lapadat & Martin, 1993, p. 26).

A methodology akin to the one described by Nuthall and Alton-Lee (1991) may better determine the role individuals' episodic memories play in learning from classroom instruction. These researchers provide a combined quantitative/qualitative analysis of the multi-layered classroom experience of four pupils in an effort to predict the knowledge these students will construct from classroom instruction.

To track their participants carefully and in extremely fine detail, they assigned one observer to each. Observers recorded the public and private behaviours and utterances of the selected case pupils, including their interaction with the stream of lesson information which was transcribed and coded in quarter-minute intervals. Prior knowledge and knowledge transformation during the course of the four days of the experimental study were assessed through a pre-test and regular interviews with the participants. Information from these assessments was used to supplement and confirm findings from the analyses of pupils' interaction with the stream of lesson information. Nuthall and Alton-Lee constructed a set of 20 evaluation rules to predict the information that would be stored in long-term memory. They also included a tagging procedure whereby pupil interactions with the stream of lesson information were marked as either apparently content focused or not. Their predictions were 83.2% accurate as measured by the posttest.

The comprehensive methodology used by Nuthall and Alton-Lee would be one appropriate for further exploration of the questions about episodic memory posed in the present investigation. To possibly increase convergent validity for measures of lesson memories, the only addition to such a methodology might be that of a written episodic memories questionnaire like the one used in this thesis.

What is remarkable about Nuthall and Alton-Lee's work is their very thorough and detailed tracking of overt behaviours as well as their apparently accurate estimates of covert cognitive process. Nonetheless, these researchers admit to shortcomings in their experimental procedures. Most significantly, their analyses do not look at how pupils come to be exposed to information or engage in relevant activities. Their research does not address the stimulus selection issue. As thorough as the analyses of Nuthall and Alton-Lee are, it appears that to understand better how it is that children come to attend to particular bits of stimulus requires even more investigation. It would seem that descriptions of classroom events and learners in terms that encompass the wide range of factors that might affect stimulus selection and memory, as described by Berlyne (1960), Hidi (1990), and Pintrich, Marx, and Boyle (in press), are called for.

Concluding Remarks

This thesis began with several questions about episodic memories in classrooms. One addressed mental activities that may affect the retrieval of episodic memories. Another pertained to the impact such memories may have on semantic memories. The final one focused on the implications of findings from research on episodic memories for teacher practice and, ultimately, teacher effectiveness. At the outset, a broad terrain was described to guide the research effort. At this juncture, the limited scope of detectable findings requires an emphasis on recommendations for alternative episodic memory research methodologies over suggestions for teacher practice based on the significance of findings.

The one salient detectable finding from data analysis procedures was that students who metacognitively self-regulate, particularly during more difficult lessons, report more episodic memories of such lessons than less metacognitively sophisticated students. This is an interesting finding and has several implications. Given that the link between episodic and semantic memories was not made in this study, it would be premature to recommend to teachers that, at least for purposes of promoting episodic (and, ultimately, semantic) memories, they instruct students in metacognitive self-regulation strategies.

Certain research efforts are indicated. First, an attempt ought to be made to replicate the one salient, detectable, finding. Lesson difficulty could be manipulated in several ways to potentiate its effects. Experimental lessons of short, medium, and long duration could be employed. Lessons could be taught in which participants had varying degrees of prior curricular knowledge of the content. Differences among the number of learning objectives per lesson could be enhanced. Subject matter traditionally viewed as easy could be compared with more difficult subject matter. Finally, lessons could also differ more systematically in the use of aids, particularly in subject areas where it has been shown that the use of aids enhances learning (c.f., Raphael & Wahlstrom, 1989).

Another possible change in a replication would be to the choice of instrument used to measure metacognitive self-regulation. Howard-Rose and Winne (in press) argued in favour of the view of metacognitive self-regulation as a disposition with large-grain components; however, findings from present factor analysis and tests of reliability indicated that data analysis using the total scale score was appropriate in this study. A total scale score was employed despite concerns over the meaningfulness of such a score.

Other measures of metacognitive self-regulation in mathematics do exist. For example, in a study of students' metacognition in mathematical problem solving, Wong (1989) reports the use of a valid and reliable instrument[5] that was originally developed by Chang (1988, 1989). Wong classified items on the instrument into four large-grain metacognitive components: orientation, organization, execution, and

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[5] Wong (1989) does not provide psychometric information for the instrument in his report.

verification. Analysis of memory reports based on psychometrically valid and reliable metacognitive self-regulation components such as these might provide a finer (but not necessarily small-grain) analysis of the relationship between self-regulation and episodic memories.

Another important avenue for future research would be to examine more closely the role collative variables play in episodic memory performance. Nuthall and Alton-Lee (1991) have recommended that stimulus selection be more thoroughly investigated in future studies of how episodic memories mediate classroom learning. Two methodologies appear appropriate. Path analysis procedures could be used with a large subject population in order to identify variables impinging on semantic memory.

As well, a more qualitative approach (a la Nuthall and Alton-Lee) could be used with a small participant population. Interview data could be gathered to identify individual differences in collative variables, and the effects of these differences on classroom learning. The same approach could be used to test the heretofore unsubstantiated relationship between strength of mental representation and episodic memory.

Given these suggestions for alternative methodological approaches, it would seem premature to accept Estes' (1989) comment that episodic memories are less educationally significant than semantic ones for the understanding of classroom learning and teaching, despite the current investigation. Efforts to detect a relationship between episodic and semantic memories have not exhausted available research methodologies.

The search for a core category of episodic memories in classrooms remains unfinished. Though the "energetic" variable was put forward as a possible candidate, more testing following recommendations within the grounded theory approach (Glaser, 1967; Glaser & Strauss, 1978; Strauss & Corbin, 1990) seems necessary. In particular, the role of episodic memories in learning ought to be examined with similar populations in similar settings, with similar populations in different settings, and with different populations in different settings.

In short, the role episodic memories play in learning from instruction requires more researcher attention. An anecdote may serve to highlight the point. Last summer, a fellow doctoral student asked me to discuss my research with a group of graduate students in a course he was teaching. I began the session by asking the students what they remembered from high school courses they'd taken. Without exception, each chose to answer the question with reference to an episodic memory, not with statements of semantic content.

Episodic memories are clearly powerful ones that can endure years, and even decades. It may be that other methods are necessary to unearth their potential applicability to classroom learning. Concomitantly, it also may be that different questions are needed to drive any research effort on the subject.

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Appendix A

Alberta Journal of Education
American Educational Research Journal
American Journal of Psychology
American Psychologist
American Scientist
Annual Review of Psychology
The Behavioral and Brain Sciences
Brain
British Journal of Psychology
Canadian Journal of Psychology
Child Development
Cognition
Cognition and Instruction
Cognitive Psychology
Cognitive Science
Developmental Review
Educational Researcher
Educational Theory
Harvard Educational Review
Human Factors
International Journal of Psychology
Journal of Abnormal and Social Psychology
Journal of the Acoustical Society of America
Journal of Comparative Psychology
Journal of Educational Psychology
Journal of Experimental Psychology
Journal of Experimental Psychology: Human Learning and Memory
Journal of Experimental Psychology: Human Perception and Performance
Journal of Experimental Psychology: Learning, Memory and Cognition
Journal of General Psychology
Journal of Memory and Language
Journal of Personality and Social Psychology
Journal of Verbal Learning and Verbal Behavior
Life Sciences
Memory and Cognition
Monographs of the Society for Research in Child Development
Nature
Psychological Bulletin
Psychological Review
Psychology Today
Quarterly Journal of Experimental Psychology
Review of Educational Research
Science
Scientific American

Appendix B

Piloting of Methods and Procedures

Twenty-six children from a pool of 28 volunteered (Appendix C) and received parental permission (Appendix D) to participate in the pilot study. Participants were from a grade six classroom in a school district in the Lower Mainland of British Columbia (the region in and around the City of Vancouver.) With two exceptions, procedures in the pilot were identical to those in the main study which are described below. The two exceptions relate to difficulties encountered in the pilot study.

First, during post-pilot data analysis it was found that, in response to the episodic memories questionnaire (E.M.Q.) (see Appendix S), students were providing only a minimal number of episodic memories which were locatable on lesson transcripts. When summed across the three lessons, students in the pilot reported a total of only 35 locatable episodic memories. This averaged out to .45 memories per student per lesson. Consequently, an extra pilot study lesson was set. Prior to this lesson, students practiced and received feedback on filling out the E.M.Q.[1] Following

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[1] This extra lesson was delivered after morning recess. To practice filling out the E.M.Q., students were asked to complete one with their memories from the recess period. As was done during the three pilot lessons, the instructions at the top of the E.M.Q. were read aloud to the students. However, unlike in those lessons, the principal investigator repeated the instructions to the students and highlighted specific points. Students were reminded to provide as many memories as they could in their response to the list question and to select the ones that stood out for them the most in their responses to the other three questions. They were encouraged to review a pretend videotape of recess in their mind's eye and to provide as much detail, including specific words heard, in their responses.

After students completed filling out the E.M.Q., individuals were asked to give examples both from the list question as well as the three prioritizing questions. Descriptive praise was used to acknowledge elements of examples given that met Tulving's criteria (described later in this chapter) for what constitutes an episodic memory. Students continued to provide examples of episodic memories until all Tulving's criteria had been identified through descriptive praise.

In the main study, students were taught how to fill out the E.M.Q. during the investigator's second school visit. They were asked to use memories either from events in the this instruction, students received a lesson on the origins of geometric shapes in the Navajo Indian blanket and again reported memories of that lesson. There was a substantial increase in the average number of memories reported for this lesson as compared to other individual lessons during the pilot. Students reported a total of 29 episodic memories of the extra lesson, averaging out to 1.1 per student for that lesson. As a result, the additional instructions for completing the E.M.Q. were added to experimental procedures in the main study.

Secondly, an attempt was made to cover too much content in lesson 1. Given time constraints, and the importance of collecting several post-instruction measures, lesson 1 in the main study was shortened through the elimination of one intended learning outcome (students' ability to slide images using only a slide rule and no slide arrow). Worksheet 1 (version 1, Appendix J) was changed to worksheet 1 (version 2, Appendix J). The latter was used during the main study and reflects the reduction in lesson 1 content covered in that main study.

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schoolyard prior to the start of the day or from morning recess.

Appendix C

Informed Consent by Participants

You are being asked to participate in a research study primarily intended to examine your learning style as well as what stands out for you in math lessons. The study is being conducted by Mr. Prupas, a graduate student at Simon Fraser University and a former teacher in your district.

For the purposes of the study, you will be asked to fill out some questionnaires. One will be trying to find out how you learn best. A few others will ask you questions about how satisfied you are with school in general and your school in particular. As well, Mr. Prupas will teach you 3 math lessons. During the lessons, you'll be asked to do some math exercises which you'll hand in. These will NOT be graded nor will your regular classroom teacher have a chance to look at them. After each lesson, you'll be asked about what stood out for you in the lesson and how you felt about your performance.

It's important for you to realize that you can decide NOT to participate in this study. As well, even if at this time you choose to be involved in the study, you can leave the study at any point in the future.

Also, please be aware that once all data have been collected, Mr. Prupas will assign you with a research code number. From that point on, only your code number will appear in data analysis procedures, not your name. As well, once all data from the videotapes has been coded, these tapes will be erased.

CHILD'S NAME:______________________________

TEACHER'S NAME:______________________________

DATE:______________________________

I have read and understood the foregoing information concerning the research study being conducted by Mr. Prupas. PLEASE CHECK ONE.

( ) I would like to participate in this study.

( ) I would not like to participate in this study.

____
Student's Signature

____
Date

Address: ______________________________

____

Appendix D

Informed Consent of Parent or Guardian

Dear Parent/Guardian:

Your child's class will be participating in a research study on increasing student participation in classroom instruction. In the study, student participation in classroom learning, learning style, and memories of classroom instruction will be examined. It is assumed that what is remembered from classroom instruction affects classroom behaviour and, ultimately, achievement. The purpose of the study is to test this assumption and to test techniques aimed at making important lesson material more memorable.

The study is being conducted by a doctoral student in the Faculty of Education at SFU, Lorne Prupas. Mr. Prupas is a former Delta teacher and is working under the supervision of Dr. Jack Martin, a full professor in the Instructional Psychology Programme at SFU's Faculty of Education.

All research will be conducted during regular school hours. Children who volunteer will participate in three math lessons lasting approximately 45 minutes from the Grade six math curriculum. In addition, approximately 90 minutes of instructional time will be required to collect data on participation in school, learning styles and school memories.

During the study, students will be asked to complete three spot checks of their learning of lesson content, three brief questionnaires on their school participation, and one questionnaire on their learning style. Students will also be asked their feelings about the lessons as well as how confident they are about their learning. After each lesson, students will be asked to report memorable aspects of that lesson. School attendance, classroom participation, and achievement data will be collected from each student's permanent school record and regular classroom teacher. In addition, three students in each class will be randomly selected for brief interviews about their participation in school and family life. None of this information will be used in any way to evaluate the school performance of individual students.

All lessons will be videotaped. These videotapes and all other data collected during the research will be reviewed solely by Mr. Prupas, Dr. Martin and S.F.U. based research assistants assigned to this project. Once data have been collected, participants will be assigned code numbers that make students' identities anonymous. After data have been coded, videotapes and questionnaires will be destroyed. From that point on, for purposes of analysis and reporting, students will be referred to by their code numbers only. At the completion of the study, a summary report will be filed with the school district office.

Participation in this project is completely voluntary. If, at any time, your child decides that s/he does not wish to participate, s/he will be excused. You also may withdraw your consent at any time. If you do not wish your child to participate in this study, it will in no way affect their status in school. If you have any complaints about this research, please contact Dr. Robin Barrow, Dean, Faculty of Education, Simon Fraser University, 291-3395.

