UNIVERSITY OF ALBERTA

Effectiveness of Instructor-Provided and Student-Generated Spatial Synthesizers on Learning from Prose

BY

Mohamed Ally ©

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DEDICATION

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ABSTRACT

The strategies one uses to study prose materials determines the amount and level at which the material is learned. According to schema theory, comprehension is facilitated when there are existing schemas to assimilate the new information. The network structure of spatial synthesizers could provide a framework in semantic memory to assimilate learning materials.

The present study investigated whether an instructor-provided or a student-generated spatial synthesizer facilitated learning from prose materials as measured by immediate, and delayed, cued recall and comprehension tests. A no-synthesizer group was used as a control group. Also, this study investigated who benefitted more from the spatial synthesizer, males or females, having either high or low spatial ability, and either high or low verbal ability.

Subjects were 162 students from a technical institute. The subjects were randomly assigned to either a student-generated synthesizer group, an instructor-provided synthesizer group or a no-synthesizer group. The General Aptitude Test Battery (GATB) spatial and verbal subtests measured subjects' spatial and verbal ability.

Results indicated that the provided-synthesizer group performed better than did the generated-synthesizer and the no-synthesizer groups on the immediate, cued recall test. There was no significant difference between the treatment groups on the immediate, comprehension test and the delayed, cued recall and comprehension tests. There was no significant relationship between

spatial ability scores and scores on the immediate, and delayed, cued recall and comprehension tests. There was a significant relationship between verbal ability scores and scores on the delayed, comprehension test. High spatial ability subjects performed better than did low spatial ability subjects on the delayed, cued recall test and on the immediate, comprehension test. There was a significant interaction between verbal ability level and treatment group. Also, high verbal ability subjects outperformed low verbal ability subjects on the immediate, and delayed, cued recall tests and on the delayed, comprehension test. There was no significant difference between males and females on the immediate, and delayed, cued recall and comprehension tests. The results suggested that instructors, textbook authors, and course developers should provide spatial synthesizers as a learning strategy.

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CHAPTER 1

Introduction

According to the tetrahedral model of text processing (Brown, Campione, and Day, 1981), four variables determine what is learned from textual materials. These variables are the characteristics of the learner, the characteristics of the text, the learning goals, and the strategies used to process text.

Cognitive psychology advocates that learning is an active, constructive, and goal-oriented process that is dependent on the way the learner processes the learning materials (Shuell, 1986). According to the multi-store memory model (Atkinson & Shiffrin, 1968), when students encounter some learning materials, the information is perceived, transferred into sensory storage, then goes temporarily into short-term memory where it is processed and transferred into long-term memory. The way in which the information is processed in short-term memory determines how the information is stored in long-term memory and the ease with which it is retrieved.

Semantic Memory

For someone to learn from a prose passage, the structure of the information in the passage has to be stored in memory to assist the integration of the details of the passage. Semantic memory is hypothesized to be a network structure in which concepts are represented as nodes (Collins & Quillian, 1969; Collins & Loftus, 1975; Rumelhart & Ortony, 1977). Related concepts in the network are connected to show their relationships. The more associated two concepts are, the greater the degree of linkages between the concepts (Gitomer & Pellegrino, 1983). Information in semantic memory is well organized, cross-referenced, and can be rearranged to suit particular tasks. Collins and Loftus (1975) proposed the spreading activation model in which each concept is represented by a node and the nodes are connected by labelled lines. The concepts are organized according to semantic similarity rather than in a hierarchical order. Hence, concepts that are similar are closer together in the network. The way the information is organized in semantic memory determines what is retrieved and how much is retrieved. A recent theory that addresses the development of memory structure in semantic memory is schema theory.

Schema Theory

It is hypothesized that when someone reads a text, the information gets integrated into existing networks of information or schema (Anderson, 1977; Howard, 1987; Rumelhart & Ortony, 1977). A schema is an organized body of knowledge that represents some part of a domain (Howard, 1987). Schemas provide much of the basis for comprehending, learning, and remembering the information in textual materials (Anderson, 1985). A schema is a representation of a domain abstracted from experience that is used to understand the world (Howard, 1987). A schema consists of sets of expectations about how part of the world is organized. Some examples of schema are a face schema, a house schema, and a telephone schema. For example, when someone notices a line drawing of a door and some windows, that person uses the existing schema for a house from past experience to fill in the details for the house.

Role of schema in comprehension. According to Anderson (1977) and Rumelhart (1980), in order for comprehension to occur, one has to select a schema that provides a suitable account of the information and assimilate the information to the existing schema. The structure of existing schema can affect how much is recalled. The more developed and related the existing schema, the more information is assimilated and hence, there is a better chance of subsequently recalling the information (Howard, 1987). A schema affects the recall of meaningful material in two ways (Rumelhart, 1980). People tend to remember the instantiated schema of some event rather than the event itself and as a result, a schema can affect the form in which the information is learned. In addition, one takes in data relevant to existing schema.

A spatial learning strategy such as a synthesizer could be used to activate an existing schema to aid assimilation of learning materials or build a framework to accommodate learning materials (Peresich, Meadows, Sinatra, 1990). R[illegible]80) claimed that comprehension may fail to occur because (a) the pers[illegible] know an appropriate schema and cannot readily construct a schema, (b) a person has an appropriate schema but a given situation does not give enough clues to elicit the schema, or (c) a person applies to the text a different schema from that intended by the author. Spatial learning strategies such as synthesizers, networks, knowledge maps, etc. could be used in instruction to help students discover an author's structure of the learning material. Knowing the structure of the learning material provides a general framework to encode the details of the materials. Howard (1987) proposed that teachers and textbook authors need to tailor materials to fit students' existing schema so that the materials can be assimilated easily. If assimilation of the materials does not occur, the materials may be learned by rote and will not be retained efficiently. However, if a student does not have an existing schema, then the materials should be designed in such a way to build the appropriate schema to assimilate the material. The material could be structured to reflect students' existing frameworks or provide a general framework so that students can attach the new materials.

Learning from Prose Materials

It is known that one of the best predictors of learning from prose material is the manner in which the material is processed cognitively. The deeper the student processes the information (Craik and Lockhart, 1972) and the more effort the student exerts on the learning task (Wittrock, 1974, 1979), the more efficiently the information is stored. As a result, a more elaborate schema is formed and retrieval is facilitated. To promote learning, students should be allowed to generate their own learning strategies to encourage depth of processing (Armbruster & Anderson, 1984; Craik and Lockhart, 1972) and generative processing (Wittrock, 1974). Recently, Lockhart and Craik (1990) claimed that memory performance is directly related to the nature of the processing underlying the original experience. Skaggs, Rocklin, Dansereau, Hall, O'Donnell, Lambiotte, & Young (1990) found that high scores obtained on a deep processing task that asked subjects to critically evaluate, and compare and contrast information facilitated the recall of information. It appears that when subjects were asked to generate a learning strategy and actively process the information, recall was facilitated.

However, most research studies (Ausubel, 1960, 1963; Bransford & Johnson, 1972; Hartley, 1973; Kaplan & Simmons, 1974; Kiewra, DuBois, Christian, McShane, 1988) have investigated learning strategies that are provided for students rather than student-generated. These provided strategies tend to facilitate shallow processing of the materials. Results from some of these studies have shown that learning strategies that are provided for students, facilitate recall of the details in the materials rather than recall of general ideas.

A limited number of studies (Brody & Legenza, 1980; Dansereau, 1989; Dean & Kulhavy, 1981; Kiewra, 1988; Skaggs et al., 1990) have examined the effect of asking students to generate their own learning strategies. These studies have shown that asking students to generate their own learning strategies facilitated recall. However, these studies did not examine the effects of student-generated learning strategies on comprehension.

The present study contributed to the research by comparing a provided learning strategy (spatial synthesizer) with a student-generated learning strategy (spatial synthesizer) on recall and comprehension. A no-synthesizer group served as a control group.

Pre- vs Post-instructional Strategies

The majority of previous learning strategy research studies (Ausubel, 1960, 1963; Hartley, 1973; Kaplan & Simmons, 1974) examined pre-instructional learning strategies rather than post-instructional learning strategies. Pre-instructional strategies are given before the materials are presented while post-instructional strategies are given after the materials have been presented. Some common types of pre-instructional strategies are advance organizers (Ausubel, 1960, 1963); pretest questions (Hartley, 1973; Rothkopf, 1970); and objectives (Dalis, 1970; Huck & Long, 1973; Lawson, 1973). Only a few studies have attempted to look at post-instructional strategies such as notes (Kiewra, 1988; Peper & Mayer, 1986), graphic post-organizers (Barron, 1980; Moore & Readance, 1979), maps (Dansereau, 1989; Dansereau, Collins, McDonald, Holley, Diekhoff, & Evans, 1979), and synthesizers (Chao & Reigeluth, 1986; McLean, Yeh, & Reigeluth, 1983).

Pre-instructional strategies have been found to facilitate the encoding of detailed materials. In addition, using a pre-organizational strategy (encoding strategy) as a post-organizational strategy (just before retrieval) facilitates performance (Corkill, Bruning, Glover, & Krug, 1988; Tulving, 1985). The present study contributed to the post-instructional strategy research by determining the relative effectiveness, on recall and comprehension, of a student-generated and an instructor-provided spatial synthesizer after students had read a prose passage.

Prose vs Visual/Spatial Learning Strategies

The majority of learning strategy research has examined prose learning strategies such as advance organizers (Ausubel, 1960, 1963), objectives (Dalis, 1970; Huck & Long, 1973; Lawson, 1973), and questions (Hartley, 1973; Rothkopf, 1970). Due to the recent development of spatial learning techniques, little research has been conducted to test their effectiveness. Limited studies have been conducted on spatial learning strategies such as graphic organizers (Barron, 1980; Moore & Readance, 1979; Snowman & Cunningham, 1975), maps (Alesandrini, 1981; Dansereau, 1989; Dansereau et al., 1979; Dean & Kulhavy, 1981; Schwartz & Kulhavy, 1981; Skaggs, Dansereau, & Hall, 1989; Skaggs & Hall, 1989) and synthesizers (Chao & Reigeluth, 1986; McLean, Yeh, & Reigeluth, 1983), which utilized both the visual and verbal subsystems of the learner. The present study contributed to the literature by examining the effectiveness of a spatial learning strategy (synthesizer) on learning from prose materials.

Individual Differences in the Use of Learning Strategies

Some studies have looked at individual differences such as ability level (Camstra & Van Bruggen, 1984; Holley & Dansereau, 1984; Swing & Petersen, 1988; Winn & Sutherland, 1989), and grade point average (Holley, Dansereau, McDonald, Garland, & Collins, 1979) in the use of learning strategies. However, research on whether there is any relationship between spatial ability and verbal ability and the use of spatial strategy is limited (Wiegmann, Dansereau, Pitre, Rewey, & McCagg, 1990). The present study investigated the relationship between spatial and verbal ability and the use of spatial learning strategies, such as synthesizers, when learning from prose materials.

Past studies claimed that males tend to have superior spatial ability when compared to females (McGee, 1979a). As a result, one could hypothesize that males use spatial strategies more effectively than females. However, there seems to be no research that has investigated gender difference in the use of spatial learning strategies. The present study investigated whether there were any differences between males and females in the use of a spatial synthesizer.

In addition, Waddill, McDaniel, and Einstein (1988) claimed that almost all visual/spatial research has been conducted with children. With more emphasis on adult learning and retraining, there is a need to determine how spatial learning strategies influence adult learners. The present study contributed to the literature by using adult technical institute students as subjects.

Conclusion

The present study compared technical institute students who used either a student-generated spatial learning strategy (synthesizer) or an instructor-provided spatial learning strategy (synthesizer) after reading a prose passage. The present study also investigated whether there was any relationship between spatial ability, verbal ability and the use of a spatial learning strategy when learning from a prose passage. In addition, the present study investigated whether either males or females benefitted more from a spatial learning strategy (synthesizer). Performance was measured by immediate, and delayed, cued recall and comprehension tests. The next section defines the terms that were used in the present study. The next chapter reviews the literature and theories related to the current study.

Definition of Terms

The terms used in the present study are defined below.

Inferential Comprehension: the ability to integrate information from more than one part of a reading passage or the development of general ideas to reflect different parts of the passage (Anderson, 1972; Barrett, 1968).

Concept Map: a two-dimensional diagram that shows the structure of the subject matter (Novak & Gowin, 1984; Novak, Gowin, & Johanse, 1983).

Cued Recall: the ability to use the information given as a cue to recall information from the reading passage. The recalled information could be the same as it appears in the passage or in the student's own words (Anderson, 1972; Barrett, 1968).

Generated Spatial Synthesizer: a spatial synthesizer that is generated by students after reading a prose passage.

Instructional Strategy: a strategy that is embedded in learning materials for students' use.

Learning Strategy: a strategy that students use to learn prose materials.

Map: a method for representing the ideas in a textual passage in the form of a diagram (Armbruster & Anderson, 1984).

Mind Map: a spatial outline of a topic for a lesson or a reading passage (Buzan, 1983).

Network: a spatial or graphic outline of information in a passage or topic to show the relationships between the ideas in the passage or topic (Dansereau, 1989; Holley & Dansereau, 1984).

Pre-instructional Strategy: a strategy that is given before students start reading or studying the learning material.

Post-instructional Strategy: a strategy that is given after students have read or study the learning material.

Provided Spatial Synthesizer: a spatial synthesizer that is provided for students to use while learning prose materials.

Schema: an organized body of knowledge extracted from experience that is used to interpret new information to make it a part of the knowledge store (Anderson & Pearson, 1984; Howard, 1987; Rumelhart, 1980).

Spatial Ability: the ability to generate, retain, and transform abstract visual images (Kyllonen, Lohman, & Snow, 1984) as measured by the General Aptitude Test Battery (GATB) spatial subtest.

Spatial Learning Strategies: learning strategies that require the use of graphics or diagrams to show the structure of the reading material and the relationships between ideas in the reading material.

Spatial Synthesizer: a spatial or graphic representation to relate and integrate the individual ideas of a single type of content to teach the interrelationships between the ideas (Reigeluth, 1983, 1987; Reigeluth & Stein, 1983; Van Patten, Chao, & Reigeluth, 1986).

Verbal Ability: any cognitive activity that involves the recognition, retrieval, and understanding of linguistic forms (Perfetti, 1983) as measured by the GATB verbal subtest.

CHAPTER 2

Review of the Literature

The literature review outlines the theories that support the present study and reviews the related research. The major sections discussed are information processing, the level of processing theories, different types of learning strategies, spatial learning strategies, spatial synthesizers, instructor-provided vs student-generated learning strategies, spatial and verbal abilities, and gender differences in spatial ability. Shortcomings in previous studies and areas where more research is needed are identified in each section. Finally, the hypotheses tested in the present study are listed.

Information Processing and Memory

Jenkins (1979) proposed that individual differences in text processing can be attributed to five main factors. These are verbal ability, prior knowledge of the materials, the criterial tasks, the characteristics of the materials, and the orienting tasks or learning strategies. The present study focused on the learning strategy factor, identified by Jenkins (1979), by investigating the use of a generated and a provided spatial synthesizer when learning from prose materials. Dansereau (1985) claimed that students' capacity for acquiring and using information could be enhanced with appropriate information processing strategies.

According to schema theory, comprehension depends on (a) the learner's knowledge of the characteristics of the message, (b) the context in which the information is given, and (c) the effort to relate the incoming idea units to each other and to previously acquired information (Weinstein & Underwood, 1985). Hence, comprehension is facilitated by requiring students to actively process the information and at the same time, relate the parts of the information to each other as in a spatial learning strategy. Spatial location in a spatial learning strategy is a type of contextual cue that is encoded with the memory representation of an item (Skaggs & Hall, 1989). The way spatial maps are stored in memory facilitates recall of textual information presented within the map (Dean & Kulhavy, 1981; Schwartz & Kulhavy, 1988).

According to the elaboration hypothesis (Reder, 1985), long-term memory is a network of interconnected propositions. When a person reads information, new information is added to a network in long-term memory (Reder, 1985). The structure of the information in long-term memory is consistent with the network models of memory (Bobrow & Winograd, 1977; Quillian, 1969; Rumelhart, Lindsay, & Norman, 1972). According to the network model of memory, propositional networks are arranged hierarchically showing the relationships between concepts ideas in the network. The networking process involves the identification of concepts or ideas showing the relationships between the concepts and ideas in the form of a network diagram. The nodes and lines in the network diagram represent the concepts or ideas and the relationships between the concepts or ideas. Hence, it appears that the way students process information from a prose passage depends on the learning strategies used while reading the passage.

Levels of Processing

Craik and Lockhart (1972) claimed that there is only one memory system with unlimited capacity; this conceptualization is equivalent to Atkinson and Shiffrin's (1968) concept of a long-term memory. According to Craik and Lockhart (1972), selected information in memory is processed through maintenance rehearsal to keep the information in conscious awareness for a certain time and through elaborative rehearsal to encourage permanent storage in memory.

It is hypothesized that the more effort one uses during a learning task, the more deeply the information is processed, resulting in a more permanent trace in long-term memory (Craik & Lockhart, 1972). The levels of processing hypothesis was expanded recently by Lockhart and Craik (1990) who claimed that memory performance not only depends on the time and effort at the time of encoding but also on the quality of the encoding. For example, summarizing a prose passage involves deeper processing than simply reading the prose passage. Ferguson-Hessler and de Jong (1990), used university students as subjects to investigate whether there were any differences in study processes between good and poor problem-solvers. Results indicated that good problem-solvers generally employed more deep processing when studying a physics text than did poor problem-solvers. Hence, the method used to process information and solve problems may facilitate encoding and retrieval.

Some theorists (Kulhavy, Lee, and Cateriono, 1985; Paivio, 1971, 1986) claimed that asking students to summarize prose materials in a spatial format encouraged better storage and retrieval of the information. The spatial summarizing process allows students to transform the prose material into a nonverbal format which makes use of the spatial subsystem of the information processing system. The spatial summarizing strategy allows students to see the major ideas and their relationships simultaneously which is not possible while reading prose materials (Paivio, 1986). Von Eye, Dixon, & Kampen (1989) claimed that for deep processing to occur, students should see the gestalt of the materials by discovering how the ideas are related to each other. Generated spatial learning strategies such as, spatial synthesizers, maps, and networks allow students to process prose materials at a deep level and see the general structure of the materials and the relationships between the ideas in the materials.

Verbal vs Visual/Spatial Processing

Kulhavy, Lee, and Cateriono (1985) proposed the conjoint retention hypothesis which states that verbal and spatial information are processed separately. As a result, learning is enhanced since learners can use both the verbal and spatial encoded representations at the time of retrieval. There is a better chance of retrieving information coded in both the verbal and spatial modes rather than in a single mode. Similarly, Paivio (1986) claimed that information is processed by two separate subsystems. One for the representation and processing of information for nonverbal events and the other for the processing of language.