Please complete the attached permission form, indicating whether you would like your child to participate, and return it to their classroom teacher by _____(date will be one week from the day the informed consent forms were distributed to students). If you have questions or concerns about the project, feel free to contact the primary researcher, Lorne Prupas, at 291-3875.

Other contacts are:
Dr. Graham Mallett, Delta School District: 596-7101;
Dr. Jack Martin, Professor, SFU: 291-3395.

Yours truly,

Lorne Prupas, M.A. (Educ)

CHILD'S NAME: ____

TEACHER'S NAME: ____

DATE: ____

I have read and understood the foregoing information concerning the research study being conducted by Lorne Prupas.

( ) I would like my child to participate in the research study on improving student involvement in classroom instruction.

( ) I would not like my child to participate in the research study on improving student involvement in classroom instruction.

____
Signature of parent/guardian

____
Date

Address: ________________________________

____
Signature of Witness

Once signed, a copy of this consent form will be provided to you.

Appendix E

S.R.L. Rating Scale

Today's Date: ______________________

Directions: Below are some questions about things you may think about or do to help you learn during a math class in which you're working with shapes. Some of the questions are concerned with whether you (silently) say things to yourself or ask yourself questions during such classes while studying. To answer the questions, try to think back (even to last year) to the actual situations the questions ask about. For each question, put a check (___) in the space under USUALLY, OFTEN, SOMETIMES, or ALMOST NEVER.

1. During a math class in which you're working with shapes, do you repeat to yourself some of the things the teacher says?

___ Usually ___ Often ___ Sometimes ___ Almost Never

2. When the teacher is explaining something in a math class in which you're working with shapes, do you ask yourself questions about things s/he says? (For example, do you ever think of things like, "How did s/he get that answer? or, "what did s/he mean just then?")

___ Usually ___ Often ___ Sometimes ___ Almost Never

3. Do you think about things your teacher says at different times during a math class in which you're working with shapes, and try to put them all together so it all makes sense?

___ Usually ___ Often ___ Sometimes ___ Almost Never

4. When a teacher is talking in a math class in which you're working with shapes, do you think of things you learned in the past or already know and how they are <u>like</u> the new things being discussed?

___ Usually ___ Often ___ Sometimes ___ Almost Never

5. Do you listen closely to what is being said during a math class in which you're working with shapes?

___ Usually ___ Often ___ Sometimes ___ Almost Never

6. If you don't understand something your teacher says during a math class in which you're working with shapes, do you try to figure out <u>why</u> you don't understand?

______ Usually ______ Often ______ Sometimes ______ Almost Never

7. When your teacher is explaining things in a math class in which you're working with shapes, do you try to figure out <u>why</u> you don't understand?

______ Usually ______ Often ______ Sometimes ______ Almost Never

8. In math classes in which you're working with shapes, do you look for changes in things and try to figure out <u>how</u> those changes came about?

______ Usually ______ Often ______ Sometimes ______ Almost Never

9. When questions are asked during a math class in which you're working with shapes and you hear the answers, do you think to yourself, "I knew that," or "I didn't know that?"

______ Usually ______ Often ______ Sometimes ______ Almost Never

10. When you make mistakes or lose marks on seatwork during a math class in which you're working with shapes, do you ask yourself, "What information do I need or what do I have to do differently to get it right?"

______ Usually ______ Often ______ Sometimes ______ Almost Never

11. When you work on seatwork in a math class in which you're working with shapes, do you consider all the things you should have done and check to make sure you did them before turning in the assignment?

______ Usually ______ Often ______ Sometimes ______ Almost Never

12. When you begin to work on seatwork (or one question in that work) in a math class in which you're working with shapes, do you think about what your response might look like <u>before</u> you start work?

______ Usually ______ Often ______ Sometimes ______ Almost Never

13. Before actually starting seatwork in a math class in which you're working with shapes, do you make a plan for how you should do it?

______ Usually ______ Often ______ Sometimes ______ Almost Never

14. When beginning to work on seatwork in a math class in which you're working with shapes, do you forget to review the instructions just before starting?

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

15. As you complete seatwork in a math class in which you're working with shapes, do you ask yourself questions along the way to make sure you are doing everything right? (For example, would you ask yourself things like, "Is this an appropriate answer?" or, "Did I use the right steps?")

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

16. When you see the work of other students (perhaps from some other subject), do you think to yourself, "I can do that," or "I know how she did that?"

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

17. Do you try to figure out and specifically remember the important points in the things you read about math that deals with shapes?

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

18. When you do seatwork in math that deals with shapes, do you find you can't remember the ways your teacher worked through similar problems or questions during class?

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

19. When you work on seatwork in math that deals with shapes, do you try to break the work into parts and decide which part to do first?

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

20. When you work on seatwork in math that deals with shapes, do you look over your responses and tell yourself something like, "Good, I'm doing fine," or, "That couldn't be right, I'd better do it over?"

______ Usually | ______ Often | ______ Sometimes | ______ Almost Never

Appendix F

The Individual Differences Questionnaire (I.D.Q.)

INSTRUCTIONS

The statements on the following pages show ways of thinking, studying, and problem solving. Some of these statements are true for some people but not for others. Read each statement and decide whether or not it is true for yourself. Then mark your answer on the separate answer sheet. Please do not make any marks on this questionnaire. If you agree with the statement or decide that it describes you, mark TRUE. If you disagree with the statement or decide that it does not describe you, mark FALSE. There are no "right" or "wrong" answers. Everyone learns in different ways and the questionnaire is designed to see how you learn. In marking your answers on the answer sheet, please make sure that the question number is the same as the one you are answering on the answer sheet. Please mark everyone TRUE or FALSE, even if you have to "guess". If you have any questions, please raise your hand.

1. I have no trouble finding the right words to explain things to people.

2. When I listen to someone tell a story, I don't usually get pictures of that story in my mind.

3. Writing assignments are difficult for me.

4. I tell jokes and stories more poorly than most people.

5. When remembering a scene, I choose words to describe it to myself instead of creating pictures in my mind.

6. When I write, I find it difficult to find enough words that mean the same thing.

7. I have difficulty expressing myself in writing.

8. I often use pictures in my mind to solve problems.

9. I can easily picture moving objects in my mind.

10. I only have a fuzzy visual impression of scenes I have experienced.

11. I can easily think of a lot of words that mean the same thing.

12. I think most people think using pictures in their mind.

13. I am able to explain my thoughts clearly.

14. My daydreams are sometimes so clear, I feel as though I actually experienced the scene.

15. I am very good at writing essays and reports.

16. I can close my eyes and easily picture a scene that I have experienced.

17. When someone describes something that happens to him/her, I sometimes find myself picturing the events that happened.

18. I am usually able to say what I mean in the first draft of a writing assignmnet (for example, a book report).

19. I never use pictures in my mind when solving problems.

20. I find it difficult to form a picture in my mind.

21. I have a better than average vocabulary and I use it.

22. My thinking often consists of pictures in my mind.

23. I do not form pictures in my mind of people or places when reading of them.

24. I often have difficulty explaining things to others.

25. I often enjoy the use of mental pictures to remember the past.

26. I am a good story teller.

27. I enjoy doing work that requires the use of words.

28. I have difficulty finding words that are related to other words.

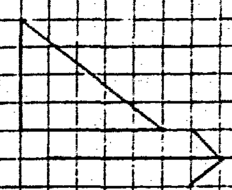
29. I often have ideas that I have trouble putting into words.

30. I often use mental images or pictures to help me remember things.

Appendix G

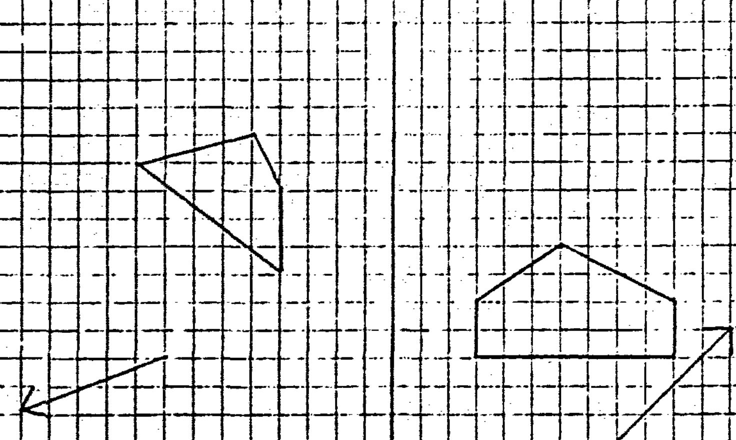
Test of Prior Knowledge, Form A

1a. Use tracing paper to draw the slide image of this triangle.

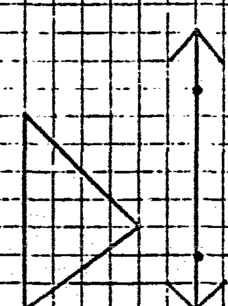


1b. Give the slide rule: ____________

2. Use tracing paper to draw the slide image for each figure using the slide arrow provided.



3. Use tracing paper to draw the following flip image.

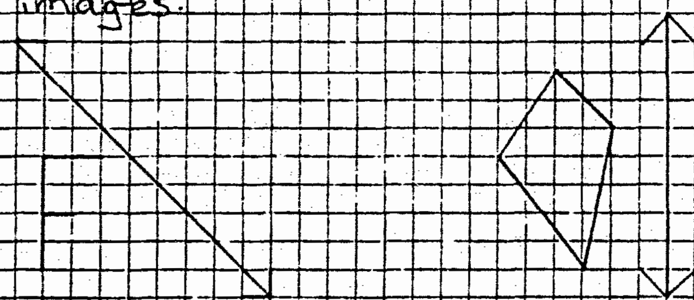


Appendix G continued

Test of Prior Knowledge, Form A

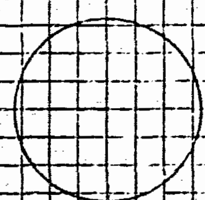
4. Use tracing paper to draw the following flip images.

4a.



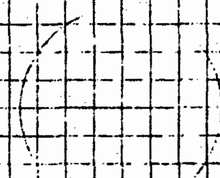
5.

5a)



start
1/4 cw (clockwise)

5b



start
1/2 ccw (counterclockwise)

6a) Use tracing paper to turn the figure as indicated by the turn angle.

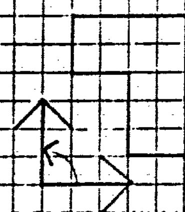
6b) Now give the turn angle of the turn above

____

Appendix G continued

Test of Prior Knowledge, Form A

7a) Use tracing paper to turn the figure as indicated by the turn angle.



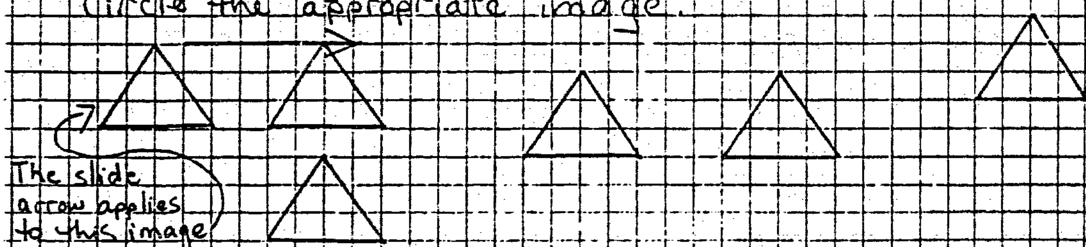
7b) Now give the turn angle of the turn above.

____

Appendix G continued

Test of Prior Knowledge, Form B

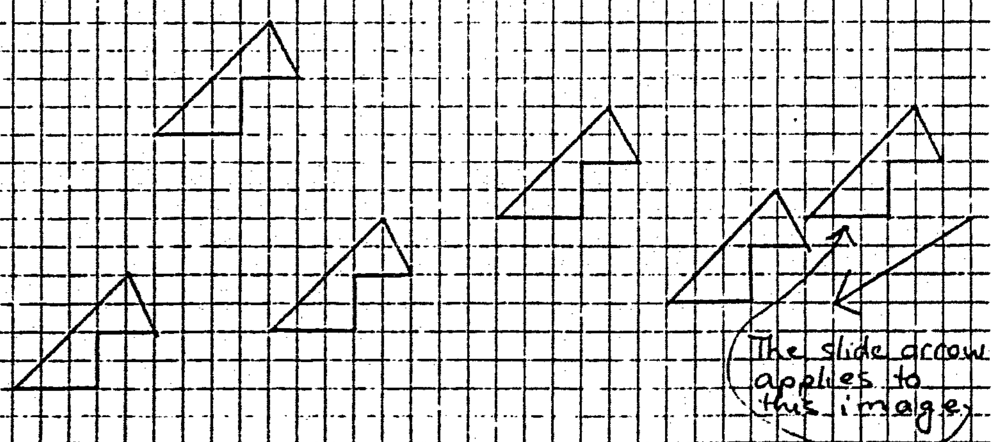
1. Examine the following images which one of the images on the right is the slide image of the image at the left hand margin? Circle the appropriate image.