Visuals, when added to prose, improved comprehension of the prose materials (Dean & Enemoh, 1983). Dwyer (1978) gave twenty-two reasons why the use of visuals could facilitate learning from prose materials. The three reasons related to the present study are (a) to illustrate spatial relationships, (b) to summarize important points in a lesson, and (c) to present relationships between ideas. Levin and Lesgold (1978) described some of the functions of pictures in the processing of prose materials. These functions include reiteration, representation, organization, interpretation, and transformation. Pictures can be reiterative by providing redundant information or additional information to verbal materials. Pictures can represent prose materials in a different form which makes it more concrete for learners. Pictures can act as an organizational tool for unstructured and difficult prose materials. Pictures can be interpretive by providing a framework for students to relate existing knowledge. Pictures can also provide a transformation function by representing text in a visual mode which is more accessible when compared to prose materials. The functions of pictures as outlined by Levin and Lesgold (1978) was corroborated by Szabo, Dwyer, and DeMelo (1981) who found increased retrieval of information as a result of a testing situation which had similar features present at the time of encoding.

Learning Strategies

Learning strategy seems to be used to describe many different processes in learning (Derry, 1989). The term learning strategy is used to refer to (a) specific learning tactics such as rehearsal, imaging, and outlining; (b) self-management activities such as planning, and comprehension monitoring; and (c) complex plans that combine several specific techniques. Derry and Murphy (1986) defined a learning strategy as a collection of mental tactics employed by an individual in a particular learning situation to facilitate acquisition of knowledge or skill. Dansereau (1985) defined a learning strategy as a set of processes or steps that can facilitate the acquisition, storage, and utilization of information. Rigney (1978) proposed that learning strategies are always employed by students either on their own or from instructions that are provided during the learning process. Stevens (1988) claimed that informing students of the importance of using learning strategies increased both the use and retention of the learning strategies. Learning strategies for promoting comprehension and retention should focus attention on important ideas, build appropriate schema, and encourage elaboration (Derry, 1989). Levin (1986) claimed that the type of learning strategy used depends on the learning outcome and nature of the instructional materials. Derry and Murphy (1986) hypothesized that if a passage is not highly structured and the primary aim of the reading is to comprehend and remember important ideas, then one should use a strategy that combines a spatial learning strategy with idea elaboration. The different types of learning strategies are explored in the next section.

Types of Learning Strategies

Learning strategies can take two forms (Rigney, 1978). They can be detached or content independent such as, instructions to form pictures, to develop synthesizers, or to think of analogies. Learning strategies can also be embedded or content dependent such as, asking questions on the content to process the information at a deep level.

Dansereau (1985) suggested that learning strategies may have many characteristics. A strategy may have direct impact on the information to be learned (primary strategy) or it may have an indirect impact by improving the learner's cognitive skills (support strategy). A strategy may be algorithmic (sequences of processes that remain fixed over tasks) or heuristic (a sequence of processes that may be modified, depending on the learning requirements and the learner).

An example of a learning strategy is the SQ3R (Survey-Question-Read-Recite-Review) strategy (Baine, 1986; Robinson, 1946) where students are asked to survey the materials, ask questions based on the survey, read the materials to find answers to the questions, recite the answers to the questions, and review the materials. Briggs, Tosi, and Morley (1971) found that students trained to use the SQ3R method obtained a GPA of 2.55 compared to 1.70 for a control group. A second learning strategy that was found to be effective is the Node Acquisition and Integration Technique (NAIT) (Dickhoff, Brown, and Dansereau, 1982). The four steps involved are (a) identification of the key concepts, (b) specification of the relationships between concepts, (c) elaboration of the materials, and (d) relationship comparisons to show similarities and differences. Another learning strategy is Concept Structuring, described by Vaughan (1984). The Concept Structuring strategy involves surveying prose materials to identify major topics or ideas, reading the materials from an analytical view, and reading the materials again to make sure nothing was left out.

The strategies mentioned above are examples of generic learning strategies. Some specific learning strategies that are provided for students or are generated by students are explored in the next section.

Provided- vs Learner-Generated Strategies

Di Vesta and Rieber (1987) distinguished between provided-strategies and learner-generated strategies. Provided learning strategies are strategies given to learners to help process learning materials. Learner-generated strategies are strategies that learners spontaneously use while studying prose materials. Some well known provided-strategies are advance organizers (Ausubel, 1960; Hartley & Davies, 1976), pre-questions (Hartley & Davies, 1976; Mayer, 1984), behavioral objectives (Hartley & Davies, 1976; Kaplan & Simmons, 1974), and pictures (Brody & Legenza, 1980). These provided-strategies are usually given before the materials as pre-instructional strategies or after the materials as post-instructional strategies. The provided-strategies are known to improve learning of factual and specific information (Gropper, 1983; Hannafin, 1987).

On the other hand, learner-generated strategies include note-taking, outlining, concept mapping, synthesizer generation, and elaboration. These learning strategies are generated by a learner either while studying the materials or after studying the materials to promote both encoding and retrieval. Learner-based strategies facilitate both encoding and retrieval while the provided-strategies facilitate encoding only. Ausubel (1963, 1968) proposed the use of an advance organizer as an organizational strategy at the time of encoding. However, the use of an encoding strategy does not guarantee successful retrieval. Repeating the context of encoding at the time of retrieval improves memory performance (Rabinowitz & Craik, 1986; Tulving, 1985).

Rereading an advance organizer at the time of retrieval improved recall and memory performance (Corkill, Bruning, Glover, & Krug, 1988). Corkill et al. (1988), used university education students as subjects and a reading passage on the solar system to investigate the effects of providing an advanced organizer just before retrieval. Results revealed that subjects who paraphrased the organizer at encoding and received the organizer again at retrieval recalled more essay content than did subjects who did not receive the organizer at retrieval. In addition, Corkill et al. (1988) found that rereading an organizer immediately before a delayed recall test improved memory of the passage.

To encourage depth of processing as proposed by Craik and Lockhart (1972), learning strategies should provide for semantic encoding and use activities that encourage elaborations and reconstruction of the information at retrieval. The spatial learning strategies proposed by Holley and Dansereau (1984) and the synthesizer proposed by Reigeluth and Stein (1983) seem to allow students to discover the structure of the materials and encourage depth of processing. The next section explores the role of spatial learning strategies during the reading of prose materials.

Spatial Learning Strategies

Spatial learning strategies are strategies learners use to represent, in a spatial format, information in a prose passage. Spatial learning strategies can be provided for students or generated by students. According to Breuker (1984), spatial learning strategies are aimed at coding and transforming textual information into spatial representations to reflect the structural information that can be abstracted from the text. Dean and Kulhavy (1981) claimed that encoding of visual information may link knowledge structures already present to incoming verbal information. Dansereau (1989) used networking as a spatial learning strategy to help students learn from expository text. Only a limited number of studies have been conducted to determine the effectiveness of spatial learning strategies on learning. The present study attempted to fill the spatial learning strategy research gap by determining whether a spatial learning strategy (synthesizer) would facilitate recall and comprehension of prose materials.

Role of Spatial Learning Strategies in Learning

According to Hall, Dansereau, & Skaggs (1989), the processing of spatial learning strategies is done through three sequential stages. In the first stage, there is comprehension where a learner acquires a general knowledge of a domain's structure. During the second stage, encoding and storage occur when the information is transferred from working memory to long-term memory through elaboration and active processing. The third stage involves the retrieval, recall, and utilization of the information acquired from the spatial strategy.

The method used to encode information determines what is learned from the information and what is retrieved from memory. Phillippe and Schwartz (1987) used university undergraduate students as subjects to determine the way in which general reference maps are retained and organized in memory. Map retention was measured by free-recall of map features and reconstruction of the original map. Subjects asked to draw a map showed superior memory for specific locations within the spatial configuration of the map when compared to subjects who were asked to list the map features. Phillippe and Schwartz (1989) postulated that when a spatial encoding tactic such as a map is used, memory for map locations is increased. As a result, memory for the spatial relations between elements in the spatial map is increased. Skaggs, Dansereau, & Hall (1989) proposed that one tends to automatically encode the location of objects in a spatial learning strategy. Weinstein (1984) claimed that spatial learning strategies force students to process information at a greater semantic depth and facilitate greater elaboration of the material to be learned. Kiewra, Mayer, Dubois, Christensen, Kim, & Risch (1990) used undergraduate students to investigate the effectiveness of a prose organizer, a linear organizer that listed the main steps in a process, and a matrix organizer that listed the steps in a matrix format. Results indicated that the linear and matrix organizer facilitated recall of subtopic information while the prose organizer facilitated recall of general topic information. Kiewra et al. (1990) postulated that spatial learning strategies allowed subjects to see across topic relationships. Spatial learning strategies provide the structure needed to assimilate the learning materials and facilitate the retrieval of the materials.

Dansereau (1989) claimed that when a visual map is presented to students, both the spatial and verbal subsystems are activated. As a result, information is stored both visually and verbally, in a manner similar to that described in Paivio's (1971, 1986) dual-coding hypothesis which states that information is encoded in memory both verbally and visually. Recall is facilitated by the dual coding of the information since both the visual and verbal subsystems are used during the recall (Kulhavy, Lee, & Caterino, 1985; Paivio, 1971, 1986). According to Harris and

Pressley (1990), one useful learning strategy is the creation of representational images to code the content of the text being read. Creating representational images facilitate memory of facts presented in the text and enhance inter-sentence integration of text content (Harris & Pressley, 1990).

Weinstein (1984) suggested that spatial learning strategies are relatively content independent. Since spatial learning strategies require representation of relationships between concepts, they facilitate abstraction and deep processing. In addition, the structure hidden in textual material can be made explicit in spatial strategies. Students must be involved in the active analysis of the structure of the materials to construct a spatial representation (Breuker, 1984). Goetz (1984) claimed that construction of spatial learning strategies requires activities such as analysis, encoding, and organization. These activities are not encouraged when students are provided with spatial strategies developed by someone else. Relatively little is known about the effectiveness of spatial learning strategies such as maps, networks, and spatial synthesizers (Lambiotte & Dansereau, 1990). The present study contributed to the research by investigating the effectiveness of spatial synthesizers when learning from prose materials. The activities involved in the generation of spatial learning strategies may contribute to their effectiveness when learning from prose materials.

Effectiveness of Spatial Learning Strategies

Research conducted on spatial learning strategies has shown facilitative effects in certain cases. Holley and Dansereau (1984) determined the effectiveness of a network using college psychology students as subjects and a reading passage on introduction to geology. Subjects were randomly assigned to a treatment group and a control group. Holley and Dansereau (1984) found that the network was more effective in the recall of main ideas than in the recall of details from the passage. Lambiotte and Dansereau (1990) used undergraduate education students as subjects and a reading passage on biology to determine the effectiveness of knowledge maps as learning strategies. Lambiotte and Dansereau (1990) found that knowledge maps facilitated recall of information from the passage for subjects with limited background in biology. McKeachie (1984) postulated that spatial learning strategies are more effective for learning difficult and unfamiliar expository materials. However, McKeachie (1984) claimed that unfamiliar and expository materials may be the most difficult to represent spatially. Jonassen and Hawk (1984) reported that using a graphic as a spatial learning strategy to present the main ideas and the relationships between ideas improved students' performance when compared to that of students who did not receive the spatial learning strategy. Alesandrini (1984) claimed that when graphics were used to summarize textual information, the graphics allowed learners to see and hence, process the information simultaneously. Students can see the actual distance between elements in a diagram, observe sequences by tracing logical paths through diagrams, and see the relationships between parts in a process (Winn and Holliday, 1982).

Dean and Kulhavy (1981) used educational psychology students as subjects and a reading passage on an imaginary African tribe to determine the effectiveness of a spatial map. Results revealed that subjects instructed to generate maps while reading a passage recalled significantly more than did control subjects who were not asked to generate maps. Subjects remembered more textual information when the information was related to elements depicted spatially in an adjunct map (Kulhavy, Lee, & Cateriono, 1985). Kiewra, Mayer, DuBois, Christensen, Kim, & Risch (1990) used undergraduate students to determine the effectiveness of a linear, a matrix, and a prose organizer. Kiewra et al. (1990) reported that subjects, given a spatial learning strategy in the form of a matrix, performed better on recall of across-topic information than did subjects who received a prose synthesizer. Kiewra, DuBois, Christian, and McShane (1988) used undergraduate students to compare text, outline, matrix, and no-notes as review strategies before performance evaluation. Kiewra et al. (1988) found that subjects in three review strategies groups (textual, outline, and matrix) performed better on recall, recognition, and transfer tests than did subjects in the no-notes group. Further analysis revealed that subjects in the matrix and the outline groups performed better than did subjects in the text review group. The results suggested that the graphical post-organizational strategy was more effective than was the textual post-organizational strategy. Kiewra et al. (1988) suggested that the superiority of the outline and matrix occurred because they allowed subjects to make more internal connections between ideas. The results also showed that the post-organizational matrix group performed better on a transfer test than did the text, outline, and no-notes groups. Kiewra et al. (1988) claimed that the matrix showed superordinate-subordinate, as well as horizontal relationships. As a result of the integrated structure, transfer tasks involving synthesis and application were facilitated. Kiewra et al. (1988) recommended that students should be trained to transform lecture materials into a matrix form to facilitate retention and transfer. This recommendation was incorporated into the present study where, before the treatment, subjects were trained to generate and process a spatial learning strategy. Transforming lecture materials into a matrix form is equivalent to asking students to generate spatial synthesizers.

Holley and Dansereau (1984) claimed that using spatial learning strategies, such as using a spatial synthesizer for reorganization processing could improve learning and performance. Holley and Dansereau (1984) believed that spatial strategies are effective because they make use of encoding activities that require learners to process the material at greater semantic depth. Spatial learning strategies facilitate learning by encouraging dual coding (Paivio, 1971, 1986), providing a reconstructive retrieval mechanism for the memory trace (Corkill et al., 1988), and representing the information in more than one dimension (Dansereau, 1989).

However, the number of relationships in a spatial learning strategy should be limited to seven. Holley and Dansereau (1984) found that six relationships were better than thirteen relationships. Six relationships seem to be consistent with Miller's (1956) evidence that one tends to work efficiently with a maximum of seven plus or minus two chunks of information. Miller's theory suggests that each node in a map should only have seven plus or minus two pieces of information. As a result, the present study ensured that there were no more than seven pieces of information in each node in the spatial synthesizer.

Representing Information Spatially

Parker and Tindal (1990) claimed that there is no consistent method for generating spatial strategies to represent texts. Some common methods for representing information spatially are described in the following sections.

Mapping. The mapping method involves placing the central idea of a passage near the center of a page and attaching the subsidiary ideas around the central idea. (Anderson, 1979; Hanf, 1971). Refer to Appendix 1 for an example of a map. Mapping is a method for representing ideas in text in the form of a diagram (Armbruster & Anderson, 1984). The mapping process involves the use of a set of relational conventions or symbols to show the relationships between ideas. Maps represent concepts and their relationships on a single display and, at the same time, reveal the structure of the information (Horn, 1985). Maps have an advantage over prose since they contain information stored in terms of location (Pezdek, Roman, & Sobolik, 1986). In addition, maps can outline the steps in a procedure and, at the same time, elaborate on these steps. Maps can be an efficient way to integrate procedural and declarative knowledge (Skaggs, Dansereau, & Hall, 1989). Maps also encourage students to use both visual and verbal processes while learning prose materials (Paivio, 1971, 1986). Schallert, Ulerick, and Tierney (1984) outlined a method for representing textual materials in a graphical form. The method involves creating a map to show a graphic representation of the concepts and their relationships. The relational map is created by identifying the concepts and graphing the relationship between the concepts to form a coherent whole.

Research on the use of maps as a learning strategy is limited. However, the small amount of research results that do exist show facilitative effects of maps as a learning strategy. Armbruster and Anderson (1980) found that mapping facilitated delayed recall of short narrative prose. O'Donnell, Dansereau, Lambiotte, Hall, Skaggs, Rewey, & Peel (1987) claimed that (a) maps were more suitable for procedural information, (b) maps resulted in long-term storage of technical information, and (c) maps facilitated recall of main ideas. When maps show the relationship between ideas using a spatial node/link structure, knowledge acquisition is enhanced and transfer is facilitated (Dansereau, O'Donnell, & Lambiotte, 1988). Maps allow learners to make between and within-domain comparisons and provide a global picture of a domain's general structure (Kiewra et al. 1990).

Tessmer and Driscoll (1986) used senior high school students to compare a prose passage and a tree-like diagram that represented information of definitions and examples of seven coordinate concepts. The reading passage for the study dealt with the changes of matter. Tessmer and Driscoll (1986) found that low ability students benefitted more from the tree-like diagram than did high ability students. Holley, Dansereau, McDonald, Garland, and Collins (1979) used undergraduate psychology students as subjects to determine the effectiveness of networks as learning strategies. Subjects were asked to study a 3000-word passage and were randomly assigned to an experimental and a control group. The dependent measures were an essay test, a concept-cloze test, and a multiple-choice test. Results indicated that the network group performed better on questions that measured main ideas from the passage than did the control group. Holley et al. (1979) claimed that asking students to produce maps resulted in two-dimensional maps which (a) encouraged depth of processing (Craik & Lockhart, 1972), (b) promoted visual representation of the information, and (c) allowed subjects to see the structure of the prose materials. Knowledge of the structure of the reading material provided a framework for reading and facilitated the recall of information from the materials (Gordon, 1990). Maps facilitate retrieval by using their general structure to access the details of the materials.

Anderson (1979) claimed that maps, when used as a post-instructional strategy, allowed learners to see the structure of the content. Similarly, Kiewra et al. (1990) postulated that spatial learning strategies allowed subjects to see the structure of the materials. As a result, the learning experience was enriched and retention was facilitated. More research is needed to determine the effectiveness of spatial learning strategies such as maps (Anderson, 1979). The present study contributed to the research by investigating the effectiveness of a spatial synthesizer on the recall and comprehension of prose materials.

Network: Another way to represent textual information spatially is by using a network. The networking concept was introduced by Dansereau and his colleagues (Dansereau & Holley, 1982; Dansereau, Collins, McDonald, Holley, Diekhoff, & Evans, 1979). The networking process involves identifying important concepts or ideas in learning materials and representing their interrelationships and structure in the form of a network. Refer to Appendix 1 for an example of a network. Quillian (1969) claimed that the structure of a network is consistent with the organization of human memory which is organized as a network of ideas showing the relationships between ideas. The network emphasizes the identification and representation of hierarchies (type-part), chains (lines of reasoning-temporal orderings), and clusters (characteristics, definitions, analogies)

(Dansereau, 1989). Networking provides a two-dimensional structure that indicates the spatial organization of the information. Holley et al. (1979) found that when students were asked to use networking strategies, they performed better on the recall of information than did students who used their own spontaneous strategies.

Concept Map. A concept map is a two-dimensional diagram that shows the structure of the subject matter (Novak, Gowin, & Johanse, 1983). Refer to Appendix 1 for an example of a concept map. The content in a concept map is arranged in a hierarchic structure from general to detailed. Relationship lines are then drawn between elements of the content to depict the structure of the content.

Mind maps. According to Buzan (1983), memory is a process which is based on linkage and association between ideas. The fewer items in the "recall store," the less chance new items are registered and connected. Buzan (1983) claimed that ninety percent of the words in verbal note-taking are not necessary for recall purposes. Hence, ninety percent of students' time is wasted writing words that have no effect on memory. To make the note-taking process more efficient, Buzan (1983) proposed that notes should be in the form of mind maps.

A mind map is a spatial outline of a topic or passage. Refer to Appendix 1 for an example of a mind map. The mind map starts from the center or main idea and branches out as dictated by the individual ideas and general form of the central theme. Buzan (1983) proposed a method for generating the mind map. Students should start out with two blank pages. The left page should be the mapped information and the right page should contain the related linear and graphic information such as, formulas and lists. The words are printed on lines in capital letters with each line connected to other lines. The words should be in units such that there is one word per line. The one word per line gives more freedom and flexibility since it allows as many connections as possible to be made to the word. As the mind map is being built, students should write down everything the mind can think of around the central idea.

Buzan (1983) recommended frequent reviews of materials to facilitate transfer and storage in long-term memory. The review should take the form of a mind map which is a spatial representation of verbal information. There should be a ten minute review for a one hour learning session. The review facilitates recall until the next day when a two to four minute review should be done. After one week and one month, a two minute review should be done to facilitate transfer into long-term memory.

Buzan (1983) claimed that the mind map has many advantages over traditional linear note-taking. In the mind map, the main idea is clearly defined and the importance of each idea can be judged by its location and distance from the center. The structure of mind maps also allows for easy changes and additions.

Graphic representations. Jones, Pierce, and Hunter (1989) claimed that when students construct graphic representations of text, they better understand which ideas in the text are important, how the ideas relate, and what points are unclear. The graphic representations could take the form of flowcharts, pie charts, network trees, spatial synthesizers, and spider maps. The graphic representations consist of frames which are the underlying schema for prose text.

Jones et al. (1989) graphic representation is equivalent to the synthesizer proposed by Reigeluth and Stein (1983). Constructing and processing a spatial synthesizer helps students become actively involved in processing the materials (Jones et al., 1989). At the same time, the graphic encourages nonlinear thinking because of its layout and structure. Nonlinear thinking in graphic representations is a major advantage over prose summaries and linear outlines.

Constructing the spatial synthesizer. The structure of the spatial synthesizer should reflect the structure of the text it represents. The procedure for constructing the spatial synthesizer is as follows (Jones et al., 1989). The students should first survey the headings, subheadings, illustrations, summary, and abstract to get an idea of the structure of the passage. Students should then form a hypothesis about the structure of the passage and mentally search existing graphic structures for the best fit. All representations have a corresponding mental model. The mental model constructed is unique to the individual and represents the individual's understanding of the structure of the passage. After the student has formed a hypothesis about the passage, the student needs to examine the text again to determine how the spatial synthesizer should be organized. After hypothesizing about the structure of the text, the student should read the materials to fill-in gaps in understanding, to look for ideas not included in the representation, and to clarify any questions. After thoroughly reading the passage, the student should reflect on the passage by asking questions such as "What are the important ideas in the passage?" "How are the ideas related?" and "How can I revise my mental model to reflect the structure of the text?" The student should complete the graphic synthesizer to reflect the structure of the passage. The student should then construct a summary based on the information in the graphic synthesizer.

Jones et al. (1989) proposed the following procedure for training students to generate graphic synthesizers.

1. Present at least one good example of a completed graphic synthesizer that matches the type of outline that is covered in the course.

2. Model how to construct either the same sample graphic synthesizer or the one to be generated. Describe the decision-making process, and show students how to ask questions to get the information to build the synthesizer.

3. Provide procedural knowledge by informing students why and when they should use the graphic synthesizer and how they should process the graphic.

4. Coach the students by allowing them to construct a graphic synthesizer as a group. Then gradually allow them to construct the synthesizer on their own.

The next sections of the review of the literature explore the theory of synthesizers and the research related to synthesizers.

Synthesizers

Reigeluth and Stein (1983) defined a synthesizer as a graphic representation designed to relate and integrate individual ideas expressed in prose for the purpose of teaching the interrelationships among the ideas. Refer to Appendix 1 for an example of a synthesizer. Reigeluth and Stein (1983) claimed that a synthesizer provides students with valuable knowledge, facilitates a deeper understanding of individual ideas, increases the meaningfulness and motivational effects of the new knowledge, and improves retention. In addition, the relationships in the synthesizer provide knowledge that is not contained in individual pieces of content (Reigeluth, 1983). In other words, the spatial synthesizer allows students to see the structure of the content (Kiewra et al. 1990, Van Patten, Chao, & Reigeluth, 1986). Goetz (1984) outlined an eight step procedure for generating spatial learning strategies such as synthesizers.

(1) Select the material to be represented.

(2) Decide at which level to represent the material.

(3) Identify at least two concepts or ideas and the relationships between them.

(4) Draw lines between the concepts or ideas to spatially represent their relationships.

(5) Identify the remaining concepts and ideas.

(6) Draw lines between the concepts to show their relationships spatially.

(7) Check the spatial representation to verify that the relationships and structure match the text passage.

(8) Study the spatial representation so that it can facilitate the encoding and retrieval of the learning materials.

Goetz (1984) claimed that the process of generating the synthesizer facilitated deep meaningful processing and forced the learner to bring prior knowledge to help learn the materials.

According to Reigeluth and Stein (1983), a synthesizer can take three forms. It can show the conceptual structure of content by using part or kind relationships as in the components of a report. A synthesizer can outline the theoretical structure of a passage by showing cause-effect relationships as in the relationships between the quantities in Ohm's Law. A synthesizer can also outline the procedural structure by showing sequential relationships as in the selection of a test for a statistical analysis. The present study investigated the effectiveness of a conceptual spatial synthesizer on reading from a prose passage. The following sections discuss the effectiveness of spatial synthesizers as learning strategies.

Effectiveness of Synthesizers

Limited studies have been conducted to determine the effectiveness of synthesizers as spatial strategies in the learning process. McLean, Yeh, and Reigeluth (1983) used senior high school students to examine the effectiveness of a visual synthesizer (tree-chart), a verbal synthesizer (prose) and a visual and verbal synthesizer (tree-chart and prose). The dependent measure was 26 short-answer questions which tested the recall of information on parts of a microcomputer system. The results of the study indicated that the tree-chart synthesizer was superior on the recall of information when compared to the verbal and the verbal-visual synthesizers. Chao and Reigeluth (1986) compared a visual and verbal procedural synthesizer on recall and applications of procedures. Subjects were college students registered in a statistics course. Subjects' performance was measured by recall of the relationships and the application of statistical relationships to solve problems. There was no significant difference in performance between the visual and verbal procedural synthesizer groups. However, both of these groups performed better than did the control group who received no synthesizer. Reigeluth (personal communication, May 1989) suggested that more research should be conducted to determine the effectiveness of synthesizers. The present study contributed to the literature by investigating the effectiveness of an instructor-provided and a student-generated spatial synthesizer on learning from prose as measured by an immediate, and a delayed, cued recall and comprehension test.

Weinstein and Mayer (1985) proposed a learning strategy called structured note-taking which is a post-organizational strategy equivalent to Reigeluth's (1987) synthesizers. The synthesizer is also equivalent to Dansereau's (1989) multiple-relationship knowledge maps that communicate the structure of a domain by presenting the interrelationships among key ideas. Dansereau (1989) claimed that the knowledge maps have an advantage over other organizational displays because they can represent a variety of relationships and structures in a single display. Spatial synthesizers act as gestalt-like maps giving an overall picture of the materials (Abel & Kulhavy, 1989; Kiewra et al., 1990).

Dansereau, McDonald, Long, Atkinson, Ellis, Collins, Williams, and Evans (1974) compared undergraduate subjects who either generated a summary for a passage, drew or described images for a passage, or generated high-level questions for a passage. There was no significant difference on an objective test between the groups. However, on an essay test, all three of the experimental groups performed better than did a control group.

Schwartz, Kulhavy, and Finley (1980) used undergraduate students to investigate whether spatial images served as a framework for storing information from a passage. The reading passage dealt with an imaginary island and performance was measured by a free recall and a cued recall test. Results revealed that subjects given maps recalled more on both the free and cued recall tests than did control subjects.

Snowman and Cunningham (1975) found that when undergraduate subjects were given a pictorial adjunct aid after reading a passage, they performed better on the recall of factual information than did subjects given a textual post-adjunct aid and subjects with no adjunct aid. Similarly, Ruddell and Boyle (1989) used college students to determine the effectiveness of maps on comprehension and written composition. Ruddell and Boyle (1989) found that subjects who were asked to draw maps that showed the interrelationships between the ideas in a passage obtained higher scores on a summarization task than did subjects who did not draw the maps. Hartman and Spiro (1989) used undergraduate subjects and a reading passage on "Prejudice and Discrimination" to determine the effect of text structure when learning from prose material. Hartman and Spiro (1989) found that subjects given explicit text structure, similar to a synthesizer, were able to transfer and apply the knowledge better than were subjects given the traditional prose text structure.

Derry (1989) claimed that spatial learning strategies such as spatial synthesizers and networks facilitated schema building. Schema building is facilitated by the process of representing the main ideas in text and identifying the relationships between the ideas. According to Swing and Petersen (1988), when information is interconnected in a graphical form showing the relationships between concepts or ideas, memory for the information is enhanced. Swing and Petersen (1988) hypothesized that the reason for improved memory is that at the time of retrieval, multiple pathways are available for learners to access the information.

Anderson (1983) elaborated on the effectiveness of spatial learning strategies during retrieval by claiming that retrieval is enhanced further as more connections are made through practice. A spatial synthesizer contains both visual and verbal representations which make use of the verbal and visual processing systems of the learner. As a result, asking students to generate their own spatial synthesizer for the information should improve recall and comprehension. The present study explored the effectiveness of spatial synthesizers by investigating whether a student-generated spatial synthesizer is more effective on a cued recall and a comprehension test than a provided spatial synthesizer and no-synthesizer.

A spatial synthesizer allows students to attend to the prose materials (Frase, 1970), process the materials at a deeper level (Craik & Lockhart, 1972; Lockhart & Craik, 1990), and form connections between ideas (Kiewra et al., 1988). Asking students to generate a synthesizer for prose materials is similar to asking a high level post-question. According to Hamaker (1986), asking students to answer high level questions promote higher level processing activities such as elaboration, synthesis, and integration.

Processing Spatial Synthesizers

Spatial synthesizers, when used as learning strategies, activate a learner's visual/spatial and verbal processing subsystems (Hall, Dansereau, & Skaggs, 1989). The visual and verbal processing subsystems are consistent with Paivio's (1971, 1986) dual coding hypothesis and Kulhavy, Lee, and Cateriono's (1985) conjoint retention hypothesis which suggest that information is processed and stored via the verbal and the visual subsystems. Hall, Dansereau, and Skaggs (1989) investigated the effectiveness of multiple relationship knowledge maps for the presentation of related information domains. Subjects were undergraduate students who studied two different passages that involved the comparison of related domains. Subjects were divided into two groups; one group studied the material in the form of a knowledge map while the other group studied traditional text. Results revealed that subjects who studied the materials in the form of a knowledge map recalled more than did subjects who studied the materials in the form of traditional text. In addition, Hall, Dansereau, and Skaggs (1989) suggested that the spatial properties of synthesizers conveyed higher level structural information while the textual properties conveyed more detailed information.

Schwartz and Kulhavy (1981) used undergraduate subjects to investigate the effects of map processing on recall. Subjects studied either (a) a map of an island with features located spatially, (b) a map outline of an island with features listed next to the map, or (c) a map outline of an island with no feature information. Subjects who studied the map with the features located spatially recalled more idea units and feature-related information than did the other two groups. Schwartz and Kulhavy (1981) claimed that there was an increase in the depth of processing when both the visual and verbal subsystems were utilized in learning.

However, asking students to use the verbal subsystem while reading prose materials and to generate spatial learning strategies at the same time may interfere with the processing of the materials (Brooks, 1968). According to Long, Winograd, and Bridge (1989), imagery reported while reading a passage differed in relation to text features, from imagery recalled after reading a passage. As a result, it may not be a good idea to ask students to generate spatial learning strategies while reading prose materials. Spatial learning strategies generated during reading may interfere with the processing of the materials. Also, students, while reading the materials, do not have all of the information required to process or generate the spatial learning strategy for the entire passage. The general relationships in the information may not be discovered until all of the material has been read. Rather, students should generate maps as spatial synthesizers or study spatial synthesizers after reading prose materials. The present study asked subjects to generate or study a spatial synthesizer as a post-learning strategy after an entire prose passage had been read.

Skaggs, Dansereau, and Hall (1989) claimed that synthesizers could provide the framework for the verbal subsystem to operate using strategies such as questioning and organization. Because of the spatial nature of synthesizers, students can verify the properties of subject matter after reading the synthesizer and at the same time process, from different perspectives, the information in the synthesizer. In addition, synthesizers generated by students tend to be stored for a longer time than do prose materials (Shepard & Cooper, 1982). Skaggs, Dansereau, and Hall (1989) used undergraduate psychology students to compare maps and text format on recall after reading a prose passage. The reading passage was extracted from a nursing handbook and dealt with administering intravenous therapy. Results revealed that maps, when used as post-learning strategies, were more effective for the recall of main ideas from a passage while textual post-learning strategies were more effective for the recall of details.

Synthesizers allow students to process prose information using different routes (Skaggs et al., 1989) depending on the background and level of the students. Hence, spatial synthesizers can accommodate individual differences in processing better than prose learning strategies are able to accommodate. Students can look at a spatial synthesizer and use existing information to interpret the synthesizer. The strategies used to process spatial synthesizers cannot be used easily with verbal materials.

The way someone processes prose material determines what is remembered and what is learned. Craik and Lockhart (1972) and Lockhart and Craik (1990) claimed that to promote learning, one has to process the information semantically and elaboratively rather than by rote rehearsal such as re-reading. Cook and Mayer (1988) used undergraduate students as subjects to sort reading passages based on the structure of the passages. Cook and Mayer (1988) claimed that when students formed internal connections among the ideas in a text, there was better recall of high conceptual rather than low conceptual materials and better problem-solving performance rather than verbatim retention. Based on the claim by Cook and Mayer (1988), it is hypothesized that a spatial synthesizer would help students make connections between ideas which could improve performance on higher level tasks. The present study investigated the effectiveness of an instructor-provided and a student-generated spatial synthesizer on recall and comprehension. Thorndyke and Stasz (1980) used college students as subjects to investigate the procedures subjects use to acquire knowledge from maps. Results revealed that subjects given training on imagery, pattern encoding, and relation encoding recalled more map information than did subjects given unrelated map training or no map training. Thorndyke and Stasz (1980) concluded that map learning depends on particular study strategies for selecting, encoding, and evaluating information. According to Thorndyke and Stasz (1980), an individual's ability may help determine which strategy, if any, the learner uses to acquire new information. Also, the ability level of the student may influence how the student uses a particular learning strategy. Students with different levels of spatial and verbal abilities may use and benefit from spatial synthesizers differently. The next section explores spatial and verbal ability.

Spatial Ability

Halpern (1986) defined spatial ability as the ability to imagine what an irregular figure would look like if it is rotated in space and as the ability to discern the relationship among shapes and objects. Kyllonen, Lohman, and Snow (1984) defined spatial ability as the ability to generate, retain, and transform abstract visual images. However, Caplan, MacPherson, and Tobin (1985) questioned the existence of the construct "spatial ability." Caplan et al. (1985) claimed that there needs to be a better definition of spatial ability. In addition, Pellegrino and Kail (1982) claimed that there appears to be little agreement among major studies as to the number of levels of spatial abilities that may exist and the description of these abilities. The lack of consistent definitions and the different ability levels have resulted in different theories of spatial ability.

Cooper and Podgorny (1976) claimed that on a spatial ability task, some students may use a holistic, parallel comparison while some students may use an analytic, sequential comparison. Hock, Gordon, and Gold (1975) reported that when undergraduate subjects were given a mental rotation task, some subjects used a structured strategy that was influenced by the stimulus orientation while others used an analytic strategy that relied on a verbal code. The research on the processing of spatial tasks led Kyllonen et al. (1984) to conclude that at least two effective strategies are used to complete a spatial visualization task. The two spatial visualization strategies are (a) a systematic mental-construction strategy involving holistic representation and comparison processes and (b) an analytic strategy in which features of the figures are encoded, transformed, and compared sequentially.

According to Lohman and Kyllonen (1983), every task that presents spatial information does not necessarily require spatial processing. On the other hand, the absence of figural stimuli could require spatial thinking. Spatial ability is usually measured by tests that require mental rotation of a figure or finding a smaller figure in a larger figure. Spatial problems are those that have a significant amount of spatial information in the original presentation of the problem or in the way a person represents the problem (Carpenter & Just, 1986). Some spatial tests present problems verbally and require subjects to generate their own spatial images. Hence, tasks such as spatial synthesizer generation and processing require spatial thinking by students. Lohman and Kyllonen (1983) claimed that spatial thinking requires the ability to encode, remember, transform, and discriminate spatial stimuli. Three spatial factors have been identified in spatial ability (Lohman and Kyllonen, 1983): (a) spatial relations, where mental rotation is the common element and represents the ability to solve problems as fast as possible;

(b) spatial orientation, which involves the ability to imagine how a stimulus array appears from another perspective; and (c) spatial visualization, which is measured by unspeeded tests and measures the ability to work with two-dimensional scaling representation.

On complex spatial tasks, two types of mental transformations are required. The first type is mental movement which involves reflecting, rotating, folding, or simply imagining that a stimulus is moved from one position to another position (Cooper, 1980). The second type of mental transformation is construction or synthesis which involves copying a design, reproducing a design from memory, and constructing a new mental spatial image (Lohman & Kyllonen, 1983; Glushko & Cooper, 1978).

According to McGee (1979a, 1979b) spatial ability seems to be comprised of two separate cognitive processes. The first process is a visualization process which includes the ability to imagine how objects appear when they are rotated. The second process is an orientation process which includes the ability to detect relationships between different stimuli and the ability to perceive spatial patterns accurately. Similarly, Harris (1981) and Halpern (1986) claimed that spatial ability consists of spatial visualization and spatial orientation.

Liben (1981) proposed that there are three types of spatial representations: (a) spatial products such as, maps and verbal descriptions which refer to the external products that represent space in some way; (b) spatial thought, which includes thinking that concerns or makes use of space in some way and is the knowledge that individuals have access to, can manipulate, and can reflect upon, as in spatial memory; and (c) spatial storage, which is any information about space in memory.

Cooper and Shepard (1973) claimed that response latency on spatial-relations problems reflects four processing steps: (a) the encoding of the stimuli which involves representing the stimuli and storing the information in working memory; (b) the rotation of the mental representation to bring the non-vertical stimulus in congruence with the vertical stimulus; (c) then a comparison of the stimulus representations to determine if they are identical; and (d) the comparison is then followed by either a positive or a negative response.