2. Circle the slide rule that is equivalent to the slide arrow above.

a) l1 u1 b) r5 u1 c) r8 d0 d) r5 u4 e) r6 u0

3. Examine the following images. Which one of the images on the right is the slide image at the right hand margin.



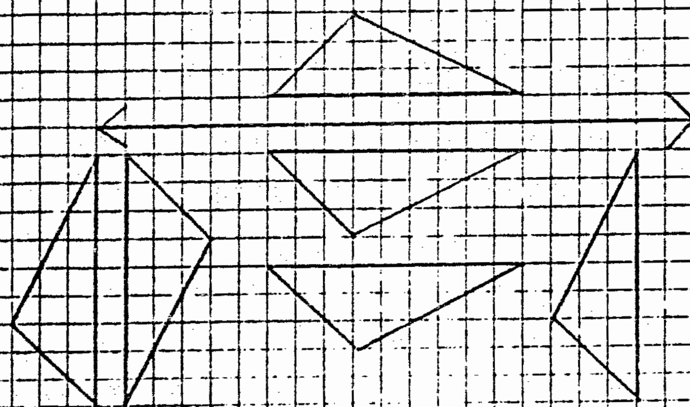
4. Circle the slide rule that is equivalent to the slide arrow above.

a) l5 d3 b) r5 u2 c) l4 d3 d) l3 d5 e) r4 d3

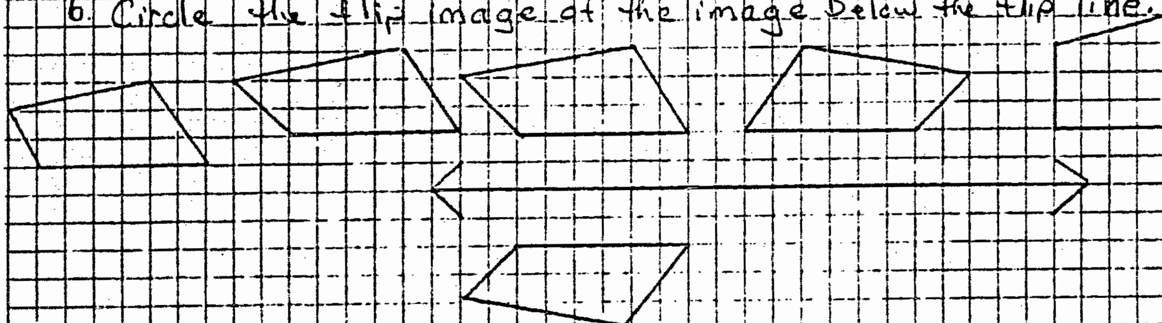
Appendix G continued

Test of Prior Knowledge Form B, page 2

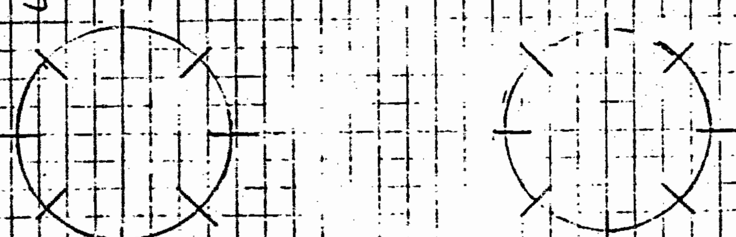
5. Circle the flip image of the image above the flip line.



6. Circle the flip image of the image below the flip line.



7. Which mark on the circle corresponds to the turn angle underneath it. Circle that mark.



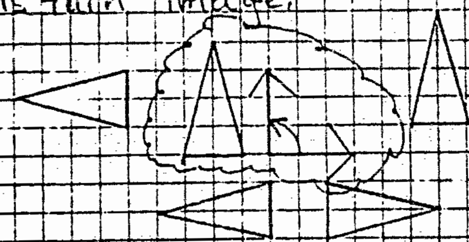
start
3/4 cw (clockwise)

start
1/4 ccw (counterclockwise)

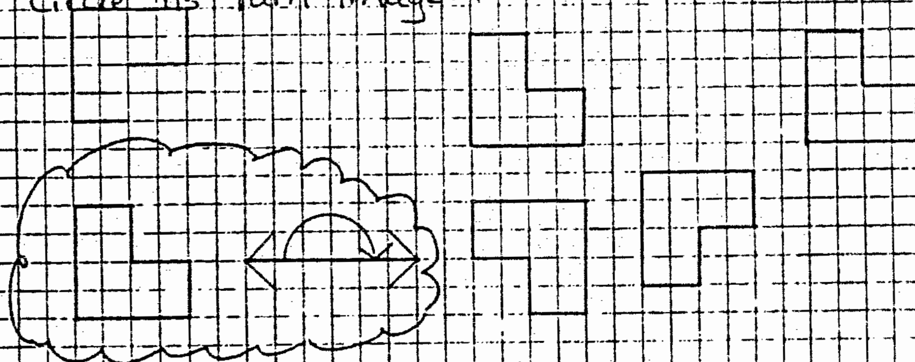
Appendix G continued

Test of Prior Knowledge, Form B, page

8. The image circled by a cloud has been turned the amount indicated by the turn angle beside it. Circle its turn image.



9. The image circled by a cloud has been turned the amount indicated by the turn angle beside it. Circle its turn image.



10. Circle the turn angle of the turn above.

a) 1/4 cw   b) 1/2 cw   c) 3/4 ccw   d) 1/2 ccw   e) 1/4 ccw

Appendix H

Test of Prior Knowledge: Drawing Test

Declarative or Procedural Knowledge	# of Items Assessing that Knowledge
Identification of slide rule	1
Sliding a triangular shape	1
Sliding a non-triangular shape	2
Flipping a triangular shape	1
Flipping a non-triangular shape	2
Identification of turn on clock	2
Identification of turn angle of image	2
Turning a triangle	1
Turning a non-triangle	1
Total Number of Items:	13

Test of Prior Knowledge: Multiple-Choice Test

Declarative or Procedural Knowledge	# of Items Assessing that Knowledge
Identification of slide rule	2
Sliding a triangular shape	1
Sliding a non-triangular shape	1
Flipping a triangular shape	1
Flipping a non-triangular shape	1
Identification of turn on clock	2
Identification of turn angle of image	1
Turning a triangle	1
Turning a non-triangle	1
Total Number of Items:	11

Appendix I: Summary of In-Class Procedures

Session 1. The first experimental session was spent giving students background information regarding both the primary investigator and the study. Times of in-class visits were announced and both the S.R.L. and I.D.Q. scales were administered.

Session 2. The second session was spent administering the two Tests of Prior Knowledge, Forms A and B. At the end of session 2, students practiced using the E.M.Q. Practice E.M.Q.'s were distributed. The primary investigator then read the E.M.Q.'s to the students, pausing for any necessary clarification. Students then completed the E.M.Q.'s using the period from their time of arrival at school to the moment just before the distribution of the E.M.Q.'s as the target memory period. After the students had finished filling out the E.M.Q.'s, individual students gave examples of their responses to items. Questions and concerns were raised as we moved through this whole class activity.

Session 3. With session 3, actual in-class instruction began. In this first lesson, students were taught the motion geometry concepts related to "slides" (images, slides, slide images, slide arrows and slide rules) and were also taught how to slide both triangular and non-triangular forms.

The lesson was introduced by the primary investigator using a large green square on flip chart graph paper and having students give slide rules (e.g., right 3, up 1) to indicate in which directions and by how many graph squares the large green square should be moved. A slide arrow was then presented and its two properties discussed, namely those of graphically showing us the direction and distance an image is to be slid. The slide arrow was differentiated from the slide rule, the latter being used to inform us of the actual direction and distance an image is to slide.

At this point during the lesson, the teacher asked the students to generate imaginal "real world" examples of slide arrows one might find in a playground, on a ski hill, or in various modes of transportation. "Real world" examples are ones drawn from, or evident in, the student's out-of-school experience, though they may be ones talked about in school. Examples elicited from the students when asked for "real world" examples of slide arrows were: a skier going down a hill, a chairlift, a boat crossing a river.

Students then practiced how to draw slide arrows to represent four different slide rules on their own graph paper. Volunteers drew the answers on four graphs on the chalkboard. Any errors volunteers made were immediately corrected. If necessary, further clarification about how to draw slide arrows from slide rules was then provided.

Students were then taught the five steps in how to slide a triangle using tracing paper. Students then practiced sliding triangles on the first page of their worksheets. They then learned how to slide a non-triangular shape (a diamond) with tracing paper following the same principles used to slide a triangle. This instruction was again followed by a "hands on" exercise in which students practiced their learning in exercises on the second page of the worksheet.

The final activity prior to post-testing was to have students give other "real world" examples of slides they might find in transportation. Again, students provided examples such as a bus going down a street, a car crossing a road, someone rollerskating, and an elevator.

The lesson concluded with students completing the post-test and E.M.Q.

Session 4. The second lesson was taught during experimental session 4. In this lesson, students were taught the motion geometry concepts related to "flips" (flip images, flip lines) and were also taught how to flip both triangular and non-triangular shapes.

The lesson was introduced by the primary investigator drawing a letter "L" on a folded piece of coloured paper. A piece of carbon paper, carbon side up, had been placed underneath the folded half of the paper. Students were then asked to describe the image they thought would appear on the folded half of the coloured paper facing the carbon. Once the intended answer, (a reversed, mirror-image, or backwards "L") was obtained, flip image terms (image, flip line, and flip image) were defined.

Next students were asked to imagine a "real world" example of a "flipable" image, that of a snow angel. No chart, blackboard or written work was done during this part of the lesson. Instead, students were asked to imagine what the flip images of a snow angel would look like when they placed flip lines of their own choosing beside it. This was followed by a request that students generate other examples of "real world" flip images.

Next, students were taught the five steps of the "tracing paper" method to flip triangular shapes. The procedure was demonstrated with two triangles on the chart paper. Students then practiced flipping triangles on their worksheets.

Following this practice, the "tracing paper" method to flip from two to four non-triangular shapes (depending on time constraints) was demonstrated. The procedure is identical to that for flipping triangles. The only difference is that non-triangular shapes are used. Again, instruction was followed by hands-on practice with examples on student worksheets.

The lesson concluded with students completing the post-test and E.M.Q.

Session 5. The third lesson was taught during experimental session 5. In this lesson, students were taught the motion geometry concepts related to "turns" (turns, turn centre, turn angle, turn image) and were also taught how to turn both triangular and non-triangular shapes.

To introduce the concept of a turn, a cardboard hexagon with vertices lettered A-F was placed on the flip chart. After students were asked to close their eyes, the hexagon was turned. When they opened their eyes, they were asked to state what had happened to the hexagon. Once the term "turn" had been elicited, the other "turn" vocabulary was explained with reference to the vertices of the hexagon.

Terms presented in the previous lessons on slides and flips were then reviewed in order to differentiate them from "turn" vocabulary.

Students were then asked to give examples of "real world" turns they might see in a playground, an amusement park or on a game show.

Next, the concepts of clockwise and counterclockwise turns was reviewed with the students. Students demonstrated clockwise and counterclockwise movement with their fingers. Six students then came up to the chart to mark off 3 clockwise and 3 counterclockwise turns of 3 possible dimensions (1/4, 1/2, 3/4). Finally, students practiced identifying such turns on their worksheets. The worksheet examples were done on the blackboard by volunteers and were checked by the teacher.

Students were then asked to imagine an unusual "real world" example of a turn. In this example, a ballerina was crossing a tightrope while carrying two trays of flaming brandy. The tightrope was on a north-south axis. While the ballerina was doing her act, a prankster clown picked up the south pole of the tightrope and moved it by various clockwise and counterclockwise turns (1/4, 1/2, 3/4). Students were asked to figure out the direction the ballerina would be facing after each turn.

This exercise was followed by a demonstration of the seven steps in the "tracing paper" method to turn images and identify turn angles. Students then practiced turning images (both triangular and non-triangular) and identifying turn angles on their worksheets.

The lesson concluded with students completing the post-test and E.M.Q.

<u>General note on lessons</u>. Lessons intended to cover the same knowledge were never exact carbon copies of each other. Though the lesson outlines as described above were rigorously followed, content did vary somewhat. In some

classes students were more forthcoming than in others and needed less prompting to provide "real world" examples. In other classes, more errors were made either by the teacher or the student. More time had to be spent correcting those errors. This reduced the amount of time available for other lesson activities (e.g., number of examples covered in demonstrations and on worksheets depended on time constraints). Occasionally the placement of "real world" examples was not identical across lessons. Finally, material generated within a specific class was sometimes used as part of the lesson for that class only (e.g., a discussion of gardening as a result of the story read during opening exercises).

Appendix I: Precise Description of In-Class Procedures

Session 1

Prior to lesson:

1. Collect permission forms from the teacher: a) student; b) parent

2. Tape name plates to each participant's desk.

3. Find out from teacher when math class is usually taught and when it will be taught during the study:

Usually taught		Taught during the study
Class 2:	10:50 a.m.	9:10 a.m.
Class 3:	9 a.m.	10:45 a.m.
Class 4:	9 a.m.	9:10 a.m.
Class 5:	9 a.m.	9:10 a.m.
Class 6:	11 a.m.	10:45 a.m.

Once students have arrived:

1. Take attendance.

2. Introduction:
   a) Introduce myself: A Ph.D. student at SFU (name on board).
   b) Announce when I'll be in the school.
   c) Announce times when the lessons will be videotaped.

3. Review the study:
   a) A study intended to examine the relationship between the way children learn and what they find memorable during classroom lessons. The results of the study may inform teachers about how to improve their instruction.
   b) Reassure students that the class is being videotaped, the videotape will be focusing on everyone and that no student(s) will be picked out for special attention.
   c) Remind students that if they wish to withdraw from the study at any time, they need only tell their teacher or myself.

4. Overview today's activities:
   Collection of some information about learning styles. Remind students that each of them has their own learning style.

5. Administer the S.R.L. Students fill out the questionnaire as I read it to them.

6. Administer the I.D.Q. Again, students fill out the questionnaire as I read it to them.

<u>Session 2</u>

1. Take attendance.

2. Administer Prior Knowledge Form A. Prior to administration, inform students that this is a test to find out how much they already know about the curriculum to be taught. Remind them that as they haven't learned the material to be tested, they're likely to find the test somewhat difficult. That's why I'll be teaching the curriculum.

3. Administer Prior Knowledge Form B.

4. Have students practice using the Episodic Memories Questionnaire (E.M.Q.). After distributing the E.M.Q., read it out loud to the students making sure they understand each of its items. Then have them complete the questionnaire using memories they have starting

from the time they arrived in school that day. Hand out memories questionnaire. After they've filled out the E.M.Q., in a whole class activity, have individual students give examples of their responses to each item. Review these examples with the rest of the class.