Generating a spatial representation. Different methods for generating spatial representations have been proposed. Carpenter and Just (1986) outlined a three-step process for generating a spatial representation. The three steps are (a) encoding a physical stimulus, (b) retrieving a previously constructed representation, and (c) constructing a new representation according to some non-iconic specification, such as a verbal description. The construction of the new representation is equivalent to the generation of a spatial synthesizer and requires more capacity than the encoding and the retrieval processes.

Egan (1979) hypothesized that for a spatial visualization task such as selecting an object after the transformation of an original object, students use many processes. Students search for a characteristic that is common in both the original and transformed representations. After locating a common characteristic, there are mental transformations through many rotate and match cycles until a match is found. If a match is found, the student confirms the match by comparing other corresponding parts of the drawings. Due to the complex processes involved in working with spatial tasks, there seem to be large individual differences when completing spatial tasks.

Individual differences in spatial ability. Individual students' spatial abilities may predict the nature of the strategies used to process spatial information (MacLeod, Hunt, & Mathews, 1978). Individual differences in performance on spatial tasks are determined, in part, by the quality of mental, spatial representations and the efficiency of processes that construct, manipulate, and examine these representations (Poltrock & Agnoli, 1986). In order to solve a spatial problem or generate a spatial representation, one has to represent the spatial information. The nature of the representation of spatial information is the source of considerable individual differences. High and low spatial ability subjects differ in the richness of their spatial representations and in their ability to maintain complex spatial structures in memory (Cooper & Mumaw, 1985). Low spatial ability subjects tend to use more rotations and take longer to do the rotations than do high spatial ability subjects. Cooper and Mumaw (1985) claimed that the reason for the differences in processing is that low spatial ability subjects do not generate a complex spatial representation that remains intact during mental transformations.

High ability subjects tend to maintain more spatial information in memory and hence, encode the information more efficiently (Carpenter & Just, 1986). Mumaw and Pellegrino (1984) used undergraduate students to determine individual differences in spatial processing. Spatial processing was assessed using the Minnesota Paper Form Board (MPFB) test which required subjects to select which of five choices is the correct figure that can be completed from a set of given elements. Mumaw and Pellegrino (1984) reported that high spatial ability subjects produced mental representations that were of higher quality than did low spatial ability subjects. High spatial ability subjects tend to perform in a manner consistent with their spatial strategy while subjects with low spatial ability tend to use a more symbolic strategy (MacLeod, Hunt, & Mathews, 1978). Sternberg and Weil (1980) used undergraduate subjects to investigate whether it was possible to train subjects to use various strategies for solving syllogism problems. Subjects were trained to solve the syllogism problems either by an algorithm or by visualization. A third group was not given any training and served as the control group. Results indicated that subjects who were given the algorithmic training performed better on solution response time than did visualization and control subjects. Sternberg and Weil (1980) also reported that subjects with high spatial ability used spatial strategies to solve syllogism problems. Carpenter and Just

(1986) proposed that high spatial ability individuals may have more stored spatial information that permits them to retrieve units that less skilled individuals may have to generate. High spatial ability subjects are better at generating, maintaining, and coordinating information during spatial transformations. As a result, one could hypothesize that high spatial ability subjects will benefit more from spatial learning strategies than will low spatial ability subjects. The present study tested this hypothesis by determining if high spatial ability subjects benefitted more from a spatial synthesizer than did low spatial ability subjects when learning from prose material as measured by an immediate, and a delayed, cued recall and comprehension test.

Cooper and Mumaw (1985) reported some relationships between spatial problem-solving and spatial ability. Performance on a spatial task was most efficient when selected strategies were compatible with relative degree of aptitude. High spatial ability subjects may have a high degree of strategy selection and may be efficient in the use of any processing strategy. Some spatial tests present problems verbally and require subjects to generate their own images. Hence, tasks such as spatial synthesizer generation and processing require spatial thinking.

Thorndyke and Stasz (1980) examined subjects' ability to learn a map as a function of various training procedures. Results showed that subjects who were already good at learning two dimensional arrays gained the most from map training while low ability subjects gained little. Based on Thorndyke and Stasz's (1980) finding, it can be postulated that subjects with high spatial ability will benefit more from the training to construct the spatial synthesizer than will low spatial ability subjects. As a result, high spatial ability subjects should be able to produce a better quality spatial synthesizer than will low spatial ability subjects. The better quality synthesizer should produce better recall and comprehension of prose materials. More research is needed to determine whether there is any relationship between spatial ability level and the use of spatial learning strategies (Brooks, Simutis, & O'Neil, 1983). The present study contributed to the research by examining whether there was any relationship between spatial ability scores and scores on tests of recall and comprehension for a provided-synthesizer group, a generated-synthesizer group, and a no-synthesizer group.

Gender differences in spatial ability. There have been many explanations for gender differences in spatial ability. The two most common explanations are sociocultural influences during development where boys are exposed to more visual and spatial tasks than girls are and the different roles of males and females in society (Harris, 1981). However, there have been inconsistent findings with regards to gender differences in spatial ability. Halpern (1986) argued that the differences between males and females can be attributed to the nature of the tests. Females are more variable on certain spatial tasks that involve visualization while males are more variable on spatial tasks involving orientation (Halpern, 1986). Male superiority in spatial ability has been reported in the literature (Maccoby & Jacklin, 1974). However, the research (Linn & Petersen, 1986) has indicated that males are superior to females only on simple and speeded visual tasks (Kail, Stevensen, & Black, 1984).

According to Alderton (1989), gender differences in spatial ability can be eliminated by practice which indicates that experience plays an important role in spatial ability. Alderton (1989) used senior high school students and accuracy and response latency as dependent measures to investigate gender difference in spatial ability. Alderton (1989) found that after 128 trials on a spatial task, males advantage over females was reduced and nearly eliminated. Hence, special training can bring females close to or at the male level of performance which supports the claim that gender differences in spatial ability are a product of differential training (Goldstein & Chance, 1965; Maccoby & Jacklin, 1974).

It seems as if it is not the ability level but the variation in scores between males and females that is different (Alderton, 1989). Females scores tend to have a skewed distribution which results in a lower mean score on spatial ability tests. Halpern (1986) suggested that more research should be conducted to investigate the differences between males and females on tasks that make use of spatial ability. Hence, the present study contributed to the gender research by determining whether males or females benefitted more from a spatial synthesizer.

Verbal Ability

Verbal processing are any cognitive activities that involve the recognition, retrieval, or understanding of linguistic forms (Perfetti, 1983). Verbal abilities rely on verbal knowledge which is the information in permanent memory accessed and manipulated by verbal processes. Lohman (1989) claimed that reading comprehension was highly correlated with general verbal abilities. Frederiksen (1982) identified three processes involved in reading comprehension: (a) word analysis processes, which involves the encoding of single and multi-letter units; (b) discourse analysis processes, which involves retrieving word meanings and resolving problems of reference; and (c) integrative processes, such as combining information from pictures and text. In his theory of reading ability, Perfetti (1986) proposed that word meanings are activated in long-term memory. The word meanings are then combined and retained in working memory in the form of propositions. The propositions are then combined with the learner's prior schematic knowledge to form a text model which reflects the learner's understanding of the text.

Sternberg and Weil (1980) reported that when solving syllogism problems, high verbal ability subjects used a verbal strategy while high spatial ability subjects used a spatial strategy. Research is non-existent in the area of verbal ability and the use of spatial learning strategies. One could predict that subjects with high verbal ability would use their own learning strategy rather than use a spatial synthesizer as a learning strategy. As a result, low verbal ability subjects would benefit more than would high verbal ability subjects from the use of spatial synthesizers (Tessmer & Driscoll, 1986). Thus, the present study contributed to the research literature by investigating whether high or low verbal ability subjects benefitted more from the use of spatial synthesizers when learning from prose materials as measured by a cued recall and a comprehension test.

The research literature (Halpern, 1986; Maccoby & Jacklin, 1974) seems to indicate that females have superior verbal ability than do males. However, Hyde and Linn (1988) did a meta-analysis of 165 studies that researched gender differences in verbal ability and concluded that there were no gender differences in verbal ability. As a result, one could postulate that at the same verbal ability level, males and females would obtain the same benefit from the use of spatial synthesizers.

Individual Differences in Spatial Learning Strategy

The research on individual differences in spatial learning strategies is mixed. Holley and Dansereau (1984) used undergraduate students to investigate the effectiveness of networks. Results indicated that high general ability students who used a spatial learning strategy performed better on questions that measured details of the material than did students who did not use the spatial learning strategy. Scevak and Moore (1990) divided senior high school students in a treatment group and a control group to determine how they processed maps when learning map-related information. Scevak and Moore (1990) claimed that generating or processing a spatial learning strategy, such as a map, seemed to help low general ability students more than it did high general ability students. Dees and Dansereau (1990) investigated whether a map summary or a text summary was effective as a supplement to a reading passage. Subjects were undergraduate psychology students and the Delta Reading Vocabulary Test was used to determine subjects' verbal ability. The reading passages for the study dealt with the nervous system and probability. Dees and Dansereau (1990) reported that low verbal ability subjects performed better on a free recall, a multiple choice, and a short answer test than did high verbal ability subjects. Holley and Dansereau (1984) used undergraduate students as subjects and found that low general ability subjects benefitted more from networking than did high general ability subjects. Holley and Dansereau (1984) also reported that both high and low ability students who used networking performed better on essay questions of main ideas than did students who did not use networking.

Camstra and Van Bruggen (1984) used undergraduate education students as subjects to investigate the effectiveness of spatial learning strategies. Results revealed that low ability subjects who used a spatial learning strategy performed worse on an easy prose passage than did control subjects. However, for a difficult prose passage, low verbal ability subjects performed better than did control subjects. Camstra and Van Bruggen (1984) claimed that the spatial learning strategy was a distraction for learning easy materials but helped maintain attention and improved comprehension on material that could not be comprehended on the first reading. It seems as if students used their own spontaneous strategies and ignored the provided strategies for easy and related materials. Afflerbach (1990) used expert readers to investigate the influence of prior knowledge on the strategies used by expert readers to identify and state the main idea of a text when the main idea is not explicit. Subjects were expert readers from anthropology and chemistry who read texts from familiar and unfamiliar domains. Verbal reports from the subjects revealed that readers automatically constructed the main idea statement more often for familiar materials than they did for unfamiliar materials. Afflerbach (1990) hypothesized that for difficult and unfamiliar materials, students may use their own strategies rather than use the main ideas in the passage to organize and store the materials.

Swing and Petersen (1988) claimed that when high and low general ability subjects were asked to picture concepts or procedures to solve a problem, high ability subjects performed better than did low ability subjects. On the other hand, other research studies have reported that low general ability subjects benefitted more from the use of spatial learning strategies than did high general ability subjects. Holliday, Brunner, and Donais (1977) reported that a picture-word diagram, which is equivalent to a synthesizer, benefitted low ability subjects more than it did high ability subjects. Holley, Dansereau, McDonald, Garland, and

Collins (1979) found that training undergraduate subjects to construct maps as a learning strategy benefitted subjects with low GPA more than it did subjects with high GPA. Holley et al. (1979) claimed that students with high GPA already possess their own learning strategies to help learn the materials. The claim that low GPA students benefit more from spatial learning strategies is consistent with McCombs and McDaniel's (1983) findings that Air Force trainees who were poor readers benefitted more from provided learning strategies than did good readers. Winn and Sutherland (1989) found that spatial learning strategies assisted low ability subjects more on the recall of details from a passage than the strategies benefitted high ability subjects. Dean and Kulhavy (1981) reported that when forced to study maps, undergraduate subjects with low vocabulary scores performed better on free recall tests than did subjects with high vocabulary scores. Similarly, asking students to generate spatial synthesizers may allow them to infer relationships between concepts in the materials. In addition, the processes used to generate the spatial learning strategy should encourage deep processing and improve memory of the materials (Goetz, 1984). The next section explores the research on student-generated spatial learning strategies.

Student-Generated Spatial Learning Strategies

Student-generated spatial learning strategies are strategies generated by students during the learning process. Students either generate these strategies while going through the materials or after completing the materials. Research

(Armbuster & Anderson, 1984; Holley & Dansereau, 1984; McGuinness, 1986; Naveh-Benjamin, McKeachie, Lin, & Tucker, 1986) has shown benefits from allowing students to generate their own spatial learning strategies. Generated spatial strategies allow one to determine the cognitive structure the student is using (Naveh-Benjamin, McKeachie, Lin, & Tucker, 1986), improve learning from textual materials (Armbruster & Anderson, 1984; Barron, 1980; Holley & Dansereau, 1984; Moore & Readance, 1979), and enhance the representation of the information (McGuinness, 1986).

Allowing learners to generate their own spatial synthesizers make use of both the visual and verbal processing subsystems resulting in the dual coding of information (Kulhavy, Lee, & Cateriono, 1985; Paivio, 1971, 1986). Also, the generation of the spatial synthesizer could result in deeper processing (Craik & Lockhart, 1972; Lockhart & Craik, 1990) of the materials which could result in efficient encoding and hence, easy retrieval (Svensson, 1977). Craik and Lockhart (1972) claimed that for effective learning to occur, the materials should be processed semantically and elaboratively rather than through rote memorization. When visual representations are provided to students, shallow processing may occur through physical properties such as lines, letters, curvatures, angles, size, and shape, etc. Deep processing of prose material requires the construction of a meaningful, semantic representation of the prose materials. Simply providing a spatial synthesizer to students may not allow students to discover the structure of the material whereas asking students to generate the spatial synthesizer may encourage the semantic representation of the structure of the material.

Winn (1982) hypothesized that the way visual information is represented in memory depends on the level at which it is processed. The higher the level of processing of visuals, the more they lose their iconic properties. Deep processing facilitates the formation of schemata which are made up of networks of propositions specifying the relationships among concepts. One method for encouraging deep, meaningful, and elaborate processing is to ask students to generate a mental image of the events described in the materials (Goetz, 1984). Abbot and Hughes (1986) found that students using a verbal-graphic note-taking strategy recorded more generative notes from a prose passage than did control subjects. Post-generative learning strategies enhanced free recall when compared to less generative strategies (Kiewra, 1983). The mental image could take the form of a spatial synthesizer to show how the ideas in the material relate to each other.

Because of the mental processes involved in generating spatial learning strategies, it is hypothesized that student-generated spatial strategies would result in deeper processing than would provided spatial strategies. However, Fransson (1977) claimed that for students to use a deep processing strategy, the content of the passage must be of interest to them. As a result, the present study used two passages for the investigation. A passage that was part of the reading requirement for the course subjects were currently taking and a passage that was unrelated to the course.

Dansereau et al. (1979) compared undergraduate subjects who were asked to generate maps to show the relationships between concepts with subjects who were asked to write down the relationships between concepts without using diagrams and subjects who imagined the concepts. Subjects who generated maps to show the relationships between concepts performed better on a final exam than did subjects asked to write down the relationships or to imagine the concepts. Dean and Kulhavy (1981) reported that subjects who generated a map for a passage showed greater retention than did control subjects. Dean and Kulhavy (1981) also found that when undergraduate subjects were forced to process a spatial map, subjects recalled more information than did subjects who were allowed to study the spatial map on their own. Forcing students to attend to the map promoted deeper processing of the materials.

Carrier, Joseph, Krey, and LaCroix (1983) claimed that when subjects were asked to generate images for a passage, they performed better on recall tests than did subjects who were supplied with visuals about the passage. Similarly, Dean and Kulhavy (1981) compared undergraduate subjects who were given a detailed map and subjects who were given a blank map and were asked to generate a map by copying the details onto the map. A control group who studied an unrelated map was also used. Subjects who were asked to generate the map by copying the details in the map performed better on a free-recall test than did control subjects and subjects who studied the map. Dean and Kulhavy (1981) concluded that subjects who generated the map by copying the details onto the blank map were forced to process the information spatially and at a deep level. The construction of the map, rather than the presence of the map, was essential for recall and comprehension.

Mayer, Dyck, and Cook (1984) used college students to investigate the effects of training students to use learning strategies to comprehend scientific passages. Subjects were trained to construct maps to show the relationships between concepts. The results of the study showed that subjects who constructed maps performed better than did control subjects. Superior performance was also observed on tests of the relationships between concepts and on tests of problem-solving that could not be answered just by reading the material. However, on tests that required verbatim recall of information from the material, the subjects who constructed maps did not perform better than did control subjects. Hence, it can be concluded that asking students to generate a spatial synthesizer for a lesson will facilitate performance on higher level questions. More studies should be conducted to determine whether asking students to generate spatial learning strategies, such as spatial synthesizers, facilitates performance on higher level comprehension questions (Szabo, personal communication, May 1989). Thus, the present study contributed to the research literature by investigating whether a provided and a generated spatial synthesizer facilitated performance on a comprehension test.

Pallrand and Seeber (1984) used college students to determine the relationship between visual/spatial abilities and achievement in science courses. Subjects were divided into four groups: (a) an experimental group, which was given training on the use and generation of spatial learning strategies; (b) a control group, which was given no training; (c) a placebo group, which was given unrelated learning materials; and (d) a second experimental group which consisted of subjects from liberal arts. Results indicated that subjects who were trained to generate spatial learning strategies showed significant improvement on spatial performance measures. In addition, subjects who generated the spatial strategies performed better on laboratory exercises and received a higher final grade in the course than did the control and placebo subjects.

Geva (1983) used college students as subjects to investigate whether training on recognition of a passage structure facilitated comprehension. Subjects were trained to develop diagrams to represent relationships between concepts in factual prose passages. Trained subjects performed better on tests that measured connections between related phrases and sentences than did control subjects. Geva (1983) also found that low ability subjects benefitted more from the diagram generation technique than did high ability subjects. Dean and Kulhavy (1981) reported than when subjects were asked to generate a map of a fictitious country while reading about the country, they performed better on the number of idea units generated, on a multiple choice test, and on constructed-response questions than did control subjects. Whitehill (1972) asked subjects to organize passage information using conceptual matrices and informational flow charts. Whitehill (1972) found that subjects with low organization skills, as measured by the Minnesota Study Habits Blank (MSHB), gained more from using the organization strategy than did subjects with high organization skills. Abel and Kulhavy (1989) used undergraduate college students to test the effects of maps on learning from a prose passage. Abel and Kulhavy (1989) found that when undergraduate college subjects were asked to generate maps, the extra effort resulted in a more accurate spatial memory. Weinstein (1978) reported that when subjects were asked to form images to differentiate arteries from veins, the image-generation group performed better on a delayed posttest than did control subjects.