Session 3
Lesson 1

Prior to lesson:

1. Distribute materials (graph paper, green squares, tracing paper, worksheets, post-tests, and research questionnaires and probes) placing them face down in the order in which they will be used during the lesson. Place large green square on flip chart graph paper at the front of the room.

Once students have arrived:

1. Take attendance.

2. **First lesson activity.** Time required for this lesson activity: 3".
On a blank sheet of flip chart graph paper, show students how I can move the green square up, down, to the left, and to the right. Have them do the same on their paper. Have different children call out how much we're to move the square. Eg. right 3 up 1; left 4, down 2.

3. **Second lesson activity.** Time required for this lesson activity: 3".
Show chart of slide arrow. Inform students of the two properties of a slide arrow, namely that it informs us of the direction and distance to move an image. Refer to the slide arrow on the chart. Demonstrate how this slide arrow is informing us to move an image to the right by 12 squares and down by 8 squares.

4. **Third lesson activity.** Time required for this activity: 1".
Turn chart paper to the graph of the same slide arrow only this time with the slide rule indicated. Tell students that the actual direction and distance that an image is to slide according to a slide arrow is called a slide rule. Slide the green square a second time highlighting the slide rule that is directing the slide.

5. **Fourth lesson activity.** Time for this activity: 1". Stay on the same piece of chart paper and review the terms slide arrow and slide rule. Remind students that the slide arrow shows us direction and distance to move an image whereas the slide rule tells us the actual direction and distance the imade is to be slid.

6. **Fifth lesson activity.** Time for this activity: 1". Make the distinction between an image and a slide image. Inform students that after moving an image according to a slide rule, it is called the slide image. Use a green square on the same piece of chart paper. Place it at the top left hand corner and indicate that, prior to the slide, it is called the image. Slide the square according to the slide rule and indicate that once it's been slid, it's called the slide image.

7. **Sixth lesson activity.** Time required for this activity: 2".
Students were asked to provide "real world" examples of slide arrows they might find in playgrounds or in modes of transportation. They gave examples such as slides, boats crossing rivers, cars crossing streets, and skiiers going down ski hills.

8. **Seventh lesson activity.** Time required for this activity: 4".
Flip the chart paper. On the next piece of chart paper are four slide rules: right 2, up 4; left 2, down 3; right 3, down 2; and, left 4 up 1. Show students how to draw a slide arrow using the first slide rule. Have students practice drawing slide arrows on their own graph paper using the remaining three slide rules.

9. **Eighth lesson activity.** Time required for this activity: 4". Ask 3 students to volunteer to come to the board and to draw their answers on graphs on the blackboard. Have students explain how they drew their slide arrows. Review steps with students who have made errors. Ask for questions from the class.

10. **Ninth lesson activity.** Time required for this activity: 4".
Turn chart graph paper to chart of a triangle with a slide arrow indicating a slide rule of right 4, down 2. Show students how to slide the triangle using the "tracing paper method".
Step 1: Extend slide arrow to at least double its original length. Step 2: Trace triangle and slide arrow. Step 3: Slide traced image along the extension

of the slide arrow until the beginning of the traced arrow sits at the tip of the original arrow. Step 4: Push hard or tear your tracing paper at the vertices of the traced triangle. Step 5: Remove the tracing paper and join the dots of your triangle which is called your slide image.
Ask for questions.
Review the steps.

11. **Tenth lesson activity.** Time required for this lesson activity: 5".
Have students practice sliding triangles using worksheet 1, version 2, p. 1 (see Appendix J).
Go around the classroom providing help to students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at the 5" mark and ask for questions.

12. **Eleventh lesson activity.** Time required for this lesson activity: 3".
Turn chart paper to chart of a diamond and a slide arrow indicating a slide rule of left 4 up 4. Show students how to slide this image using the "tracing paper method" described above. Ask for questions and review the steps.

13. **Twelfth lesson activity.** Time required for this lesson activity: 9".
Have students practice sliding non-triangular images using worksheet 1, version 2, p.2 (see Appendix J).
Go around the classroom providing help to students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at the 9" mark and ask for questions.

14. **Thirteenth lesson activity.** Time required for this lesson activity: 2".
Again have students provide other "real world" examples of slides, perhaps again from the realm of transportation.

15. **Fourteenth lesson activity.** Time required for this lesson activity: 8". Administer post-test Lesson 1 (see Appendix N).

16. **Fifteenth lesson activity.** Time required for this lesson activity: 10". Episodic memories questionnaire (see Appendix S). Students respond to questions 1 and 2 after I read them aloud to them. They complete the remainder of the questionnaire on their own.

Total Lesson Time: 60".

Session 4
Lesson 2

Prior to lesson:

1. Distribute materials (tracing paper, worksheets, post-tests, and research questionnaires and probes) placing them face down in the order in which they will be used during the lesson.

Once students have arrived:

1. Take attendance.

2. **First lesson activity.** Time required for this lesson activity: 5".
Place a piece of coloured paper on the flip chart. Draw a dotted line down the middle of the coloured paper and fold it in half along the dotted line. Place a piece of carbon paper, carbon side up, underneath the folded paper. Have the students watch as you draw a large 'L' on the coloured paper. Then ask the students what they think will appear on the folded half of the coloured paper facing the carbon. Once you obtain the answer that a reversed, mirror-image, or backwards 'L' will appear, show the students what actually did appear and define terms for them. The first 'L' prior to reversal, is called the image. The dotted line is called the flip line. The 'L' that is the mirror image of the first 'L' is the flip image.

3. **Second lesson activity.** Time required for this lesson activity: 3".
Present an example of a image that might not be that common in geometry texts, that of a snow angel. Ask students how they might make a flip image of that snow angel. Ask them where they might place the flip line. Ask them what the flip image would look like and where it would be. Once you've gotten one way of flipping the snow angel, ask for another.

4. **Third lesson activity.** Time required for this lesson activity: 4".

Ask students to generate examples of images they might flip that might not necessarily be found in math textbooks. If students don't give examples, suggest that they consider flipping images or cut up pieces of fruit.

5. **Fourth lesson activity.** Time required for this lesson activity: 5"
Turn flip chart to page on which two triangles are to be flipped, one horizontally and the other vertically. Show students how to flip the first triangle using the "tracing paper method" following these steps: 1) put dots on flip line; 2) place tracing paper over triangle and flip line and trace flip line, dots and triangle; 3) turn the tracing paper over making sure that dots on traced flip line cover dots on original flip line; 4) mark vertices of flip image by pressing (or tearing if necessary) at the vertices of the image on the tracing paper; 5) remove the tracing paper and join the dots on the graph paper.
Repeat this procedure for the second triangle on the flip chart. Check for comprehension by having students repeat the steps to you.

6. **Fifth lesson activity.** Time required for this lesson activity: 5".
Have students work on the examples on worksheet 2, p. 1 (see Appendix K).
Go around the classroom providing help to students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at the 5" mark and ask for questions.

7. **Sixth lesson activity.** Time required for this lesson activity: 5".
Turn chart paper to chart of four non-triangles (e.g., a four-sided figure, a pentagon, a hexagon, and an asymmetric 'X.' Have different students select the image they'd like you to flip. Flip the image following the "tracing paper method" for flipping images as described above, eliciting the steps from the students while working through examples. Do only the number of examples that can be done in the 5" period.

8. **Seventh lesson activity.** Time required for this lesson activity: 10".
Have students work on the examples on worksheet 2, p. 2 (see Appendix K).
Go around the classroom providing help to students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at

the 10" mark and ask for questions.

9. **Eighth lesson activity.** Time required for this lesson activity: 8". Administer post-test Lesson 2 (see Appendix O).

10. **Ninth lesson activity.** Time required for this lesson activity: 10". Episodic memories questionnaire (see Appendix S). Students respond to questions 1 and 2 after I read them aloud to them. They complete the remainder of the questionnaire on their own.

<u>Total Lesson Time: 55"</u>.

<u>Session 5</u>
<u>Lesson 3</u>

Prior to lesson:

1. Distribute materials (tracing paper, worksheets, post-tests, and research questionnaires and probes) placing them face down in the order in which they will be used during the lesson.

Once students have arrived:

1. Take attendance.

2. **First lesson activity.** Time required for this lesson activity: 5".
   Place a large green cardboard hexagon with vertices labelled A-F on the flip chart. Have the students close their eyes. Then, using vertex 'D' as the turn centre, turn the hexagon counterclockwise. Have the students open their eyes. Elicit from them the fact that the image has turned. As well, provide them with the core vocabulary for this lesson: a) A 'turn' is when an image is moved in such a way that, if it were to keep moving, it would make a circle, coming back to its original position; b) the 'turn centre' is the vertex about which the image is turned; c) the 'turn angle' is the number of degrees each vertex moves in a turn. It is the angle formed by the lines from the vertex to the turn centre prior to and following a turn.

3. **Second lesson activity.** Time required for this lesson activity: 3".
   Review slide/flip/turn vocabulary.
   a) Slides: A slide arrow shows us graphically the direction and distance we are to move an image. The

actual direction and distance is known as the slide rule. After we move an image according to a slide rule, the image is called the slide image.
b) Flips: An image can be flipped over a "flip line." The resulting image is called the "flip image." The flip image is the mirror image of the first image. All parts of the mirror image and original image are equidistant from the flip line.
c) Turns: See "2." above.

4. **Third lesson activity.** Time required for this lesson activity: 3".
Students generated "real world" examples of turns they might find in a playground, an amusement park, and on game shows.

5. **Fourth lesson activity.** Time required for this lesson activity: 2".
Review the concepts of clockwise and counterclockwise by having the students draw circles in the air showing the clockwise and counterclockwise motion of the second hand of a clock. Have them check whether or not they're moving their hands correctly by looking at the second hand on the classroom clock.

6. **Fifth lesson activity.** Time required for this lesson activity: 4".
Turn the flip chart to the page with six circles. Each circle has a vertical marker at the center of its base. Have six students come up to the chart to mark off 3 clockwise turns (1/4 cw, 1/2 cw, 3/4 cw) and 3 counterclockwise turns (1/4 ccw, 1/2 ccw, 3/4 ccw) using the vertical marker as the starting point of the turn.

7. **Sixth lesson activity.** Time required for this lesson activity: 3".
Have students work on the six examples on the top half of worksheet 3, p. 1 (see Appendix L). Go around the classroom providing help to students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at the 3" mark and ask for questions.

8. **Seventh lesson activity.** Time required for this lesson activity: 2".
Have six students come up and mark six circles on the blackboard with their answers to the six examples. Correct any errors and ask for comprehension questions.

9. **Eighth lesson activity.** Time required for this lesson activity: 3".
Tightrope image exercise. Have students imagine that a ballerina who is balancing two trays with glasses filled with flaming brandy in her two hands is on a tightrope facing facing north. Next, have them imagine that a circus clown picks up the south pole of the tightrope and moves it 3/4 of a turn ccw. This clown leaves the north pole in the ground. Ask the students to determine the direction the tightrope walker would be facing after the turn.
Have them try the image exercise again. Ask them to start over, imagining the same tightrope walker with the same trays of flaming brandy facing north on a north/south tightrope. Again, have them imagine that a circus clown picks up the south pole of the tightrope, only this time moves it 1/2 turn cw. Ask the students to determine the direction the tightrope walker would be facing after the turn.

10. **Ninth lesson activity.** Time required for this lesson activity: 6".
Show students how to use the "tracing paper method" to turn images on the flip chart. Turn only as many of the four images as can be turned within the six minute time limit. Have individual students select which of the images they'd like to have the teacher turn. (The first image is a rectangular horseshoe to be turned 3/4 ccw; the second is a triangle to be turned 1/2 cw; the third is a parallelogram to be turned 1/4 ccw; and the fourth is a hexagon to be turned 3/4 cw.) Spend only six minutes on this activity. Follow these steps: 1) trace everything that's on the flip chart onto the tracing paper (image plus turn angle) and make sure to keep the tracing paper covering the image and turn angle; 2) identify the start and end lines of the turn angle (the start line is the line where the arrow starts, the end line is the line to which the arrow is pointing); 3) place a pencil at the vertex of the turn angle; 4) turn the image following the direction of the turn arrow so the start line ends up covering the finish line; 5) now press hard with the pencil at each vertex of the turn image so that it can be traced onto the graph paper;r; 6) remove the tracing paper and join the dots; 7) identify the turn angle.

11. **Tenth lesson activity.** Time required for this lesson activity: 9".
Have students work on the six examples on the bottom half of worksheet 3, p. 1 and worksheet 3, p.2. (see Appendix L). Go around the classroom providing help to

students requesting individual attention. Ask students to stop working even if they haven't completed the worksheet at the 9" mark and ask for questions.

12. **Eleventh lesson activity.** Time required for this lesson activity: 8". Administer post-test Lesson 3 (see Appendix P).

13. **Twelfth lesson activity.** Time required for this lesson activity: 10". Episodic memories questionnaire (see Appendix S). Students respond to questions 1 and 2 after I read them aloud to them. They complete the remainder of the questionnaire on their own.

<u>Total Lesson Time: 58"</u>.

Following the lesson:

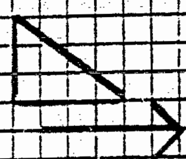
1. Review the permanent record cards privately in the school office. Collect the following data:
   a) Total no. of school days at that school in the 1990-1991 school year.
   All classes: 186.5
   b) Grade 5 grades in Lang. Arts., Math, Science and Socials.

Appendix J continued

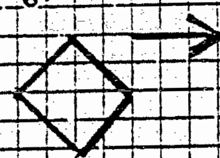
Lesson 1
Page 2 (tracing paper)
Version 1

Use tracing paper to draw the slide image.

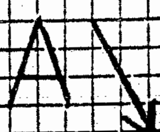
5.



6.



7



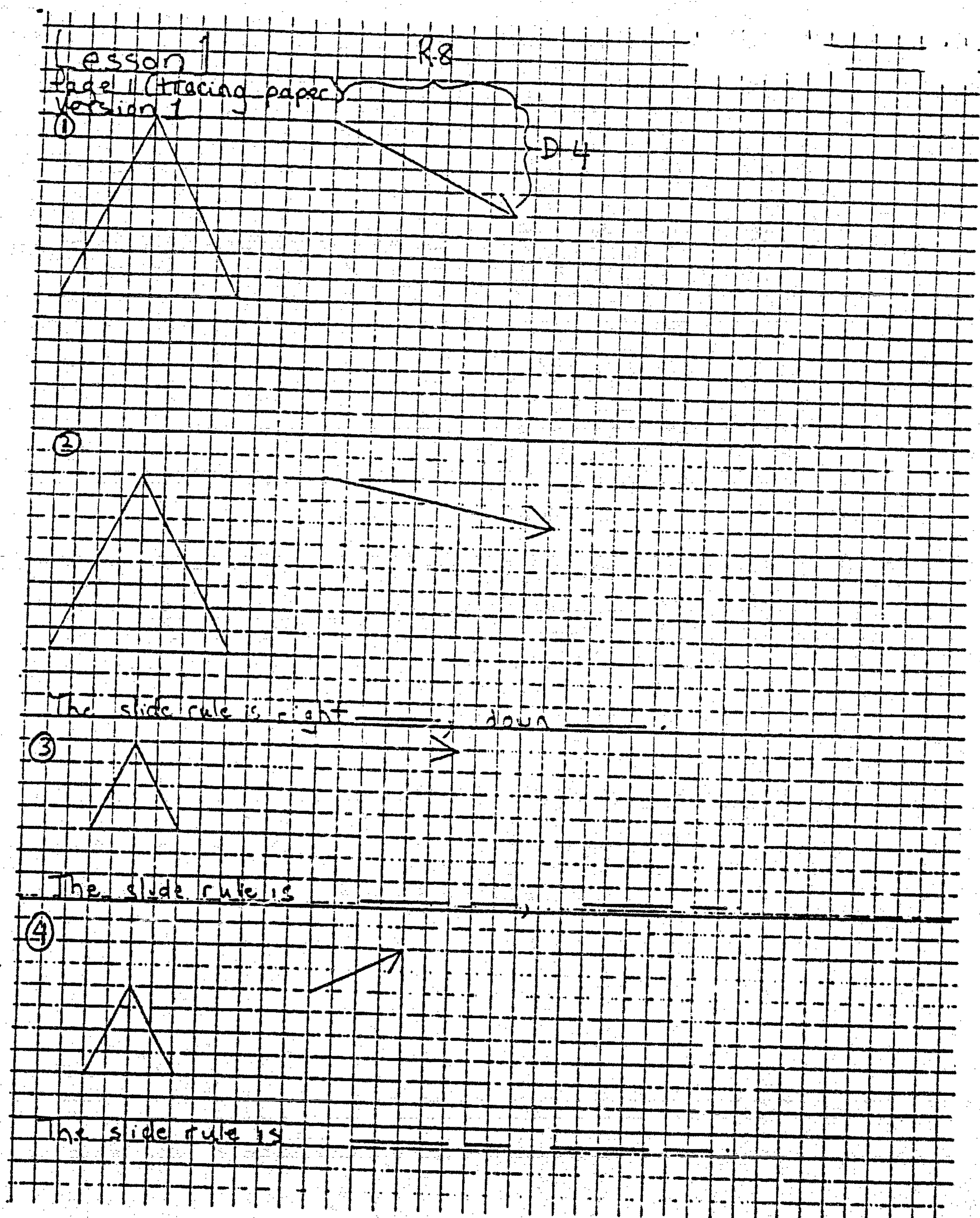
8

9.

10.

Give the slide rule for each slide arrow underneath the slide image.

Appendix J

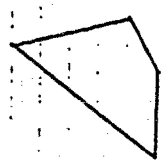


Lesson 1
R 8
Page 1 (tracing paper)
Version 1
D 4
①
②
The slide rule is right ____ down ____.
③
The slide rule is ____ ____, ____ ____
④
The slide rule is ____ ____ ____ ____.

Appendix J continued

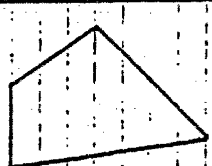
Lesson 1, version 1
Page 3
No Tracing Paper

Draw the slide image for the rule or slide arrow. This time, use the counting method, not the tracing method.

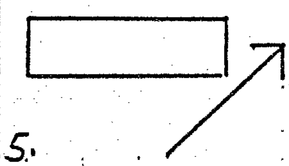


1. (L5, D2)
2. (R0, U3)

3. (L2, U4)

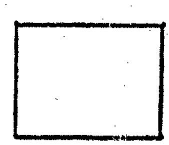


4. (R3, D5)



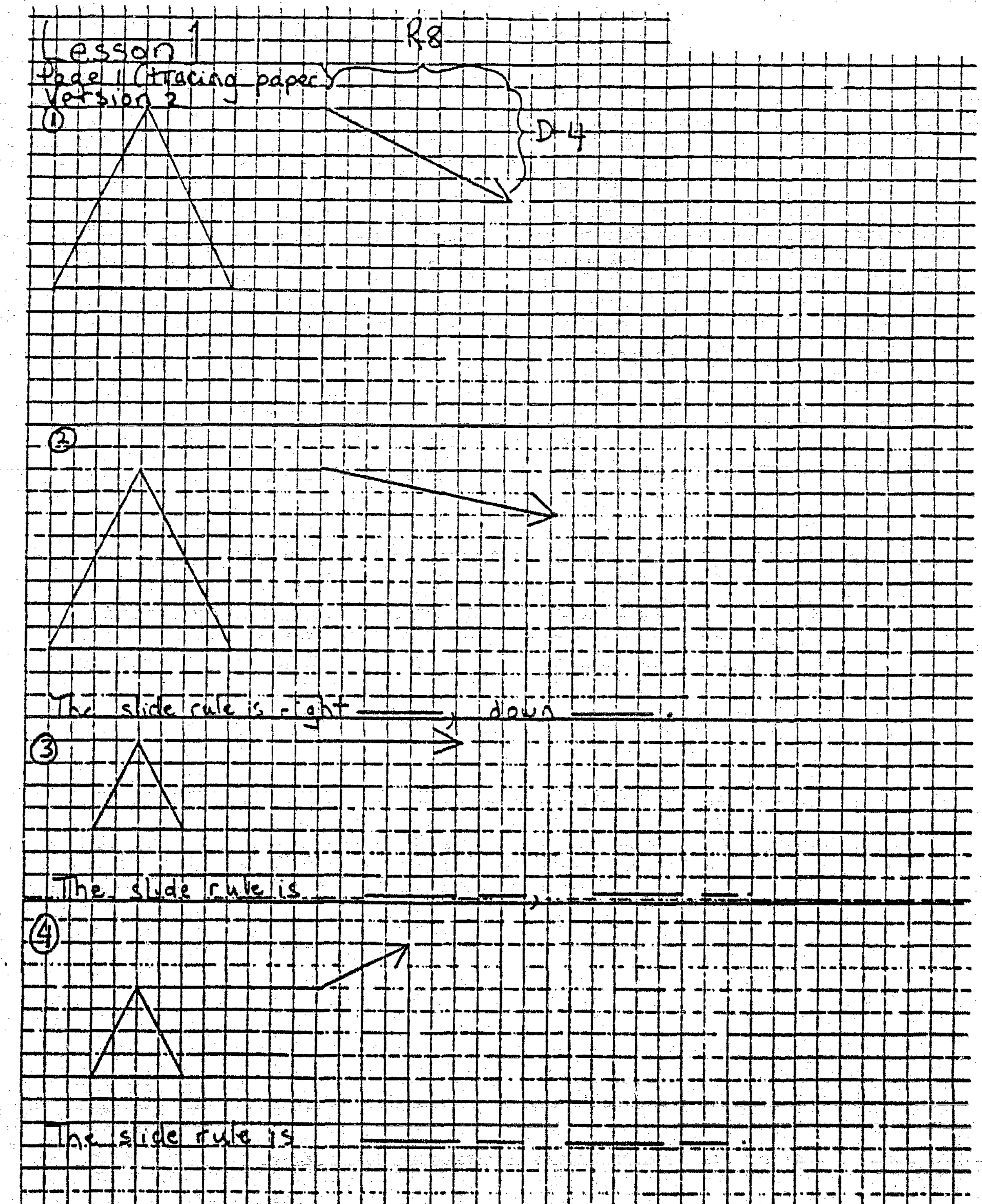
5.

6. (R0, D4)

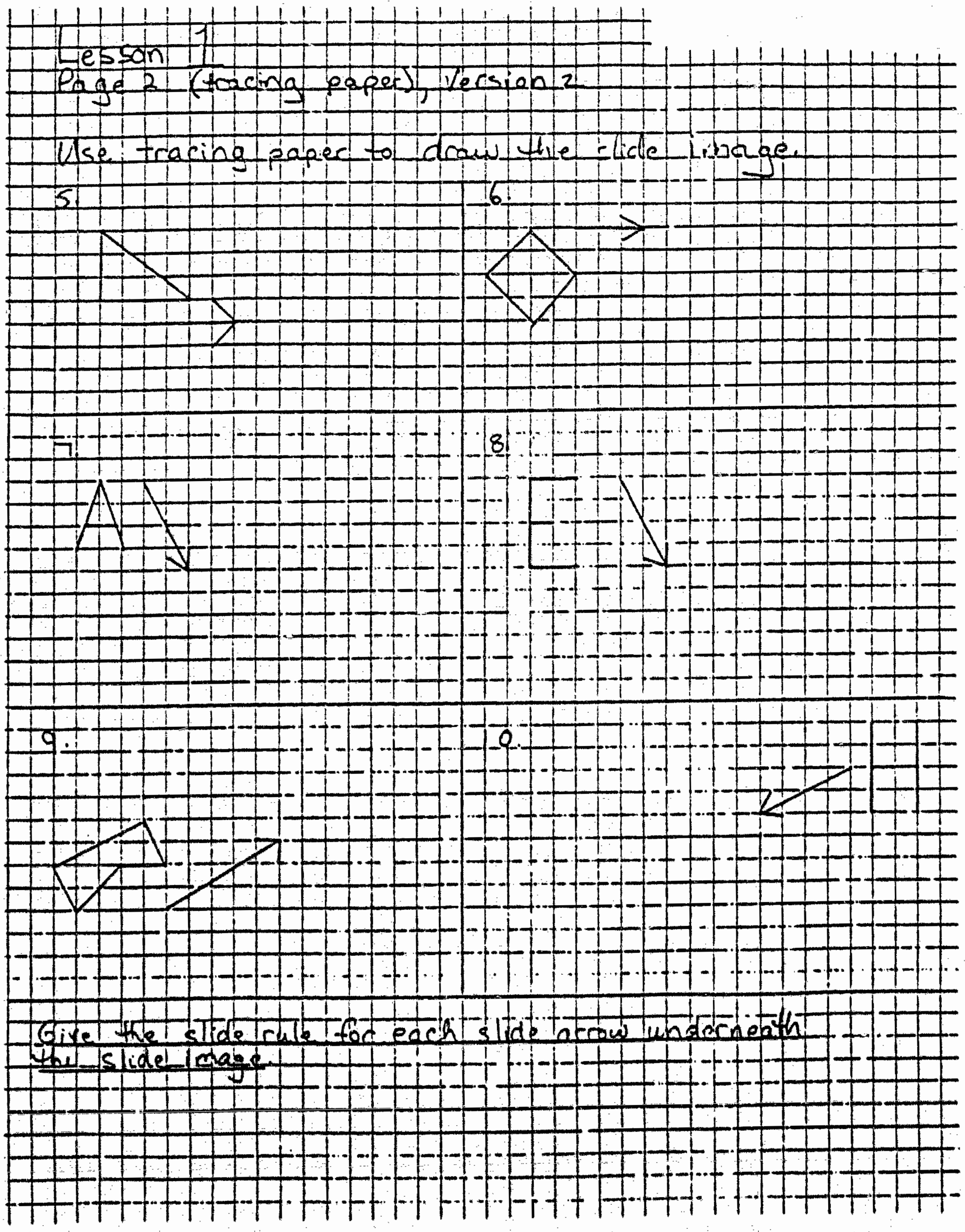


7. (L4, D5)