Because of the time required for students to generate spatial learning strategies, some theorists have claimed that spatial learning strategies should be provided for students (Abel & Kulhavy, 1986; Levie & Lentz, 1982). However, provided learning strategies do not facilitate deep processing when compared to generated learning strategies (Craik & Lockhart, 1972; Wittrock, 1974). Winn (1987) claimed that spatial diagrams such as synthesizers are essential for students to see the relationships between concepts. Winn (1987) suggested that it takes time to train students to generate synthesizers and it may be more cost effective to prepare the synthesizers and give them to students. There is a need to find out whether the time invested by students to generate a spatial learning strategy, such as a synthesizer, is more beneficial to learning than is a provided-synthesizer. Thus, the present study addressed the issue of the effectiveness of the time spent by students to generate a synthesizer by investigating whether providing students with a spatial synthesizer improved performance when compared to asking students to generate the spatial synthesizer as measured by a cued recall and a comprehension test. Provided spatial learning strategies are explored in the next section.

Instructor-Provided Spatial Learning Strategies

Most people who develop instructional materials tend to have a large amount of prior knowledge in the subject matter. As a result, the language and complexity of the developed materials are a reflection of what the developer knows about the materials and assumptions made about the students (Schallert, Ulerick, & Tierney, 1984). Geeslin and Shavelson (1975) reported that the organization of students' knowledge after instruction was close to that of experts. Also, students whose cognitive structures resembled those of the expert got better grades than did students whose cognitive structures were different from those of the expert (Fenker, 1975; Geeslin & Shavelson, 1975).

A spatial synthesizer can be constructed using a top-down approach or a bottom-up approach (Dansereau, 1989). The top-down approach starts with the general information from the passage and is followed by the details in the passage. The top-down approach requires considerable knowledge of the learning materials to construct the spatial synthesizer (Lambiotte, Dansereau, Cross, & Reynolds, 1989). As a result, students may not be able to make effective use of an instructor-provided synthesizer since students do not have the general knowledge to comprehend and store the synthesizer. Students, on the other hand, will tend to generate bottom-up synthesizers starting from the details and expanding to the general structure (Dansereau, 1989).

Rewey, Dansereau, Skaggs, Hall, and Pitre (1989) claimed that student-generated spatial learning strategies take a long time for students to develop. Rewey et al. (1989) suggested that it would be more efficient to give students an expert-generated spatial learning strategy. However, research (Berry & Broadbent, 1984; Chi, Glaser, & Rees, 1981) has reported that experts possess more complicated cognitive structures and as a result, may produce spatial learning strategies that are not suitable for novice students. Thus, the present study addressed the controversial issue of instructor-provided synthesizers by investigating whether an instructor-provided spatial synthesizer was more effective in enhancing recall and comprehension than was a student-generated spatial synthesizer.

In some cases, an instructor may generate a spatial learning strategy and provide it for students' use. The instructor-generated spatial learning strategy shows students the interrelationships and structure of ideas (Armbruster & Anderson, 1984) and facilitates visual storage of the materials which could facilitate retrieval (Amlund, Gaffney, & Kulhavy, 1985). However, provided learning strategies may make students dependent on the provision of strategies hence, hindering transfer to other situations (Di Vesta & Rieber, 1987). Also, when learning strategies are provided to students, there is no guarantee that they will use these strategies. Instead, students may use spontaneous strategies they have used in previous learning situations.

Hannafin, Phillips, Rieber, and Garhart (1987) found that college students who used their own learning strategies performed better on factual and inferential questions than did students who were provided with learning strategies. Hannafin et al. (1987) claimed that learners tended to use their own strategies regardless of how they were prompted during instruction. Howe and Singer (1975) found that students provided with no strategies had better recall than did subjects who used summarizing and other active learning strategies. It appears that subjects' strategies were more effective than were the provided strategies. Hannafin et al. (1987) suggested that more research should be conducted to determine whether students use provided strategies or whether they revert to individual spontaneous strategies. According to his "reconstruction" hypothesis, Spiro (1980) claimed that during the learning process, learners amend, modify, and reconstruct lesson concepts and details after initial lesson presentation, as well as, during the lesson.

The processes involved in the "reconstruction" may result in the development of algorithmic and heuristic spontaneous learning strategies which are more effective than provided strategies. Thus, the present study contributed to the research literature by looking at whether a provided, a student-generated or no-spatial synthesizer enhanced performance on a cued recall test and a comprehension test.

Conclusion

The literature review outlined the theoretical basis for using spatial learning strategies. It also identified the different types of spatial learning strategies and the research related to these strategies. The present study investigated the effectiveness of a provided and a generated spatial synthesizer when learning from prose material. Based on the information discussed in the literature review, the following hypotheses were tested in the present study.

Hypothesis 1

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on an immediate, cued recall and comprehension test than will subjects with no spatial synthesizer.

Hypothesis 2

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on a delayed, cued recall and comprehension test than will subjects with no spatial synthesizer.

Hypothesis 3

There is a significant relationship between spatial ability scores and immediate, and delayed, cued recall and comprehension tests' scores.

Hypothesis 4

There is a significant relationship between verbal ability scores and immediate, and delayed, cued recall and comprehension tests' scores.

Hypothesis 5

Low verbal ability subjects who used synthesizers will perform better on immediate, and delayed, cued recall and comprehension tests than will high verbal ability subjects who used synthesizers.

Hypothesis 6

High spatial ability subjects who used synthesizers will perform better on immediate, and delayed, cued recall and comprehension tests than will low spatial ability subjects who used synthesizers.

Hypothesis 7

There is a significant gender difference on the immediate, and delayed, cued recall and comprehension tests.

Hypothesis 8

High spatial ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low spatial ability subjects.

Hypothesis 9

High verbal ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low verbal ability subjects.

The next chapter reports on the method that was used for the present study.

CHAPTER 3

Method

Subjects

One hundred and sixty-two students from a technical institute volunteered as subjects for this study. The technical institute is the third largest in Canada with an enrolment of over 6,000 full-time and 29,000 part-time students. The majority of students come directly from high school or returned to technical institute for a change of career or upgrading. The students involved in this study were enrolled in the business communications course in the first year business administration program. The business communications course is one course required for completing the two-year business diploma program. Forty-three percent of the subjects were female while fifty-seven percent were male. The average age of the subjects was approximately 22 years. Subjects were randomly assigned to either a provided-synthesizer group, a generated-synthesizer group or a no-synthesizer group. Pre-experimental analysis indicated that the groups were equivalent in terms of verbal and spatial abilities as measured by the verbal and spatial subtests on the General Aptitude Test Battery (GATB). The study was administered over two sessions with a one week interval between sessions.

Design

The design for the study was a multi-group posttest-only control group design (Huck, Cormier, & Bounds, 1974). According to the requirements for the design, subjects were randomly assigned to treatment groups. Each group of subjects was given a different treatment, and posttest data was collected from all subjects. The diagram for the design is as follows.

R	X	O
R	Y	O
R		O

Independent variables. The independent variables for this study were as follows.

1. Synthesizer Type (Provided, Generated, None)
2. Verbal Ability Level (High, Low)
3. Spatial Ability Level (High, Low)
4. Gender (Male, Female)

Dependent variables. The dependent variables for this study were as follows.

1. Unrelated Course Passage Tests
    a. Immediate, Cued Recall
    b. Immediate, Comprehension

c. Delayed, Cued Recall

d. Delayed, Comprehension

2. Related Course Passage Tests

a. Immediate, Cued Recall

b. Immediate, Comprehension

3. Unrelated Course Passage Questionnaire

4. Related Course Passage Questionnaire

Statistical Analysis Used

A microcomputer statistical software called STATS+ (Statistical System with Data Base Management and Graphics) was used to analyze the data collected in the present study (Statsoft, 1988). For a multi-group posttest-only control group design, Huck et al. (1974) recommended the use of analysis of variance to test for any differences between the groups. If necessary, the analysis of variance should be followed by post-hoc multiple comparison investigation. Fisher (cited in Fergenson, 1981) developed the analysis of variance method to examine all pairs of means simultaneously to determine if one or more of the means deviated significantly from other means (Hopkins & Glass, 1978). Thus, in the present study, an analysis of variance (ANOVA) was used to test whether there were any significant differences between the treatment groups. Post-hoc analysis was conducted using the Scheffé Test. The Scheffé Test was chosen because it is the most conservative when compared to the other post-hoc tests (Huck, Cormier, & Bounds, 1974).

Correlation analysis was used to determine whether there were any relationships between spatial and verbal ability scores and scores on the recall and comprehension tests.

Materials

The materials used in this study consisted of (a) the training materials to show subjects how to construct a spatial synthesizer, (b) a spatial and a verbal ability test, (c) two reading passages (a unrelated course passage and a related course passage), (d) the treatment materials (a provided-synthesizer, the instructions to generate a spatial synthesizer, and instructions for the no-synthesizer group), (e) an immediate, and a delayed, cued recall and comprehension test, and (f) two attitude questionnaires.

Training materials. The training materials showed all subjects in the present study how to construct the spatial synthesizer. The training materials consisted of an example of a spatial synthesizer and the procedure for generating a spatial synthesizer. The example used to outline the procedure was a spatial map of information subjects had already encountered in class. Refer to Appendix 2 for the training reading passage, the sample spatial synthesizer, and the procedure used for training subjects to construct the spatial synthesizer.

Text passages. Two reading passages were used in the study. The first passage was unfamiliar to subjects and was not related to the course subjects were taking. The unfamiliar and unrelated passage dealt with Shannon's Communication Theory. The unfamiliarity of the passage was confirmed from the data on one question on the attitude questionnaire. Subjects were asked to respond on a scale of familiarity of one to five (1 - not familiar and 5 - very familiar) relative to the information in the unrelated course passage. The mean response for the provided-synthesizer group was 1.59, the mean response for the generated-synthesizer group was 1.57, while the mean response for the no-synthesizer group was 1.45. Analysis of variance revealed no significant difference between the three treatment groups, $F(2, 152) = .41$, $p > .05$. The result indicated that none of the three treatment groups were familiar with the unrelated course passage.

The information for the unrelated course passage was selected from an article on communications from a Scientific American Magazine (Pierce, 1972). The passage was typed on one page and consisted of 610 words. The readability level of the passage was Grade 12 as determined by the Flesch (1948) readability formula. For the remainder of the thesis, the Shannon's Communication Theory passage is referred to as the "unrelated course passage." The unrelated course passage was used to determine whether the same results would be obtained using an unfamiliar and difficult passage. Also, the use of the unrelated course passage allowed for the administration of a delayed, cued recall and comprehension test which was not possible for the second passage. The second passage is described in the next section.

The second reading passage was directly related to the course students were taking. The passage was four and one half pages long and consisted of 2,087 words.

The Flesch (1948) readability formula indicated that the reading level of the passage was Grade 10. The passage dealt with the procedure for developing formal presentations and was based on one chapter from the textbook (Bovee and Thill, 1989) for the course in which subjects were enrolled. However, the instructors for the course were asked not to assign students any readings or cover any materials on the information in the reading passage used in the study. Two questions were included on the questionnaire to determine whether subjects had read the chapter prior to the study and the level of familiarity with the passage. Ninety-seven percent of the subjects said that they had not read the chapter prior to the present study. The other question asked subjects to respond on a scale from 1 (not familiar) to 5 (very familiar) to indicate how familiar they were with the information in the passage. The mean response for the provided-synthesizer group was 2.76, the mean response for the generated-synthesizer group was 3.15, while the mean response for the no-synthesizer group was 2.97. Analysis of variance revealed that there was no significant difference between the three groups, $F(2,128) = 1.47$, $p > .05$ on the level of familiarity of the passage.

For the remainder of the thesis, the second passage will be referred to as the "related course passage." Refer to Appendix 3 for the two reading passages that were used in the present study.

Provided spatial synthesizer. The provided spatial synthesizer was developed using the procedure outlined by Dansereau (1989), Goetz (1984), Holley and

Dansereau (1984), and Van Patten, Chao, and Reigeluth (1986). The procedure that was used to develop the spatial synthesizer is as follows.

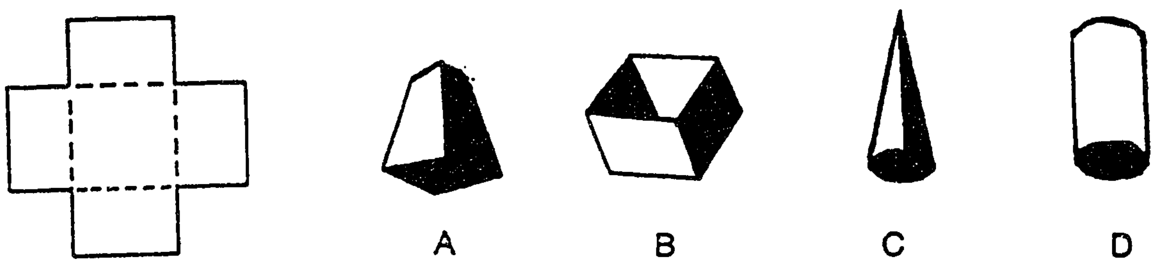
1. Place the title of the passage at the top of the page.
2. Visualize and write the major sections or topics in the passage.
3. Visualize the structure of the passage.
4. Place the concept or idea in an order that reflects the structure of the passage. Use the title of the passage as the highest level.
5. Visualize the relationship between two concepts or ideas.
6. Draw a line between the two concepts or ideas that are related.
7. Label the line with a word or short phrase to describe the relationship between the two concepts or ideas.
8. Visualize the relationship between all of the concepts or ideas.
9. Draw lines to connect all concepts or ideas that are related.
10. Label each line with a word or short phrase to describe the relationship.
11. Visualize the structure of the passage and check to determine that the spatial synthesizer reflects the structure of the passage.

The provided-synthesizer was developed on one sheet of paper using word processing software. After reading the passage, the provided-synthesizer group was given the spatial synthesizer and instructions on how to use the synthesizer. Refer to Appendix 4 for the provided-synthesizer and the instructions given to the provided-synthesizer group.

Generated spatial synthesizer. After reading the passage, the generated-synthesizer group was given the procedure for generating the spatial synthesizer and two blank sheets of paper to use to generate the synthesizer. The procedure given to subjects to generate the spatial synthesizer was similar to the procedure used to develop the provided-synthesizer. Refer to Appendix 5 for the instructions given to the generated-synthesizer group.

No-synthesizer. The no-synthesizer group was asked to wait for further instructions after reading the passage. Refer to Appendix 6 for the instructions given to the no-synthesizer group.

Aptitude tests. A spatial and a verbal aptitude test were administered to subjects at the beginning of the experiment to determine their spatial and verbal ability levels. The tests were the spatial and verbal subtests of the Canadian version of the General Aptitude Test Battery (GATB) aptitude test (Canada Employment and Immigration Commission, 1983). The original GATB aptitude test was developed by the United States Department of Labor (1970). The spatial subtest measures spatial ability which is the ability to think visually of geometric forms and to comprehend two-dimensional representational objects. The task on the spatial aptitude test is to select the proper three-dimensional representation of a flat, two dimensional drawing. Each item on the spatial subtest presents a drawing which represents a flat piece of metal with dotted lines to show where the metal is to be bent. At the right of the metal drawing are drawings of four objects. The subjects' task was to select which of the four objects can be made from the metal piece when it is folded along the dotted lines. A sample question on the GATB spatial subtest is shown below.



The verbal subtest measures verbal ability which is the ability to comprehend language, to understand relationships between words and to understand meanings of whole sentences and paragraphs. For the verbal subtest, the task is to select two words from a list of four words which are the same in meaning (synonym) or opposite in meaning (antonym). The following is a sample question that is similar to the questions on the verbal subtest.

For the following exercise find the two words which are most nearly the same in meaning or opposite in meaning.

a. good b. excellent c. bad d. small

Subjects' task was to select the two words that were either synonyms or antonyms. The words good and bad are antonyms. Hence, the correct answer is a and c.

Reliability coefficients. Cronbach alpha reliability coefficients were determined for the spatial and verbal ability subtests using 36 subjects from the present study. The alpha coefficients for the spatial and verbal ability subtests were .95 and .91 respectively.

Test-retest reliability coefficients for the spatial and verbal subtests were reported in the literature (U.S. Department of Labor, 1970). The test-retest reliability of the General Aptitude Test Battery was determined on job applicants and high school students. In the job applicants group (N = 522), there were 276 males and 246 females with a mean age of 29.9 years. For the job applicants group, the test-retest reliability of the spatial subtest was .86 and the verbal subtest was .94. In the high school students group (N = 1,159), there were 605 males and 554 females with a mean age of 17.7 years. For the high school students group, the test-retest reliability of the spatial subtest was .80 and the verbal subtest was .86 (U.S. Department of Labor, 1970).

Stability coefficient. The stability coefficient for the GATB spatial and verbal ability subtests was determined using U.S. Government employees. Subjects age ranged between 25 and 34 years. A total of 1,309 subjects were involved in the study. Reported stability coefficients for the verbal subtest for test-retest periods for one year to three years ranged from .85 to .86 while the range for the spatial subtest was from .75 to .82 (U.S. Department of Labor, 1970).

Predictive validity. The predictive validity of the verbal subtest and the spatial subtest was determined using business education students enrolled at a college. The sample consisted of 50 business education students and the criterion measure was grade point averages for courses in business. For the verbal subtest, the correlation was .57 ($p < .01$) while the correlation was .32 ($p < .05$) for the spatial subtest (U.S. Department of Labor, 1970).

Correlation with other aptitude tests. The verbal subtest of the GATB had acceptable correlations with other verbal subtests (U.S. Department of Labor, 1970). Using 64 high school students as subjects (male = 21 and female = 43) with an average age of 17 years, there was a correlation of .78 between the GATB verbal subtest and the Lorge-Thorndike Intelligence Test.

Using 56 university students as subjects with a mean age of 24.3 years, there was a correlation of .64 between the GATB verbal subtest and the Miller Analogies Test.

There was a correlation of .69 between the GATB verbal subtest and the reading comprehension subtest on the California Achievement Test. Subjects were 60 high school students (31 males and 29 females) with an average age of 15.4 years.

For the Wechsler Adult Intelligence Scale (WAIS), there was a correlation of .83 between the GATB verbal ability subtest and the WAIS vocabulary subtest and .71 with the WAIS comprehension subtest. Subjects were 69 vocational employees with an average age of 23 years (U.S. Department of Labor, 1970).

There was a correlation of .60 between the GATB spatial subtest and the Space Relations subtest on the Differential Aptitude Test. Subjects were 464 office applicants with a mean age of 25.1 years.

Testing materials. A cued recall and an inferential comprehension test were developed for both reading passages. Refer to Appendix 7 for the tests for both passages. The tests were constructed using the procedure outlined by Anderson (1972) and Barrett (1968). All of the questions were developed using the short answer format. The questions either asked a direct question, provided a stimulus word or phrase, or posed a specific situation (Hopkins, Stanley, & Hopkins, 1990). The answers to the questions consisted of either one word or a short phrase.

The cued recall questions required short answers and assessed explicitly stated information in the passage. The correct answer to each question could be obtained directly from the passage. The inferential comprehension questions also required short answers and could be answered using information from the passage in a different form. Correct answers required the integration of information from more than one part of the passage or the development of general ideas to reflect parts of the passage.

The unrelated course passage test consisted of four cued recall questions and six comprehension questions. The related course passage test consisted of 12 cued recall questions and 13 comprehension questions.