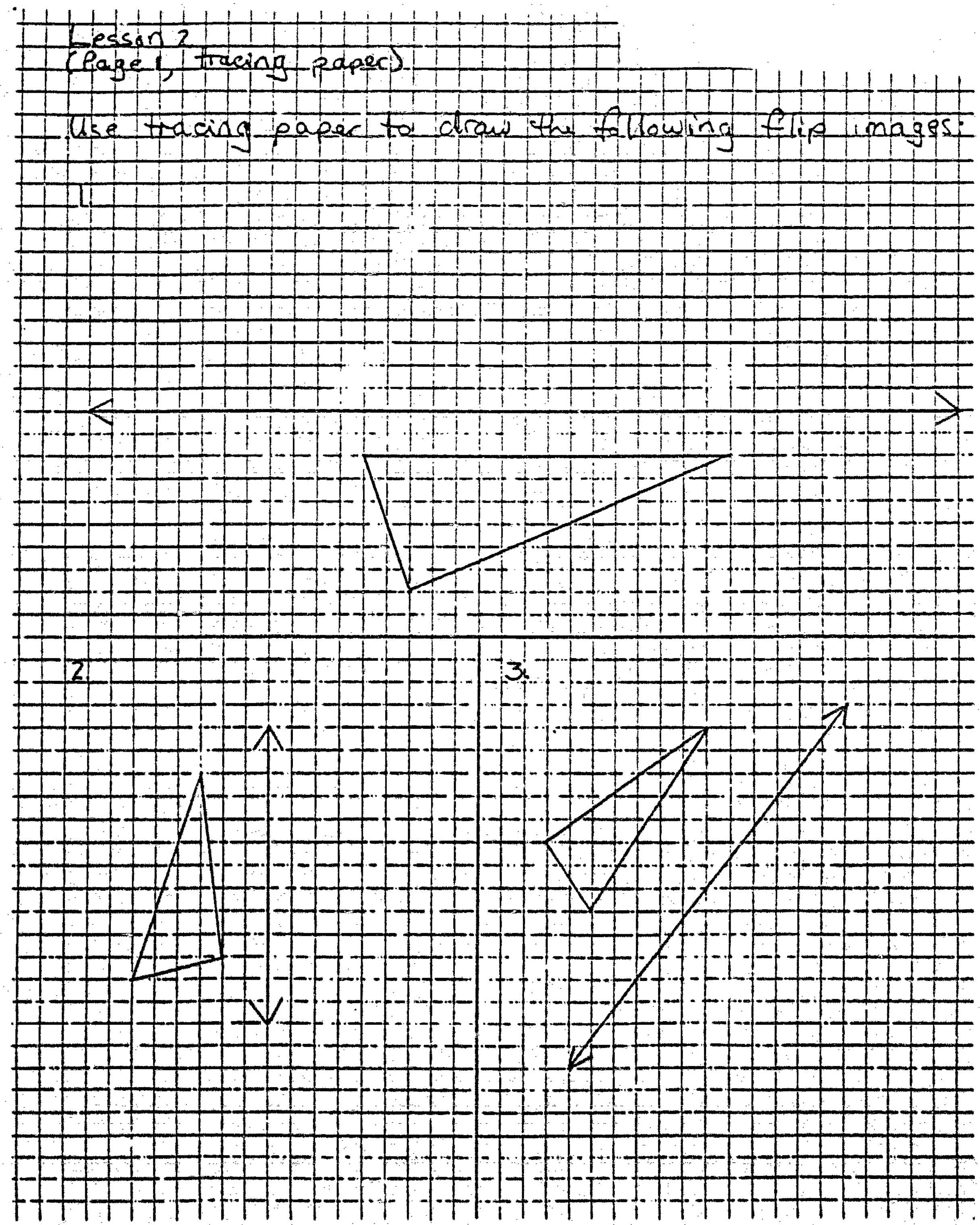
Appendix J continued



Appendix J continued



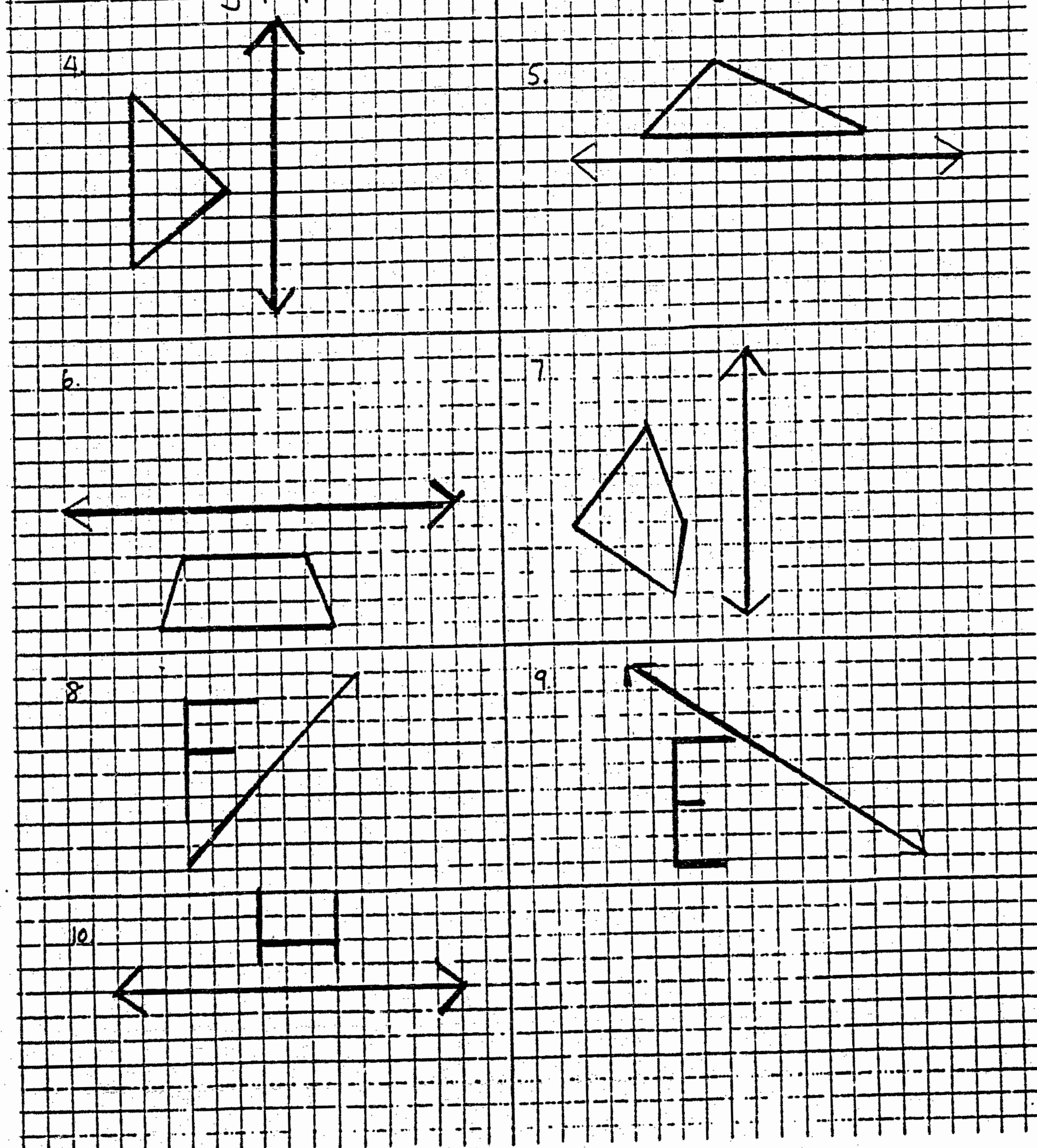
Appendix K


Lesson 2
(Page 1, tracing paper)
Use tracing paper to draw the following flip images:
1
2
3.

Appendix K continued

Lesson 2
(Page 2, tracing paper)

Use tracing paper to draw the following flip images.

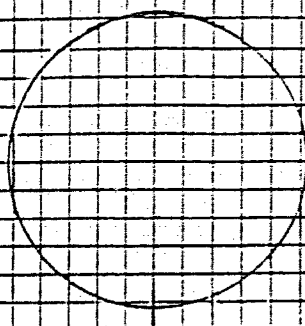


Appendix L

Lesson 3, page 1

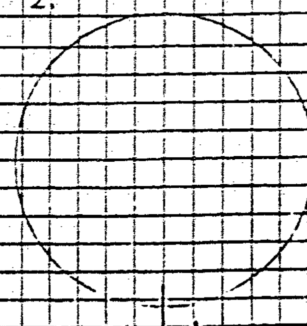
Mark the circles as indicated.

1



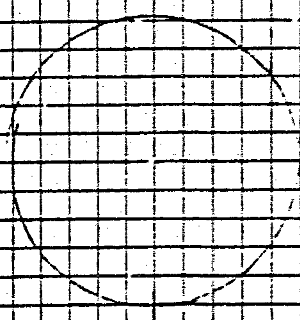
start
1/4 cw (clockwise)

2.



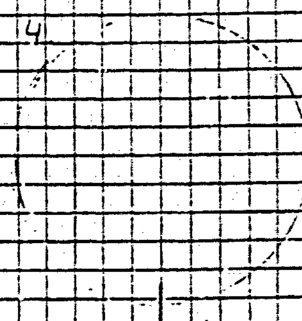
start
1/2 cw

3.



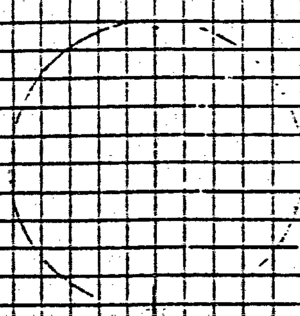
start
3/4 ccw

4



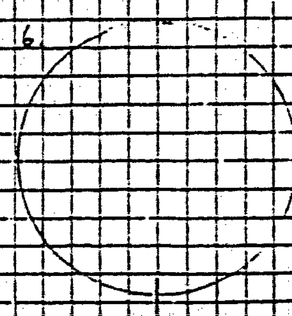
start
3/4 ccw (counterclockwise)

5.



start
1/2 ccw

6.



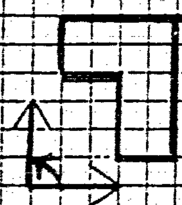
start
1/4 ccw

Appendix L continued

Lesson 3
Page 2.

Use tracing paper to turn the figure as indicated by the turn angle.

7.

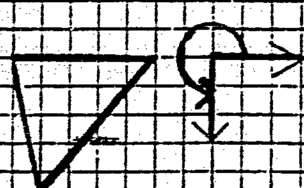


8.

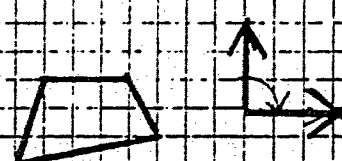
After drawing the turn image, give the turn angle of each turn above.

Do the same for the next four images.

9.



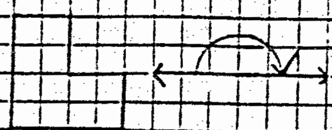
10.



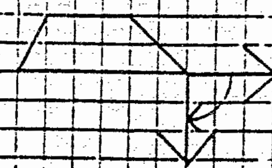
Appendix L continued

Lesson 3, page 3

11.



12.



Appendix M

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Worksheet #1	
Identification of slide rule	9
Sliding a triangular shape	5
Sliding a non-triangular shape	5

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Worksheet #2	
Flipping a triangular shape	5
Flipping a non-triangular shape	5

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Worksheet #3	
Identification of turn angle on clock	6
Identification of turn angle of image	6
Turning a triangle	2
Turning a non-triangle	4

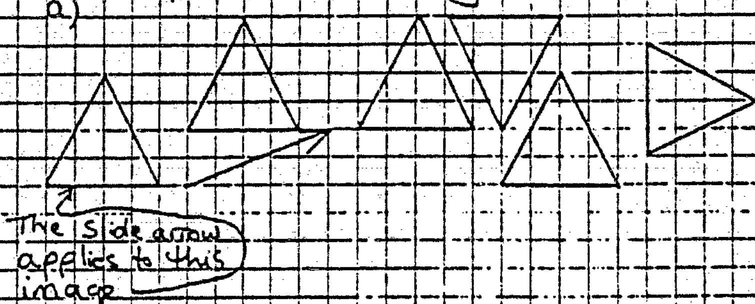
Appendix N

Lesson 1 Test, page 1

How good was my teaching?
Answer these questions to help me find out how well I taught today.

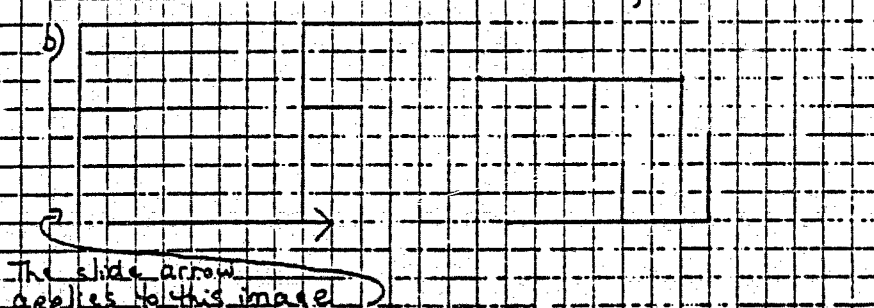
Examine the following images which one of the images on the right is the slide image of the image at the left hand margin? Circle the appropriate image.

a)



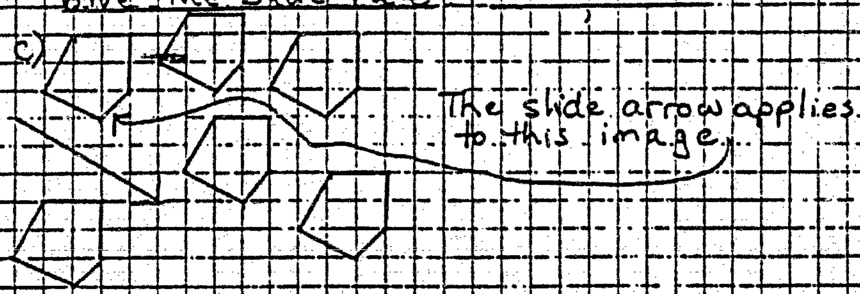
Give the slide rule: ______

b)



Give the slide rule: ______

c)



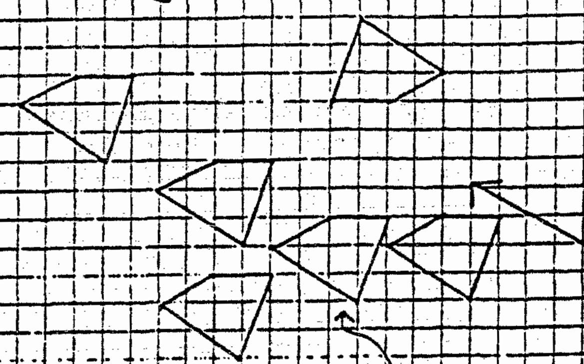
Give the slide rule: ______

Appendix N continued

Lesson 1 Test, page 2

Examine the following images. Which one of the images on the left is the slide image of the image at the right hand margin? Circle the appropriate image.

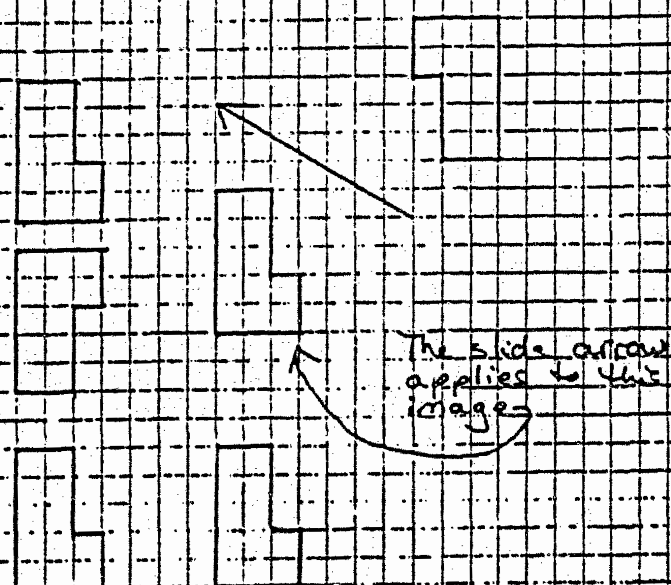
d)



The slide arrow applies to this image

Give the slide rule: ____________

e)

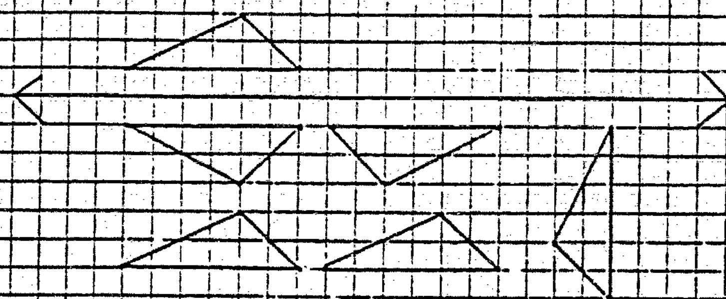


Give the slide rule: ____________

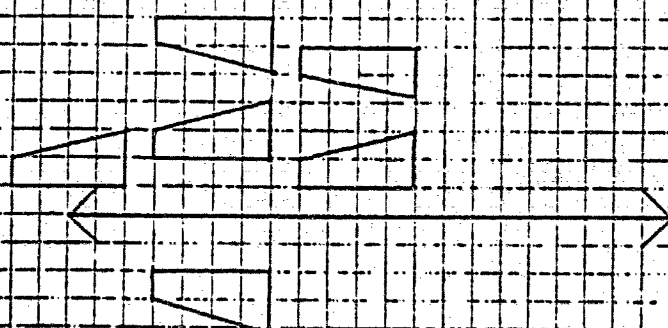
Appendix O

Lesson 2 Test page 1

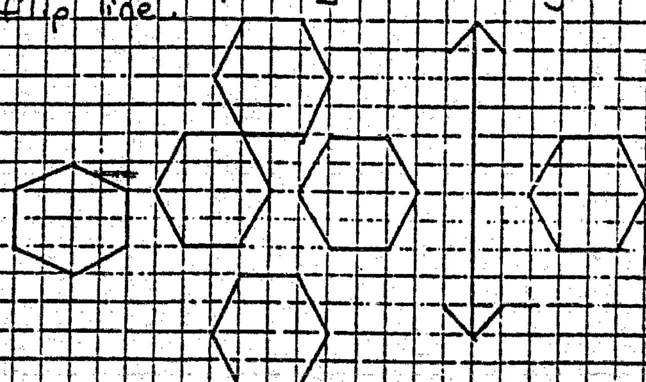
1. Circle the flip image of the figure above the flip line.



2. Circle the flip image of the figure below the flip line.



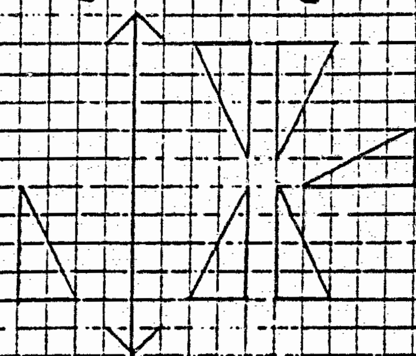
3. Circle the flip image of the figure to the right of the flip line.



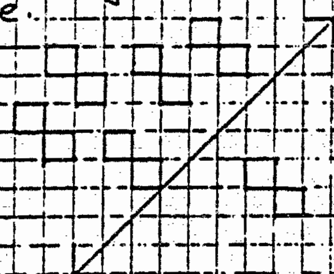
Appendix O continued

Lesson 2 Test page 2

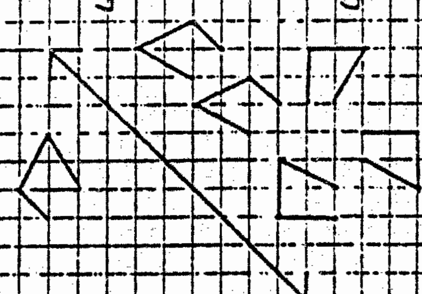
4. Circle the flip image of the figure to the left of the flip line.



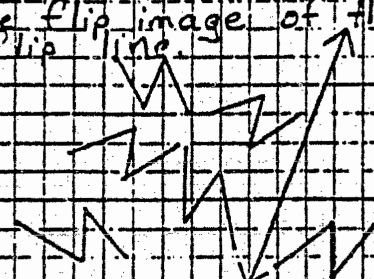
5. Circle the flip image of the figure to the right of the flip line.



6. Circle the flip image of the figure to the left of the flip line.



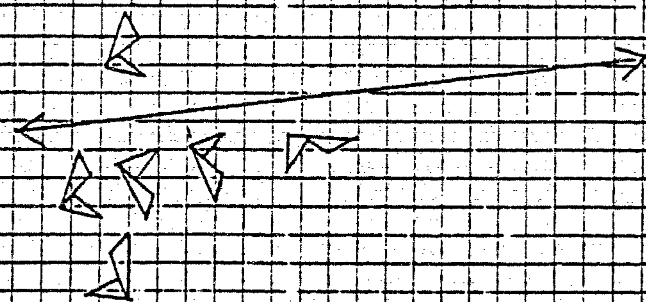
7. Circle the flip image of the figure to the right of the flip line.



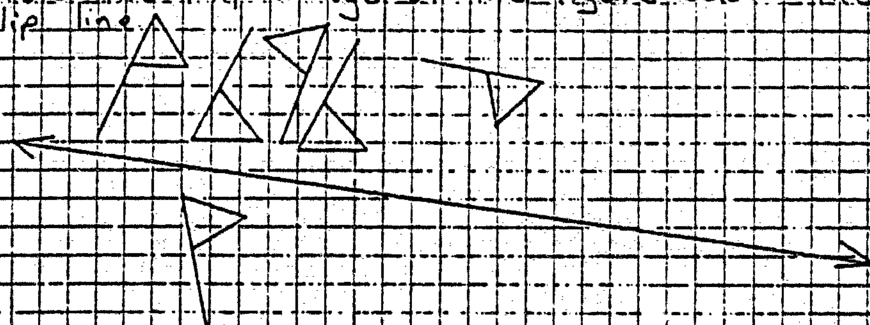
Appendix O continued

Lesson 2 Test page 3

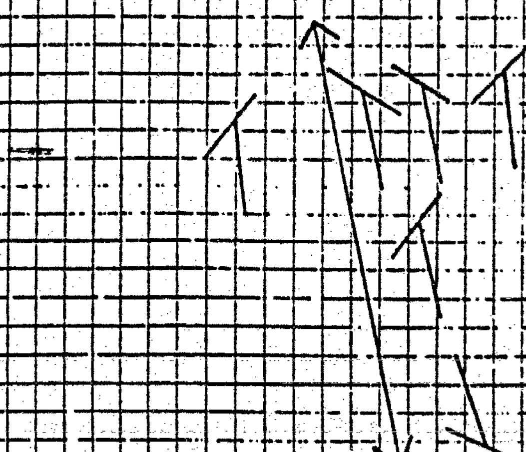
8. Circle the flip image of the figure above the flip line.



9. Circle the flip image of the figure below the flip line.



10. Circle the flip image of the figure to the left of the flip line.

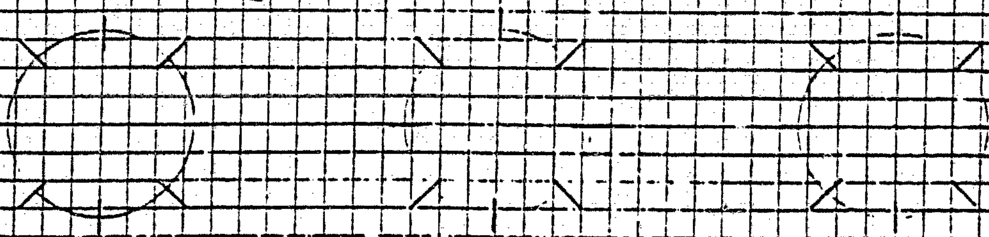


Appendix P

Lesson 3 Test page 1

How good was my teaching?
Answer these questions to help me find out how well I taught.

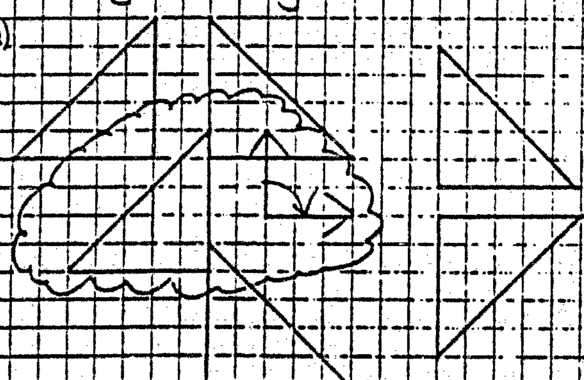
1. Which mark on the circle corresponds to the turn angle underneath it. Circle that mark.



start — 1/2 cw (clockwise)   start — 1/4 ccw (counterclockwise)   start — 3/4 cw (clockwise)

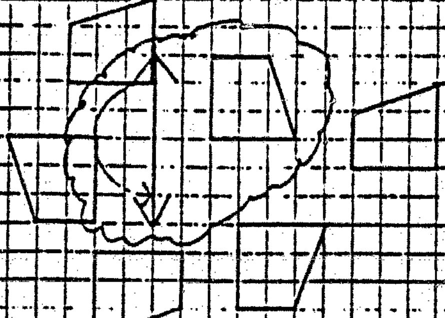
2. The following images that are circled by clouds have been turned the amount indicated by the turn angles near them. Circle their turn images and give their turn angles.

a)



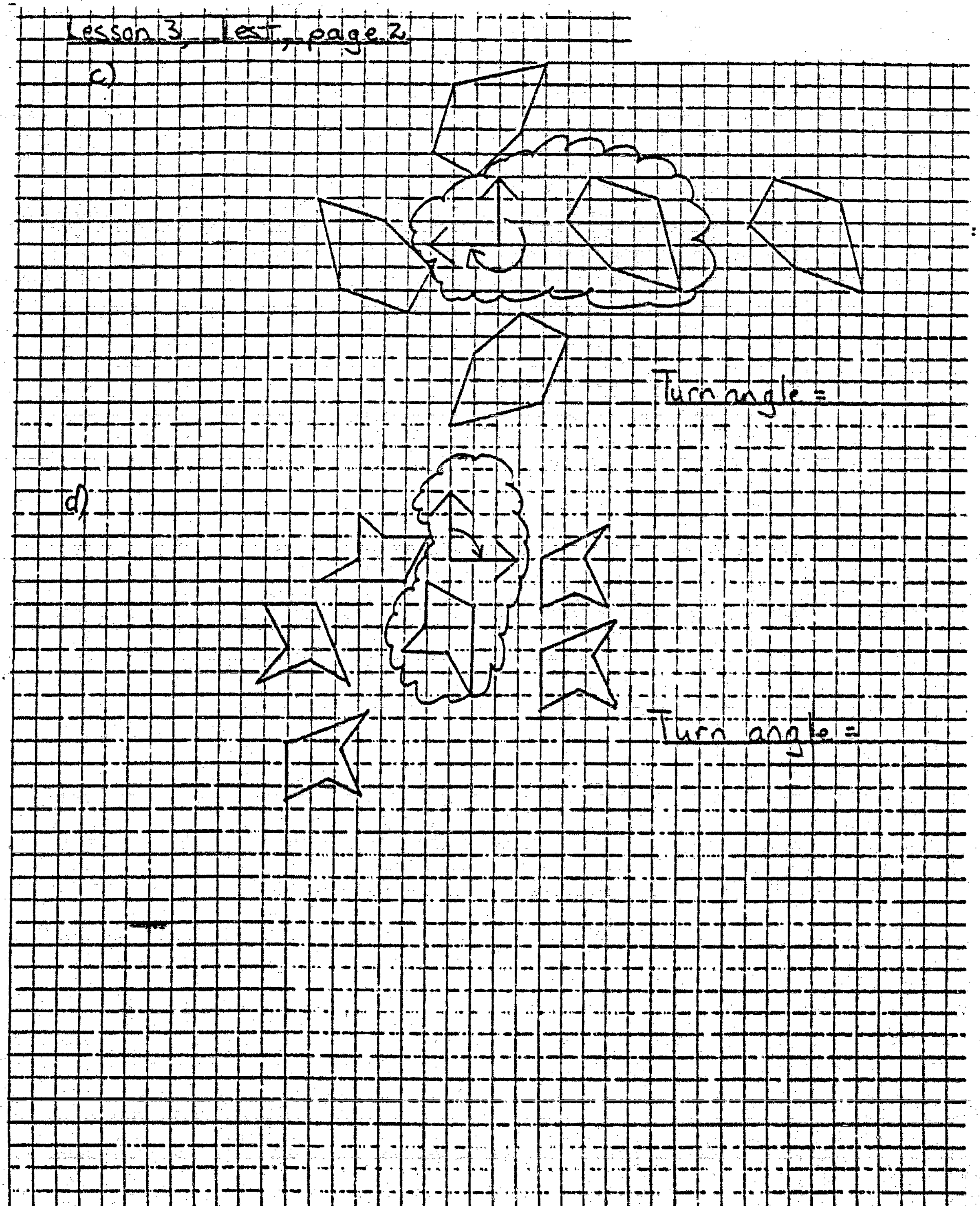
Turn angle: ______

b)