Reliability. The reliability of the tests was determined by the test-retest method. There was a one-day interval between the test and the retest. The test-retest reliability for the related course passage test was determined using 18 subjects who were involved in the study. The test-retest reliability coefficient for the related course passage test was .88. The test-retest reliability of the unrelated course passage test was determined with 13 subjects who were involved in the study. The test-retest reliability coefficient for the unrelated course passage test was .78.

Content validity. The content validity of the related course passage test was determined by giving the passage and test to an instructor in business communication to judge whether the test measured cued recall and inferential comprehension of the passage. Only one question was judged as being invalid for the related course passage. After discussion with the instructor, it was decided to drop this question from the test. Because of the technical nature of the unrelated course passage, the content validity was determined by giving the passage and test to a college graduate with a science background to judge whether the test measured cued recall and inferential comprehension of the passage. For the unrelated course passage, all of the questions were judged to be valid to test the contents of the passage.

To determine whether the questions were classified correctly as cued recall and comprehension, the tests were given to an instructor in business communication to judge each question. The instructor was given the definition of cued recall and inferential comprehension and asked to classify each question as either cued recall or comprehension. The proportion of correct classification was .92 for the related course passage and 1.0 for the unrelated course passage.

To determine the validity of the answers to the questions, the tests were given to an instructor in business communications to judge whether the answers to the questions were correct. Two answers were judged as being partially correct. The answer key was then changed to reflect the correct answers.

Attitude Questionnaire. An attitude questionnaire was given to subjects after each passage to determine their feelings toward the treatment materials and the experiment. The questions on the questionnaire required yes or no responses or response to a Likert type scale ranging from one to five. Refer to Appendix 8 for the attitude questionnaires. The attitude questionnaires were developed using the Krathwohl, Bloom, and Masia (1964) taxonomy for the affective domain. The questions were based on the following taxonomy as outlined by Krathwohl et al. (1964): (a) receive or attend to the information (receiving), (b) actively attending (responding), (c) hold a particular value (valuing), (d) set priority of values (organization), and (e) a particular value or set of values (characterization by a value or value complex.

The test-retest method, with a one day interval between the test and the retest, was used to determine the reliability of the attitude questionnaire. The test-retest reliability coefficient for the unrelated course passage questionnaire was .77

using a group of 16 subjects. The test-retest reliability for the related course passage questionnaire was determined using 10 subjects. The test-retest reliability coefficient for the related course passage questionnaire was .82.

Procedure - Session 1

Refer to Chart 1 for the sequence of activities that was followed during session one of the study.

Session one took 55 minutes to complete. During session one, all subjects were trained to generate and process spatial synthesizers, the spatial and verbal aptitude subtests were administered, the unrelated course passage and treatments were given, and the immediate, cued recall and comprehension tests were administered.

Training. At the beginning of the first session, subjects were asked to volunteer to participate in the study. The experimenter then trained all subjects on how to construct a spatial synthesizer. The training was based on the procedure for generating spatial learning strategies proposed by Dansereau (1989); Goetz (1984); Holley and Dansereau (1984); Jones, Pierce, and Hunter (1989); and Van Patten, Chao, and Reigeluth (1986). Dansereau (1989) proposed that students should be trained using familiar materials to optimize cognitive resources to learn about the spatial synthesizer rather than processing the materials.

Chart 1

Sequence of Activities for Session 1

Activities	Groups		
	Provided Syn.	Generated Syn.	No Syn.
Training	x	x	x
Aptitude Test	x	x	x
Reading Passage	x	x	x
Provided Syn.	x		
Generated Syn.		x	
No Syn.			x
Interpolated Task	x	x	x
Cued Recall Test	x	x	x
Comprehension Test	x	x	x
Attitude Questionnaire	x	x	x

As a result, the training materials for this study used materials already covered in the course. Then, the procedure for generating the synthesizer was outlined. The steps used to train subjects to generate the synthesizer were as follows.

1. Write the title of the passage at the top of the page.
2. Visualize and write the major sections or topics in the passage.
    a. This is usually obtained from headings and topic sentences.
    b. Use one word or a short phrase to describe each section.
    c. Refer back to the passage if needed.
3. Visualize the structure of the passage.
4. On another piece of paper, place the concept or idea in an order that reflects the structure of the passage. Use the title of the passage as the highest level.
5. Visualize the relationship between two concepts or ideas.
6. Draw a line between two concepts or ideas that are related.
7. Label the line with a word or short phrase to describe the relationship between the two concepts or ideas.
8. Visualize the relationship between all of the concepts or ideas.
9. Draw lines to connect all concepts or ideas that are related.
10. Label each line with a word or short phrase to describe the relationship.
11. Visualize the structure of the passage and check to determine that the synthesizer reflects the structure of the passage.

The last part of the training outlined the steps for studying the synthesizer. Subjects were asked to study the synthesizer using the following steps.

1. Start reading the synthesizer from top to bottom.
2. If there is a line connecting more than one box, place the relationship in the form of a sentence and read the sentence quietly.
3. Repeat step 2 for all of the relationships in the synthesizer.
4. For each box try to recall the information from the passage that is related to that box.
5. If you cannot recall the details for a box, go back to the passage and look for the details.
6. Take a final look at the synthesizer to get an overall picture of the content.

After the training, subjects were allowed to ask any questions on the procedure used to generate the spatial synthesizer. The total time for training subjects on how to generate the spatial synthesizer was 15 minutes.

Treatment. The materials were packaged in 8.5" x 11" envelopes. A total of 162 subjects were given the treatment in their regular classrooms consisting of small groups ranging in size from 11 to 22 students. One subject was ill and another subject was not following instructions during the experiment. As a result, the experimenter decided to drop these two subjects from the experiment. The small size of the groups allowed for adequate training and efficient administration of the experimental materials. Subjects came into the classroom for their regular instruction. After all of the subjects had taken their seats, they were trained on how to generate and study the spatial synthesizer. After the training, each subject was randomly given one of the treatment packages. There were 56 subjects in the provided-synthesizer group, 53 subjects in the generated-synthesizer group, and 51 subjects in the no-synthesizer group. Subjects were told not to open their packages until instructed to do so.

Subjects were instructed to take out the GATB booklet and turn to the spatial subtest. The instructions for completing the spatial subtest were read aloud to the subjects. The instructions were followed by five practice items to get subjects prepared for the test. Subjects were then given six minutes to complete the spatial subtest consisting of 40 questions. At the end of six minutes, subjects were asked to stop working on the spatial subtest.

Subjects were then asked to turn to the verbal ability subtest in the GATB booklet. Again the instructions for completing the verbal subtest were read aloud and subjects were allowed to complete the five practice items. After the practice items, subjects were given six minutes to complete the 60 item verbal subtest. At the end of six minutes, subjects were asked to stop working on the verbal subtest and to place the GATB booklet back into the envelope.

Subjects were then asked to take out the one page passage on "Shannon's Communication Theory" and study it for five minutes. They were told to study the passage the same way they study any other reading material for the course. Subjects were informed that they would be given a test after reading the passage to determine how much they had learned from the passage. At the end of five minutes, subjects were asked to take out the next set of instructions from the envelope. Depending on the treatment group, subjects were asked either to wait for further instructions (no-synthesizer group), to use the instructions to study the provided-synthesizer (provided-synthesizer group), or to use the procedure to generate the synthesizer (generated-synthesizer group). Subjects were given fifteen minutes to complete the treatment task. At the end of fifteen minutes, subjects were asked to place all papers back in the envelope.

As an interpolated task, subjects were given two addition problems to solve. The addition task was used to reduce possible recency effects (Dean & Enemoh, 1983) so that subjects would access the information from long-term memory to answer the test questions. The interpolated task took one minute to complete.

Subjects were then asked to take out the cued recall and comprehension tests from the envelope. Five minutes was allowed to complete the unrelated course passage tests which consisted of ten questions. After the tests, subjects were asked to complete the attitude questionnaire.

Procedure - Session 2

Refer to Chart 2 for the sequence of activities for session two.

Session two was administered one week after session one and was 55 minutes in duration. A total of 130 subjects showed up for session two. During session two, all subjects were given the delayed, cued recall and comprehension tests for the

Chart 2

Sequence of Activities for Session 2

Activities	Groups		
	Provided Syn.	Generated Syn.	No Syn.
Delayed Tests	x	x	x
Reading Passage	x	x	x
Provided Syn.	x		
Generated Syn.		x	
No Syn.			x
Interpolated Task	x	x	x
Cued Recall Test	x	x	x
Comprehension Test	x	x	x
Attitude Questionnaire	x	x	x

unrelated passage, the related course passage and treatment materials, the cued recall and comprehension tests for the related passage, and the attitude questionnaire.

Treatment. The materials were packaged in 8.5" x 11" envelopes. Subjects were in their regular classrooms of small groups ranging in size from 11 to 22 students. Subjects came into the classroom for their regular instruction. After all students had taken their seats, they were randomly given the treatment packages. All of the subjects were given a package using the same procedure. There were 42 subjects in the provided-synthesizer group, 45 subjects in the generated-synthesizer group, and 43 subjects in the no-synthesizer group. Subjects were told not to open their packages until instructed to do so.

First, the unrelated passage delayed cued recall and comprehension tests were administered. The delayed tests consisted of four cued recall and six comprehension questions and subjects were allowed five minutes to complete the test.

All subjects were then asked to take out the related course passage and to read the passage for twelve minutes. Subjects were informed that they would be given a test after they read the passage to determine how much they had learned from the passage. After reading the passage, subjects were asked to take out the instructions for the treatment. Depending on the treatment group, subjects were allowed fifteen minutes either to study the provided-synthesizer, to generate a synthesizer for the passage, or to wait for further instructions (no-synthesizer group).

Subjects were then asked to solve two addition problems as an interpolated task to reduce possible recency effects (Dean & Enemoh, 1983). This was followed by the test which consisted of 12 cued recall and 13 comprehension questions. Subjects were given 15 minutes to complete the test. After the test, subjects were asked to complete the attitude questionnaire. At the end of the experiment, students were thanked for their participation in the study.

Scoring Procedures

Cued recall and comprehension tests. The answers to the cued recall and comprehension questions consisted of single words or short phrases. For the scoring of the test, each answer was judged as being either correct, partially correct, or incorrect. The correct answer was given a score of 2, the partially correct answer was given a score of 1, and the incorrect answer a score of 0. For questions with more than one answer, each answer was scored separately. The scorer was unaware of each subject's treatment group during the scoring.

Interrater reliability. Fifteen percent of the tests were randomly selected and given to two judges to score to determine the reliability of the scoring procedure. One judge was an instructor in business communication while the other judge was a college graduate with a science background. Two judges with different background were chosen because of the different content of the passages. The two judges scored both of the passages. The judges' scores were correlated with the marker's scores.

The interrater reliabilities for the unrelated course passage test were .91 and .87 respectively. For the related course passage test, the interrater reliabilities were .97 and .98 respectively.

Generated-synthesizer. The synthesizers generated by the generated-synthesizer group were scored to judge their completeness. The judgement was made on comparison with the provided-synthesizer. The provided-synthesizer consisted of main ideas with lines showing the relationships among the ideas. Each main idea in the student-generated synthesizer was given a score. A score of 2 was given if the main ideas in student-generated synthesizer was exactly the same as the main idea in the provided-synthesizer. A score was 1 was given if the main idea was partially correct while a score of 0 was given for the incorrect main idea. In addition, each link or line showing the relationship among the main ideas was compared with relationships in the provided-synthesizer and given a score. A score of 2 was given if the correct relationship and the word or phrase describing the relationship in the student-generated synthesizer was the same as in the provided-synthesizer. A score of 1 was given for the correct relationship but no word or phrase describing the relationship, and a score of 0 for an incorrect relationship. To determine the reliability of the scoring procedure for the generated-synthesizer, fifteen percent of the synthesizers were given to a college graduate in science to score. The interrater reliability for the scoring procedure was .88.

The next chapter presents the results that were obtained from the statistical analysis.

CHAPTER 4

Results

The following sections present the results obtained from the present study. Analysis of variance (ANOVA) was used to test whether there were any significant differences between the treatment groups. Each hypothesis is listed followed by the results for each hypothesis. Then, conclusions on whether to reject or accept the hypothesis are stated. Since two reading passages (an unrelated and a related course passage) were used in this study, the results for the hypotheses are given for the passages separately. The results are followed by a conclusion for each passage.

Results for the Hypotheses

Hypothesis 1

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on an immediate, cued recall and comprehension test than will subjects with no spatial synthesizer.

Unrelated course passage. Analysis of variance was used to determine if there was any significant difference between the treatment groups (provided-synthesizer, generated-synthesizer, and no-synthesizer) on the immediate, cued recall test and on the immediate, comprehension test. Results showed that there was a significant main effect for the treatment groups, $F(2,157) = 14.46$, $p < .05$ on the immediate, cued recall test. Refer to Table 1 for the analysis of variance summary for the immediate, cued recall test. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer group (M = 11.64, SD = 3.56) outperformed the generated-synthesizer group (M = 8.75, SD = 4.43) and the no-synthesizer group (M = 7.29, SD = 4.79). There was no significant difference between the generated-synthesizer group and the no-synthesizer group on the immediate, cued recall test.

There was no significant difference between the treatment groups on the immediate, comprehension test, $F(2,157) = 1.08, p > .05$. Table 2 shows the analysis of variance summary for the immediate, comprehension test. Refer to Table 3 for the means, standard deviations, and number of subjects in each group and Figure 1 for a graph of the means.

Table 1

Analysis of Variance for the Treatment Groups on the Immediate, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	528.34	2	264.17	14.46	.000*
Within	2867.26	157	18.26		

*$p < .05$

Table 2

Analysis of Variance for the Treatment Groups on the Immediate, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	16.01	2	8.01	1.08	.341
Within	1158.36	157	7.38		

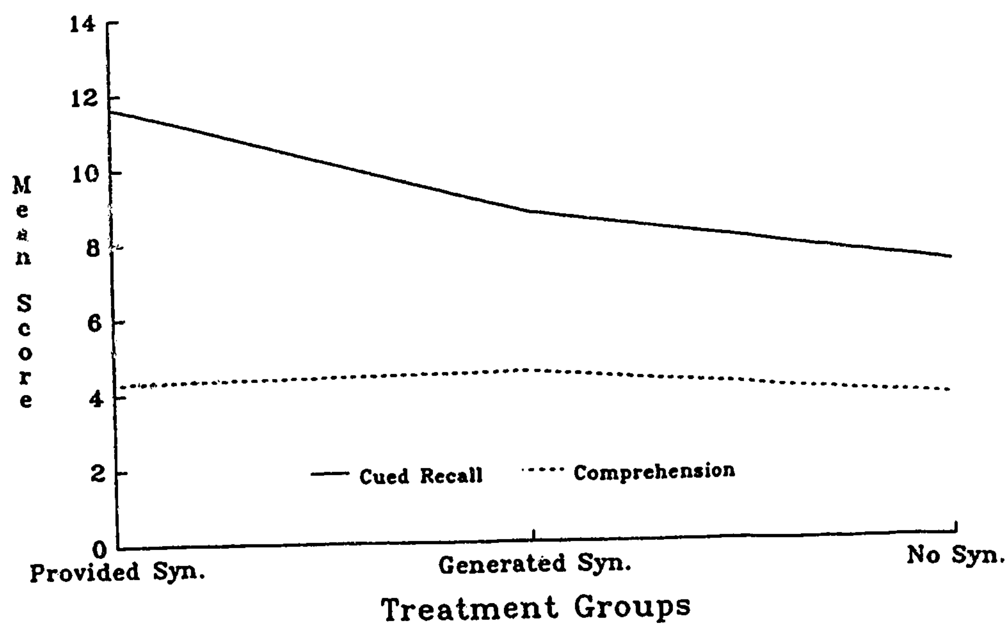


Figure 1. *Mean Score on the Immediate, Cued Recall and Comprehension Tests for the Unrelated Course Passage*

Table 3

Means and Standard Deviations for the Unrelated Course Passage Immediate, Cued Recall and Comprehension Tests

	Immediate Cued Recall		Immediate Comprehension	
Treatment Group	M	SD	M	SD
Provided-Synthesizer (n = 56)	11.64	3.56	4.28	2.48
Generated-Synthesizer (n = 53)	8.75	4.43	4.51	2.74
No-Synthesizer (n = 51)	7.29	4.79	3.74	2.92
Maximum Score	18.00		14.00	

Part of Hypothesis 1 was accepted for the unrelated course passage on the immediate, cued re[illegible]all test since the provided-synthesizer group outperformed the no-synthesi [illegible]n. The generated-synthesizer group performed as well as the no-synthesizer [illegible]e immediate, cued recall test. For the immediate, comprehension [illegible]ere was no significant difference between the three groups.

Related course passage. Analysis of variance was used to determine if there was any significant difference between the treatment groups (provided-synthesizer, generated-synthesizer, and no-synthesizer) on the immediate, cued recall and comprehension tests. There was a significant main effect for the treatment groups, $F(2,115) = 10.60, p < .05$ on the immediate, cued recall test. Refer to Table 4 for the analysis of variance summary. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer group ($M = 26.62$, $SD = 7.51$) outperformed the generated-synthesizer group ($M = 21.24$, $SD = 6.48$) and the no-synthesizer group ($M = 19.46$, $SD = 7.49$). There was no significant difference between the generated-synthesizer group and the no-synthesizer group on the immediate, cued recall test.

There was no significant difference between the treatment groups on the immediate, comprehension test, $F(2,115) = .24, p > .05$. Table 5 shows the analysis of variance summary. Refer to Table 6 for the means and standard deviations and Figure 2 for a graph of the mean scores.

For the immediate, cued recall test, hypothesis 1 was accepted since the provided-synthesizer group performed better than did the no-synthesizer group. However, for the immediate, comprehension test, the hypothesis was rejected since there was no significant difference between the groups.