Turn angle: ______

Appendix P continued



Appendix Q

Post-tests

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Post-test 1	
Identification of slide rule	5
Sliding a triangular shape	1
Sliding a non-triangular shape	4

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Post-test 2	
Flipping a triangular shape	2
Flipping a non-triangular shape	8

Declarative and Procedural Knowledge	# of Items Assessing That Knowledge
Post-test 3	
Identification of turn angle on clock	3
Identification of turn angle of image	4
Turning a triangle	1
Turning a non-triangle	3

Appendix R

Post-Test Items Testing Specific Lesson Content

Declarative and Procedural Knowledge	Post-test Items Testing That Knowledge
Lesson 1	
a) Identification of slide rule for a slide arrow separate from procedure for sliding a triangular or non-triangular shape	2, 4, 6, 8, 10
b) Steps in sliding a triangular shape excluding identification of slide rule	1
c) Steps in sliding a non-triangular shape excluding identification of slide rule	3, 5, 7, 9
d) Combination of a + b + c: slide vocabulary and "real world" examples of slides without specification of slide procedures, slide arrows or rules	1, 2, 3, 4, 5 6, 7, 8, 9, 10
Lesson 2	
a) Steps in flipping a triangular shape	1,4
b) Steps in flipping a non-triangular shape	2, 3, 5, 6, 7, 8, 9, 10 8, 9, 10
c) Combination a + b: flip vocabulary and "real world" examples of flips without description of flip procedures	1, 2, 3, 4, 5 6, 7, 8, 9, 10
Lesson 3	
a) Identification of turn angle on clock	1, 2, 3
b) Identification of turn angle of image	5, 7, 9, 11
c) Turning a triangle	4
d) Turning a non-triangle	6, 8, 10
e) Combination a + b + c + d: turn vocabulary and "real world" examples of turns without description of turn procedures	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Appendix S

Episodic Memories Questionnaire (E.M.Q.)

Today's Date: ______________________________

Lesson: ______________________________

1. In a moment I'm going to ask you to close your eyes. When you do, I want you to think back on today's lesson and to imagine that you're watching and listening to a videotape of that lesson. I'm interested in what you recall of the lesson. However, I'm interested in more than just your recall of lesson content. I'm interested in absolutely anything you remember about what happened from the time the lesson started to when I stopped teaching. You might remember hearing words people said (you, other students, the teacher). You might remember seeing things that happened. Use the techniques you were taught on my second day here to remember as much as you can in as much detail as possible. Now, close your eyes and in your mind's eye, quickly scan the "videotape" of the lesson for the next 30 seconds.

2. Make a list of specific words you heard or events you saw during the lesson. Again, use the memory reporting techniques you were taught on my second day in the class.

____

____

____

____

____

____

____

____

____

3. Circle the items on that list that stood out for you. You may circle as many items as you like.

4a. Now, from that videotape, select one thing you remember that stood out most for you during today's lesson. Please be as specific as possible in reporting what you heard or saw happen. Remember to use the memory reporting technique you were taught the second day I was here.
Write that part down here.

4b. Help me in finding that event on the videotape. What happened just before that event?

4c. What happened just after that event?

5a. What's another specific event (if any) that stood out for you? Remember you may be recalling something you heard or something you saw. Write that event here.

5b. What happened just before that event?

5c. What happened just after that event?

6a. What's a third specific event (if any) that stood out for you? Remember you may be recalling something you heard or something you saw. Write that event here.

____

____

6b. What happened just before that event?

____

____

6c. What happened just after that event?

____

____

Appendix T

Instructions on Completion of the Card Sort Task

Background to the Study

During the fall, 1991, I taught 3 math lessons on motion geometry (slides, flips and turns) to each of five Grade 6 classes. At the end of each lesson I asked the students to list as many memories of the lesson as they could regardless of whether or not they were memories of lesson content. Then I asked students to select the three memories that stood out for them the most. Each of these remembered events appears on an index card. (If an event was reported by more than one student, it appears on only 1 index card.)

Your Task

Your task is to categorize the index cards according to a classification scheme of your own creation. The only restriction is that you have at least 2 piles/categories. However, you may use as many piles/categories as you wish. After you have completed the task, I will record the categories you've created as well as the events you put into that category. There are no right or wrong answers.

Appendix U

Letter to Number GPA Conversion Key

The following letter to number grade conversion key was used for the calculation of GPA:

A+:	4.33	C+:	2.33
A:	4.00	C:	2.00
A-:	3.67	C-:	1.67
B+:	3.33	D:	1.00
B:	3.00	F:	0.00
B-:	2.67		

If a student was in a French Immersion programme in grade 5, their grade for French was entered for their score in language arts. If two grades appeared in one subject area (e.g., language arts/reading; language arts/written expression) the two were averaged to obtain the number grade.

Appendix V

Two Factor Solution, S.R.L. DATA

	Factor 1	Factor 2
SRL1	.17925	**.35362**
SRL2	.02356	**.39001**
SRL3	.19282	**.38975**
SRL4	.26426	.29801
SRL5	**.52758**	-.03869
SRL6	.27120	**.57193**
SRL7	.32658	**.52716**
SRL8	**.50852**	.31678
SRL9	.08616	**.33599**
SRL10	**.43607**	.34899
SRL11	**.42871**	.07023
SRL12	.10608	**.30033**
SRL13	.28682	.15174
SRL14	**.46778**	-.20126
SRL15	**.56464**	.40191
SRL16	**.31372**	.19517
SRL17	**.61697**	.14324
SRL18	.19682	**-.43009**
SRL19	.00369	**.57521**
SRL20	**.37040**	.31345

Initial subscales were created from items with boldened factor loadings.

Appendix W

Two Factor Solution, I.D.Q. Data

	Factor 1	Factor 2	
IDQ1	**-.35316**	-.01515	
IDQ2	.06825	**-.52528**	
IDQ3	**.46379**	.03757	*
IDQ4	.13833	-.16843	
IDQ5	.04847	-.28875	*
IDQ6	**.40447**	-.10178	*
IDQ7	**.51386**	-.14361	*
IDQ8	-.03098	**.52072**	*
IDQ9	-.10761	**.47259**	*
IDQ10	.18578	-.28955	*
IDQ11	**-.45450**	.11298	*
IDQ12	.06425	.23535	
IDQ13	**-.55411**	-.00639	*
IDQ14	.17554	.28986	
IDQ15	**-.52838**	.10454	*
IDQ16	-.30661	**.39814**	*
IDQ17	.06758	**.40231**	*
IDQ18	**-.38219**	.12361	*
IDQ19	.09565	**-.56326**	*
IDQ20	.27552	**-.62728**	*
IDQ21	**-.54650**	.01190	
IDQ22	.11437	**.67128**	*
IDQ23	.23900	**-.47777**	*
IDQ24	**.58865**	-.00824	*
IDQ25	-.11484	**.40986**	*
IDQ26	**-.44749**	.15640	*
IDQ27	**-.39890**	-.02282	*
IDQ28	**.51751**	-.20771	*
IDQ29	**.43166**	-.01936	*
IDQ30	-.15171	**.54763**	*

I.D.Q. Verbal and Imaginal subscales were created from items with boldened factor loadings.

Asterisked items loaded in similar ways in both Specht's (1992) and the present factor analysis procedures.

Appendix X
Pearson R Correlations Among All Variables

	SRL	GPA	IDQV	IDQI	IDQ Sum
SRL	1.00	-.08	.15	.31	.27
n	0	108	113	113	109
p	.	.42	.11	<.01	<.01
GPA		1.00	.31	.17	.30
n		0	103	106	100
p		.	<.01	.09	<.01
IDQV			1.00	.27	.85
n			0	109	109
p			.	<.01	<.01
IDQI				1.00	.74
n				0	109
p				.	<.01

	Memories Lesson 1	Memories Lesson 2	Memories Lesson 3	Memories Total
SRL	.25	.04	.20	.20
n	115	110	112	106
p	<.01	.66	.04	.04
GPA	.49	.32	.30	.48
n	109	104	107	100
p	<.01	<.01	<.01	<.01
IDQV	.25	.09	.14	.19
n	110	105	107	101
p	<.01	.38	.15	.06
IDQI	.13	-.06	.05	.06
n	111	107	109	103
p	.19	.55	.58	.52
IDQ Sum	.23	.01	.08	.15
n	109	105	107	101
p	.02	.93	.40	.12

	Memories Lesson 1	Memories Lesson 2	Memories Lesson 3	Memories Total
Memories Lesson 1	1.00	.52	.45	.82
n	0	113	116	109
p	.	<.01	<.01	<.01
Memories Lesson 2		1.00	.35	.78
n		0	113	109
p		.	<.01	<.01
Memories Lesson 3			1.00	.77
n			0	109
p			.	<.01

	Quiz Lesson 1	Quiz Lesson 2	Quiz Lesson 3	Quiz Total
SRL	<.01	-.12	-.04	-.07
n	114	111	113	106
p	.93	.21	.67	.50
GPA	.48	.50	.56	.63
n	109	105	107	100
p	<.01	<.01	<.01	<.01
IDQV	.19	.05	.04	.13
n	110	106	108	102
p	.05	.63	.67	.20
IDQI	.20	.01	.06	.12
n	111	107	110	102
p	.03	.94	.53	.21
IDQ Sum	.22	.02	.04	.14
n	106	102	104	98
p	.02	.81	.66	.16
Memories Lesson 1	.35	.25	.38	.38
n	117	112	113	109
p	<.01	<.01	<.01	<.01
Memories Lesson 2	.26	.21	.27	.29
n	110	113	111	108
p	<.01	.03	<.01	<.01

	Quiz Lesson 1	Quiz Lesson 2	Quiz Lesson 3	Quiz Total
Memories Lesson 3	.22	.08	.21	.20
n	113	112	116	109
p	.02	.39	.02	.04
Memories Total	.31	.23	.35	.36
n	108	109	109	108
p	<.01	.02	<.01	<.01
Quiz Lesson 1	1.00	.39	.65	.83
n	0	111	113	109
p	.	<.01	<.01	<.01
Quiz Lesson 2		1.00	.51	.76
n		0	112	109
p		.	<.01	<.01
Quiz Lesson 3			1.00	.88
n				109
p				<.01

Appendix Y

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Slide Rules, Lesson 1

NUMBER OF ITEMS CORRECT	0	1	2	3	4
5	3	4	4	1	1
4	7	3	3		
3	4	2	2		
2	5	3	3		
1	6	3	1	2	
0	36	15	7	2	

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Sliding a Triangular Shape, Lesson 1

NUMBER OF ITEMS CORRECT	0	1	2
1	44	21	3
0	28	19	3

NUMBER OF EVENTS REPORTED

Table 8
Frequency Plot of No. of Events Reported and No. of Items Correct Related to Sliding a Non-Triangular Shape, Lesson 1

NUMBER OF ITEMS CORRECT	0	1	2
4	31	3	1
3	20	3	
2	15	2	
1	19		
0	24		

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Slide Rules, Sliding Triangular Shapes and Sliding Non-Triangular Shapes, Lesson 1

NUMBER OF ITEMS CORRECT	0	1	2
10	7	1	
9	10	1	
8	3		
7	7	1	
6	8		
5	13	1	1
4	10		1
3	14		
2	12	1	
1	12		
0	14	1	

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Flipping a Triangular Shape, Lesson 2

NUMBER OF ITEMS CORRECT	0	1	2	3
2	61	26	3	1
1	11	4		
0	7	1		

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Flipping Non-Triangular Shapes, Lesson 2

NUMBER OF ITEMS CORRECT	0	1	2
8	29	3	3
7	14	7	1
6	19	2	
5	9	4	1
4	1	1	
3	3	2	
2	3		
1	2		
0	10		

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Flipping Triangular and Non-Triangular Shapes, Lesson 2.

NUMBER OF ITEMS CORRECT	0	1	2	3
10	17	12	6	
9	12	3	3	1
8	15	3	2	1
7	9	5	1	1
6	1			
5	2	1		
4	1	3		
3	4			
2	1	2		
1	0	1	1	
0	3	3		

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Identification of Turn Angle on Clock, Lesson 3.

NUMBER OF ITEMS CORRECT	0	1	2
3	34	24	5
2	16	13	
1	10	1	1
0	12		1

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Identification of Turn Angle for Turned Image, Lesson 3.

NUMBER OF ITEMS CORRECT	0	1	2
4	47	6	3
3	9	1	
2	8		
1	11	2	
0	28	2	

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Turning a Triangle, Lesson 3.

NUMBER OF ITEMS CORRECT		0	1
	1	57	4
	0	54	2

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Turning a Non-Triangle, Lesson 3

NUMBER OF ITEMS CORRECT		0	1	2	3
	3	26	6		1
	2	23	10	1	
	1	9	2		
	0	36	5		

NUMBER OF EVENTS REPORTED

Frequency Plot of No. of Events Reported and No. of Items Correct Related to Identifying Turn Angles on Clocks and Images, Turning Triangular and Non-Triangular Shapes, Lesson 3.

NUMBER OF ITEMS CORRECT		0	1	2	3
	11	20	2		
	10	7	5		
	9	9	1		
	8	7	1		
	7	5	1		1
	6	10	1		
	5	6			
	4	11	1		
	3	16	1		
	2	5	1		
	1	4			
	0	1	1		

NUMBER OF EVENTS REPORTED