Table 4

Analysis of Variance for the Treatment Groups on the Immediate, Cued Recall Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1087.36	2	543.68	10.60	.000*
Within	5896.12	115	51.27		

*$p < .05$

Table 5

Analysis of Variance for the Treatment Groups on the Immediate, Comprehension Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	6.77	2	3.38	.24	.789
Within	1630.37	115	14.17		

Table 6

Means and Standard Deviations for the Related Course Passage Immediate, Cued Recall and Comprehension Tests

Treatment Group	Immediate Cued Recall		Immediate Comprehension	
	M	SD	M	SD
Provided-Synthesizer (n = 40)	26.62	7.51	7.40	3.86
Generated-Synthesizer (n = 41)	21.24	6.48	6.83	3.56
No-Synthesizer (n = 37)	19.46	7.49	7.02	3.89
Maximum Score	56.00		34.00	

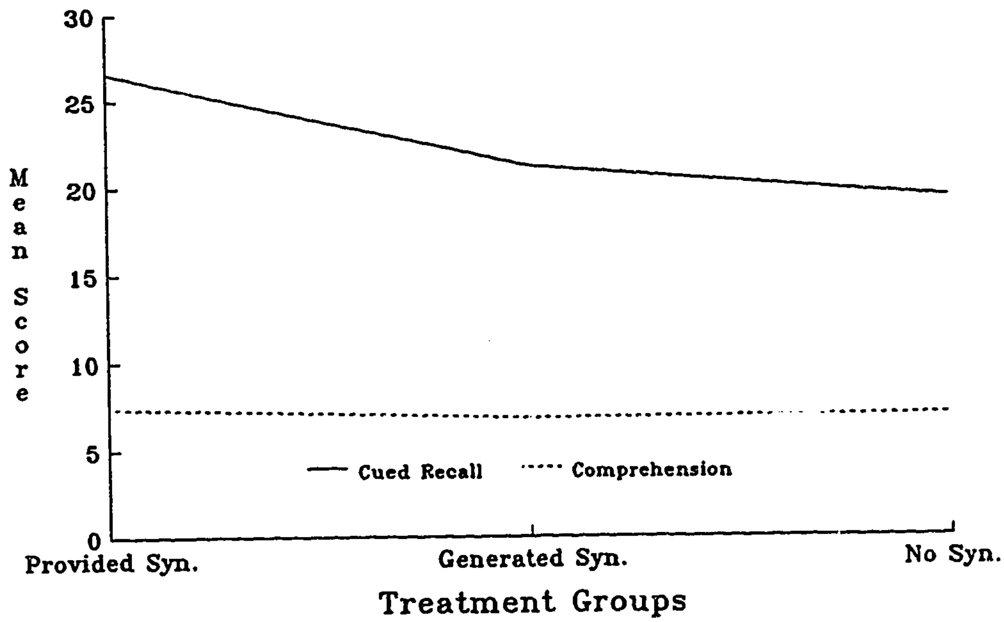


Figure 2. *Mean Score on the Immediate, Cued Recall and Comprehension Tests for the Related Course Passage*

The same result was obtained for both the unrelated and related course passages. For both passages, the provided-synthesizer group outperformed the generated-synthesizer group and the no-synthesizer group on the immediate, cued recall test. There was no significant difference between the generated-synthesizer group and the no-synthesizer group on the immediate, cued recall test. Also, there was no significant difference between the three groups on the immediate, comprehension test.

Hypothesis 2

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on a delayed, cued recall and comprehension test than will subjects with no spatial synthesizer. The data for the delayed tests was obtained for the unrelated course passage only since the course instructor covered the related course passage with the students before the delayed test could be administered.

Unrelated course passage. Analysis of variance revealed no significant difference between the treatment groups on the delayed, cued recall test, $F(2,102) = .54$, $p > .05$. Table 7 shows the summary of the analysis of variance for the delayed, cued recall test. Also, there was no significant difference between the groups on the delayed, comprehension test, $F(2,102) = .15$, $p > .05$. Table 8 shows the analysis of variance summary for the delayed, comprehension test. Refer to Table 9 for the means and standard deviations and Figure 3 for a graph showing the mean scores on the delayed, cued recall and comprehension tests.

Hypothesis 2 was rejected since there was no significant difference between the three groups on the delayed, cued recall and comprehension tests .

Table 7

Analysis of Variance for the Treatment Groups on the Delayed, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	14.27	2	7.13	.54	.589
Within	1347.38	102	13.21		

Table 8

Analysis of Variance for the Treatment Groups on the Delayed, Comprehension Score for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1.16	2	.58	.15	.853
Within	379.83	102	3.72		

Table 9

Means and Standard Deviations for the Unrelated Course Passage Delayed, Cued Recall and Comprehension Tests

	Delayed Cued Recall		Delayed Comprehension	
Treatment Group	M	SD	M	SD
Provided-Synthesizer (n = 36)	6.17	3.89	2.72	2.09
Generated-Synthesizer (n = 33)	5.36	2.95	2.64	1.85
No-Synthesizer (n = 36)	5.42	3.92	2.47	1.83
Maximum Score	18.00		14.00	

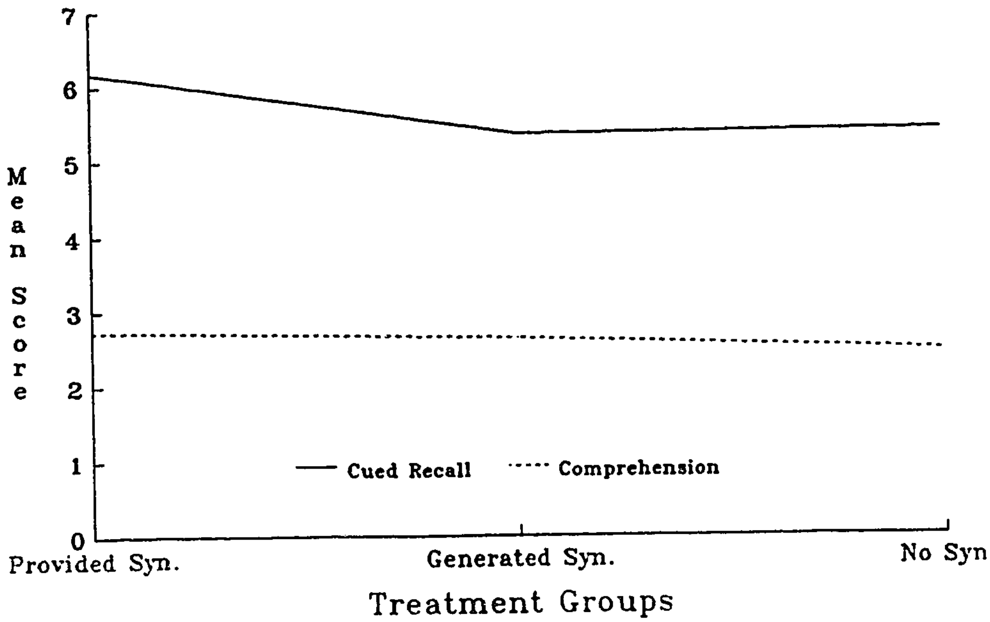


Figure 3. *Mean Score on the Delayed, Cued Recall and Comprehension Tests for the Unrelated Course Passage*

Hypothesis 3

There is a significant relationship between spatial ability scores and the immediate, and delayed, cued recall and comprehension tests' scores.

Unrelated Course Passage

Provided-synthesizer group. For subjects who were provided with the synthesizer, there was no significant relationship between spatial ability scores and scores on the immediate, cued recall test ($r = -.14$, $p > .05$) and the immediate, comprehension test ($r = .07$, $p > .05$). Similarly, there was no significant relationship between spatial ability scores and scores on the delayed, cued recall test ($r = .21$, $p > .05$) and the delayed, comprehension test ($r = .09$, $p > .05$). Hence, hypothesis 3 was rejected for the provided-synthesizer group.

Generated-synthesizer group. For subjects who were asked to generate the spatial synthesizer, there was no significant relationship between spatial ability scores and scores on the immediate, cued recall test ($r = -.04$, $p > .05$) and the immediate, comprehension test ($r = -.17$, $p > .05$). There was no significant relationship between spatial ability scores and scores on the delayed, cued recall test ($r = -.03$, $p > .05$). Also, there was no significant relationship between spatial ability scores and scores on the delayed, comprehension test ($r = -.04$, $p > .05$). As a result, hypothesis 3 was rejected for the generated-synthesizer group.

Related Course Passage

Provided-synthesizer group. For subjects who were provided with the spatial synthesizer, there was no significant relationship between spatial ability scores and scores on the immediate, cued recall test ($r = -.11$, $p > .05$) and the immediate, comprehension test ($r = .13$, $p > .05$). Hence, hypothesis 3 was rejected for the provided-synthesizer group.

Generated-synthesizer group. For those subjects who were asked to generate the spatial synthesizer, there was no significant relationship between spatial ability scores and scores on the immediate, cued recall test ($r = .01$, $p > .05$) and the immediate, comprehension test ($r = .17$, $p > .05$). Hence, hypothesis 3 was rejected for the generated-synthesizer group.

Hypothesis 4

There is a significant relationship between verbal ability scores and the immediate, and delayed, cued recall and comprehension tests' scores.

Unrelated Course Passage

Provided-synthesizer group. For subjects who were provided with the synthesizer, there was no significant relationship between verbal ability scores and scores on the immediate, cued recall test ($r = -.11$, $p > .05$) and the immediate, comprehension test ($r = .17$, $p > .05$). Similarly, there was no significant relationship between verbal ability scores and scores on the delayed, cued recall test ($r = .28$, $p > .05$) and the delayed, comprehension test ($r = .38$, $p > .05$). Hence, hypothesis 4 was rejected for the provided-synthesizer group.

Generated-synthesizer group. For subjects who were asked to generate the spatial synthesizer, there was no significant relationship between verbal ability scores and scores on the immediate, cued recall test ($r = .25$, $p > .05$) and the immediate, comprehension test ($r = .28$, $p > .05$). Also, there was no significant relationship between verbal ability scores and scores on the delayed, cued recall test. ($r = .11$, $p > .05$). However, there was a significant relationship between verbal ability scores and scores on the delayed, comprehension score ($r = .64$, $p < .05$). As a result, hypothesis 4 was rejected for the immediate, cued recall and comprehension tests and the delayed, cued recall test. However, hypothesis 4 was accepted for the delayed, comprehension test.

Related Course Passage

Provided-synthesizer group. For subjects who were provided with the spatial synthesizer, there was no relationship between verbal ability scores and scores on the immediate, cued recall test ($r = .17$, $p > .05$) and the immediate, comprehension test ($r = .29$, $p > .05$). As a result, for the provided-synthesizer group, hypothesis 4 was rejected.

Generated-synthesizer group. For those subjects who were asked to generate the spatial synthesizer, there was a significant relationship between verbal ability scores and scores on the immediate, cued recall test ($r = .43$, $p < .05$). However, there was no significant relationship between verbal ability scores and scores on the immediate, comprehension test ($r = .28$, $p > .05$).

Hence, for the immediate, cued recall test, hypothesis 4 was accepted since there was a significant relationship between verbal ability scores and scores on the immediate, cued recall test. However, hypothesis 4 was rejected for the immediate, comprehension test.

Hypothesis 5

Low verbal ability subjects who used synthesizers will perform better on immediate, and delayed, cued recall and comprehension tests than will high verbal ability subjects who used synthesizers.

A median split was used to divide subjects into high and low verbal ability groups.

Unrelated Course Passage

Immediate tests. A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and verbal ability level (high and low). The dependent variables were scores on the immediate, and delayed, cued recall and comprehension tests. There was a significant two-way interaction between treatment group and verbal ability level on the immediate, cued recall test, $F(2,154) = 4.51$, $p < .05$. Post hoc planned comparisons revealed that for the generated-synthesizer group, high verbal ability subjects ($M = 9.86$, $SD = 4.23$) performed better on the immediate, cued recall test than did low verbal ability subjects ($M = 7.30$, $SD = 4.34$), $t(154) = 2.21$, $p < .05$. There was no significant main effect for verbal ability, $F(1,154) = .86$, $p > .05$. Refer to Table 10 for the analysis of variance summary for the immediate, cued recall test. Table 11 shows the means and standard deviations and Figure 4 is a graph of the means.

Table 10

Analysis of Variance for Verbal Ability Level by Treatment Group on the Immediate, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	562.48	2	281.24	16.06	.000
B. Verbal	15.15	1	15.15	.86	.356
A x B	158.07	2	79.03	4.51	.012*
Within	2696.87	154	17.51		

*$p < .05$

Table 11

Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels on the Immediate, Cued Recall Test

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	31	10.71	3.76	25	12.80	2.97
Generated-Synthesizer	30	9.86	4.23	23	7.30	4.34
No-Synthesizer	25	8.00	5.01	26	6.61	4.58
Maximum Score		18.00			18.00	

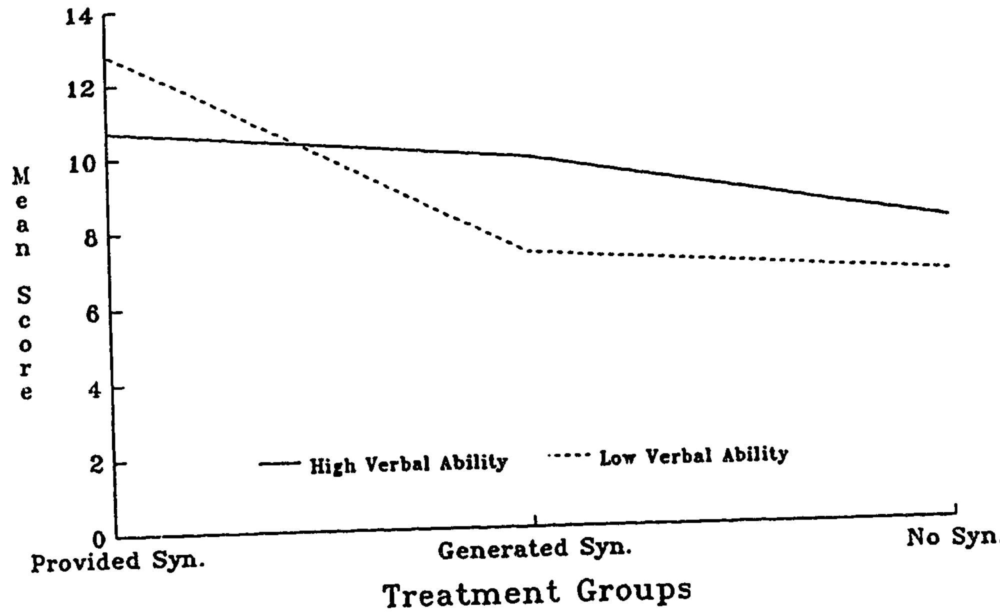


Figure 4. *Mean Score for High and Low Verbal Ability Levels on the Immediate, Cuec Recall Test for the Unrelated Course Passage.*

There was no significant interaction between treatment group and verba ability level, $F(2,154) = .05$, $p > .05$ on the immediate, comprehension test. Table 1: gives a summary of the analysis of variance for the immediate, comprehension tes Refer to Table 13 for the means and standard deviations on the immediate comprehension test. Refer to Figure 5 for a graph of the means. Hypothesis 5 wa rejected for the unrelated course passage on the immediate tests since low verb ability subjects did not perform better than did high verbal ability subjects. Also, fc the generated-synthesizer group, high verbal ability subjects performed better tha did low verbal ability subjects.

Table 12

Analysis of Variance for Verbal Ability Level by Treatment Group on the Immediate Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	13.47	2	6.57	.89	.414
B. Verbal	24.74	1	24.74	3.36	.065
A x B	.72	2	.36	.05	.941
Within	1133.00	154	7.36		

Table 13

*Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels o*ı

the Immediate, Comprehension Test

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	31	4.58	2.57	25	3.92	2.3
Generated-Synthesizer	30	4.93	2.96	23	3.96	2.3
No-Synthesizer	25	4.12	2.71	26	3.38	3.1
Maximum Score		14.00			14.00	

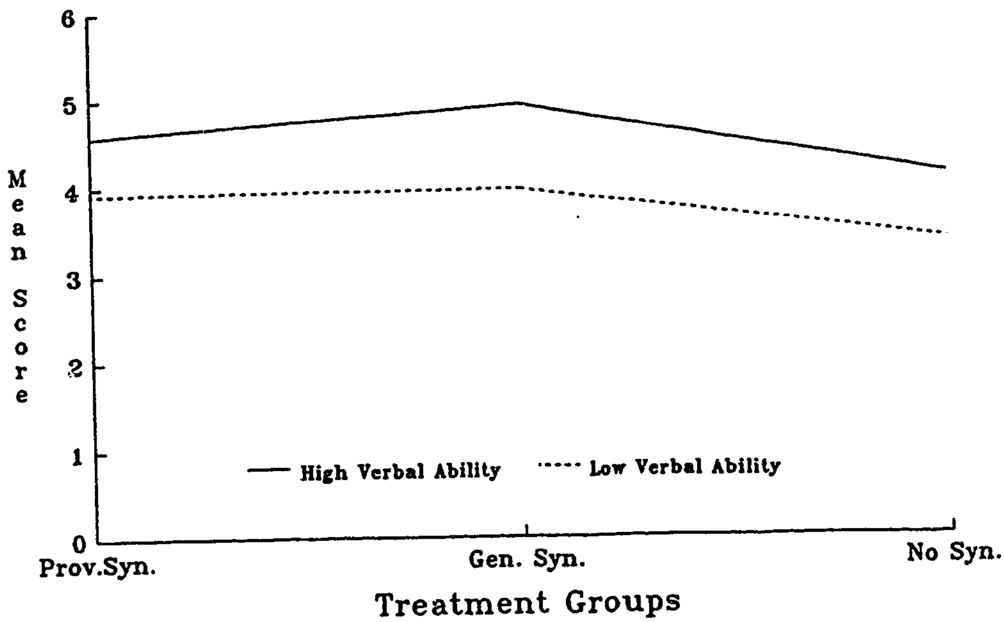


Figure 5. *Mean Score for High and Low Verbal Ability Levels on the Immediate, Comprehension Test for the Unrelated Course Passage.*

Delayed tests. A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and verbal ability level (high and low). The dependent variables were the delayed, cued recall and comprehension tests. There was no significant interaction between verbal ability level and treatment group on the delayed, cued recall test, $F(2,99) = 1.19$, $p > .05$. However, there was a significant main effect for verbal ability on the delayed, cued recall test, $F(1,99) = 5.66$, $p < .05$.

Refer to Table 14 for the summary of the analysis of variance. High verbal ability subjects performed better than did low verbal ability subjects. Refer to Table 15 for the means and standard deviations on the delayed, cued recall test and to Figure 6 for a graph of the means.

Table 14

Analysis of Variance for Verbal Ability Level by Treatment Group on the Delayed, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	11.04	2	5.52	.44	.650
B. Verbal	71.00	1	71.00	5.66	.018*
A x B	30.04	2	15.02	1.19	.305
Within	1240.73	99	12.53		

*$p < .05$

Table 15

Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels on the Delayed, Cued Recall Test

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	19	7.53	3.82	17	4.65	3.48
Generated-Synthesizer	20	5.45	2.98	13	5.23	3.00
No-Synthesizer	17	6.41	4.48	19	4.53	3.20
Maximum Score		18.00			18.00	

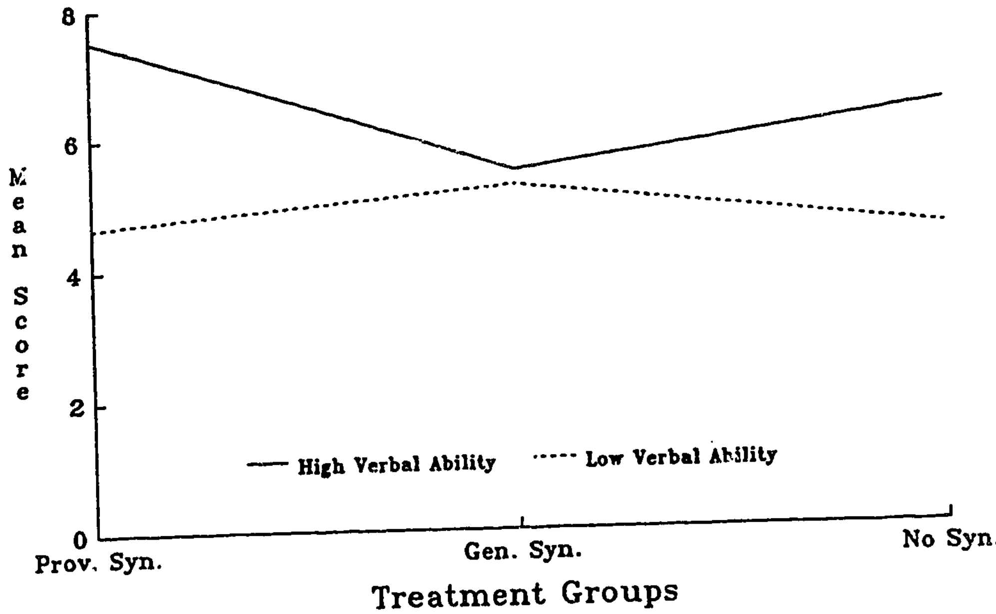


Figure 6. *Mean Score for High and Low Verbal Ability Levels on the Delayed, Cued Recall Test for the Unrelated Course Passage.*

On the delayed, comprehension test, there was no significant interaction between verbal ability level and the treatment group, $F(2,99) = .36$, $p > .05$. However, there was a significant main effect for verbal ability on the delayed, comprehension test, $F(1,99) = 15.88$, $p < .05$. Refer to Table 16 for a summary of the analysis of variance for the delayed, comprehension test. High verbal ability subjects outperformed low verbal ability subjects. As a result, hypothesis 5 was rejected for the delayed, cued recall and comprehension tests since low verbal ability subjects did not benefit more from the spatial synthesizer than did high verbal ability subjects. Refer to Table 17 for the means and standard deviations and Figure 7 for a graph of the means.

Table 16

Analysis of Variance for Verbal Ability Level by Treatment Group on the Delayed, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	.94	2	.47	.14	.863
B. Verbal	52.26	1	52.26	15.88	.000*
A x B	2.39	2	1.19	.36	.700
Within	325.77	99	3.29		

*$p < .05$

Table 17

Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels on the Delayed, Comprehension Test

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	19	3.47	2.36	17	1.88	1.36
Generated-Synthesizer	20	3.30	1.69	13	1.61	1.66
No-Synthesizer	17	3.00	2.12	19	2.00	1.41
Maximum Score		14.00			14.00	

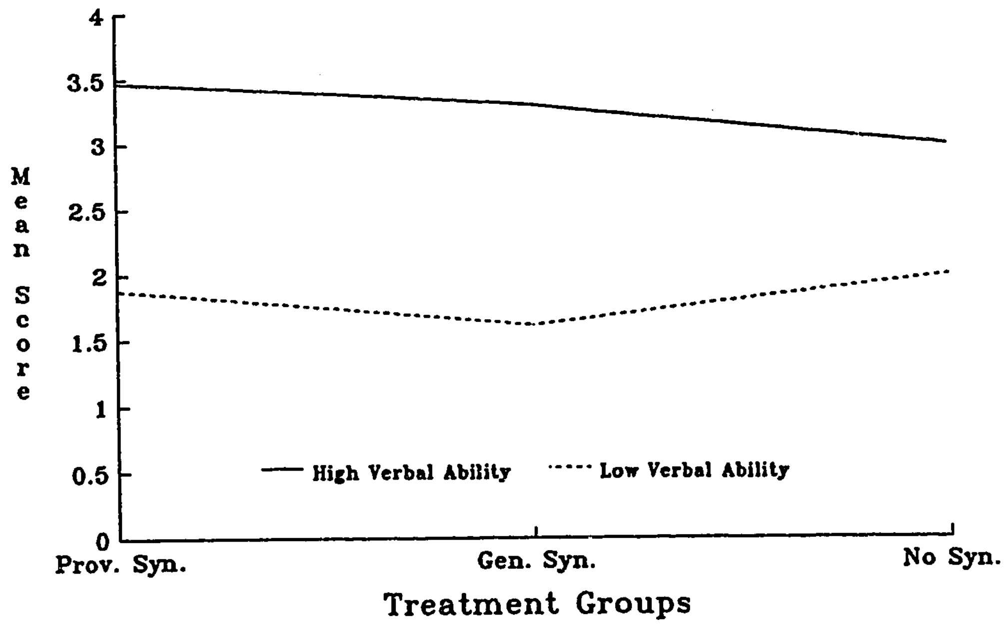


Figure 7. Mean Score for High and Low Verbal Ability Levels on the Delayed, Comprehension Test for the Unrelated Course Passage.

Related Course Passage

A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and verbal ability level (high and low). The dependent variables were the immediate, cued recall and comprehension tests. On the immediate, cued recall test, there was no significant interaction between verbal ability level and treatment group, $F(2,124) = .05$, $p > .05$. Refer to Table 18 for the analysis of variance summary for the immediate, cued recall test. There was no significant main effect for verbal ability level on the immediate, cued recall test, $F(1,124) = 3.41$, $p > .05$. Refer to Table 19 for the means and standard deviations and Figure 8 for a graph of the means.

Table 18

Analysis of Variance for Verbal Ability Level by Treatment Group on the Immediate, Cued Recall Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1243.65	2	621.82	11.79	.000
B. Verbal	180.18	1	180.18	3.41	.063
A x B	5.41	2	2.70	.05	.939
Within	6540.50	124	52.74		

Table 19

Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels on the Immediate, Cued Recall Test for the Related Course Passage

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	21	27.71	7.44	21	25.43	7.50
Generated-Synthesizer	20	22.35	6.75	25	20.44	6.16
No-Synthesizer	19	20.53	6.65	24	17.62	8.69
Maximum Score		56.00			56.00	

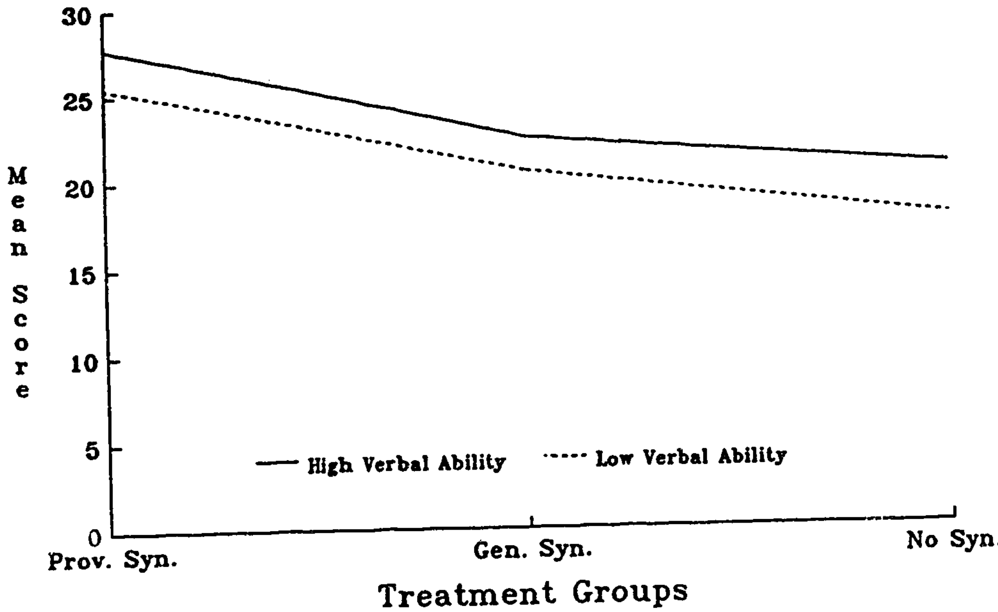


Figure 8. *Mean Score for High and Low Verbal Ability Levels on the Immediate, Cued Recall Test for the Related Course Passage.*

On the immediate, comprehension test, there was no significant interaction between verbal ability level and the treatment group, $F(2,124) = .76$, $p > .05$. However, there was a significant main effect for verbal ability, $F(1,124) = 9.50$, $p < .05$. Refer to Table 20 for the summary of the analysis of variance for the immediate, comprehension test. High verbal ability subjects outperformed low verbal ability subjects. Refer to Table 21 for the means and standard deviations and Figure 9 for a graph of the means. Hypothesis 5 was rejected since on the immediate, cued recall test, low verbal ability subjects did not benefit more than did high verbal ability subjects from the spatial synthesizer. Also, on the immediate, comprehension test, high verbal ability subjects benefitted more than did low verbal ability subjects.

Table 20

Analysis of Variance for Verbal Ability Level by Treatment Group on the Immediate, Comprehension Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	3.78	2	1.89	.14	.867
B. Verbal	129.86	1	129.86	9.50	.002*
A x B	20.84	2	10.42	.76	.472
Within	1694.94	124	13.66		

*$p < .05$

Table 21

Means and Standard Deviations for the Treatment Groups and Verbal Ability Levels on the Immediate, Comprehension Test for the Related Course Passage

	Verbal Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	21	8.00	4.29	21	6.33	3.47
Generated-Synthesizer	20	7.80	3.61	25	6.56	3.66
No-Synthesizer	19	8.37	4.27	24	5.25	2.86
Ma..imum Score		34.00			34.00	

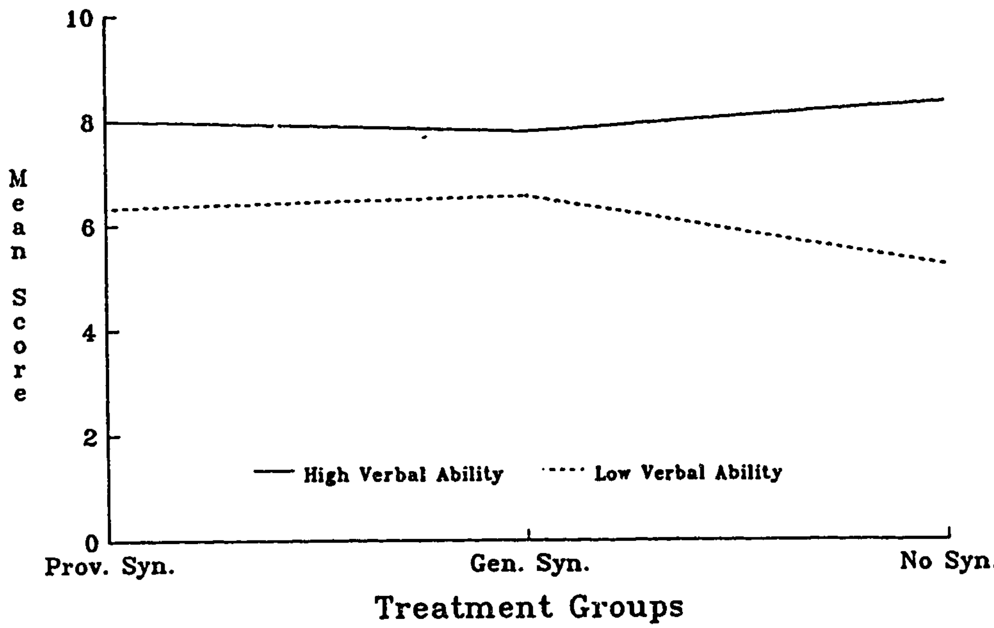


Figure 9. *Mean Score for High and Low Verbal Ability Levels on the Immediate, Comprehension Test for the Related Course Passage.*

Hypothesis 6

High spatial ability subjects who used synthesizers will perform better on immediate, and delayed, cued recall and comprehension tests than will low spatial ability subjects who used synthesizers.

Unrelated Course Passage

Immediate tests. A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and spatial ability level (high and low). The dependent variables were scores on the immediate, cued recall and comprehension tests. On the immediate, cued recall test, there was no significant interaction between spatial ability level and treatment group, $F(2,154) = 2.11$, $p > .05$. Also, there was no significant main effect for spatial ability level on the immediate, cued recall test, $F(1,154) = 1.83$, $p > .05$. Refer to Table 22 for the summary of the analysis of variance for the immediate, cued recall test. Refer to Table 23 for the means and standard deviations and Figure 10 for a graph of the means.

Table 22

Analysis of Variance for Spatial Ability Level by Treatment Group on the Immediate, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	515.65	2	257.82	14.37	.001
B. Spatial	32.99	1	32.99	1.83	.173
A x B	75.94	2	37.97	2.11	.121
Within	2761.85	154	17.93		

Table 23

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Immediate, Cued Recall Test

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	30	11.37	3.88	26	11.96	3.19
Generated-Synthesizer	27	9.04	4.54	26	8.46	4.37
No-Synthesizer	24	8.75	5.18	27	6.00	4.09
Maximum Score		18.00			18.00	

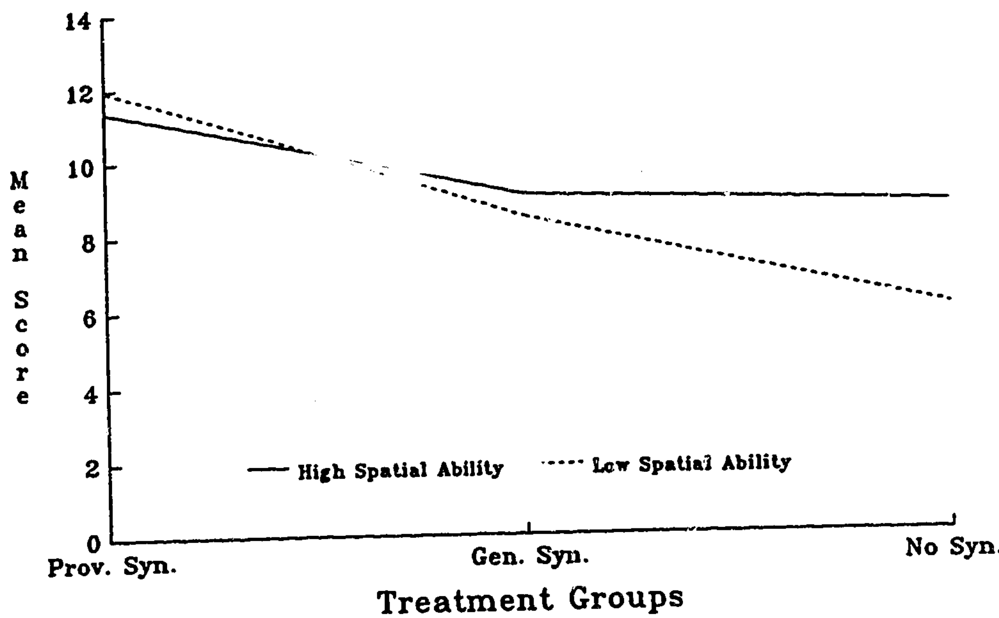


Figure 10. *Mean Score for High and Low Spatial Ability Levels on the Immediate, Cued Recall Test for the Unrelated Course Passage.*

On the immediate, comprehension test, there was no significant interaction between treatment group and spatial ability level, $F(2,154) = 1.67$, $p > .05$. Also, there was no significant main effect for spatial ability, $F(1,154) = .29$, $p > .05$ on the immediate, comprehension test. Table 24 shows the summary of the analysis of variance for the immediate, comprehension test. Refer to Table 25 for the means and standard deviations and Figure 11 for a graph of the means. Hypothesis 6 was rejected for the immediate, cued recall and comprehension tests since high spatial ability subjects did not benefit more from the spatial synthesizer than did low spatial ability subjects.

Table 24

Analysis of Variance for Spatial Ability Level by Treatment Group on the Immediate, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	15.95	2	7.97	1.08	.341
B. Spatial	2.20	1	2.20	.29	.591
A x B	24.55	2	12.27	1.67	.189
Within	1131.68	154	7.34		

Table 25

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Immediate, Comprehension Test

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	30	4.47	2.39	26	4.08	2.62
Generated-Synthesizer	27	3.85	2.69	26	5.19	2.67
No-Synthesizer	24	3.87	2.70	27	3.63	2.70
Maximum Score		14.00			14.00	

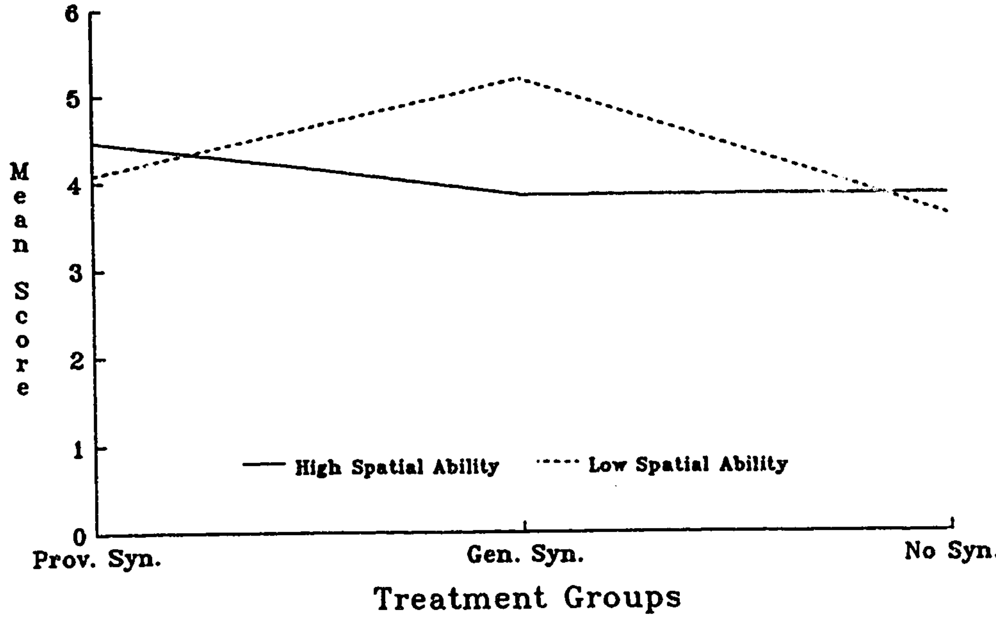


Figure 11. *Mean Score for High and Low Spatial Ability Levels on the Immediate, Comprehension Test for the Unrelated Course Passage.*

Delayed tests. A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and spatial ability level (high and low). The dependent variables were the delayed, cued recall and comprehension tests. On the delayed, cued recall test, there was no significant interaction between spatial ability level and treatment group, $F(2,99) = .38$, $p > .05$. However, there was a significant main effect for spatial ability, $F(1,99) = 6.59$, $p < .05$. Table 26 gives a summary of the analysis of variance for the delayed, cued recall test. High spatial ability subjects performed better on the delayed, cued recall test than did low spatial ability subjects. Refer to Table 27 for the means and standard deviations and Figure 12 for a graph of the means. Part of hypothesis 6 was accepted for the delayed, cued recall test since high spatial ability subjects benefitted more from the spatial synthesizer than did low spatial ability subjects.

Table 26

Analysis of Variance for Spatial Ability Level by Treatment Group on the Delayed, Cued Recall test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	8.69	2	4.34	.34	.714
B. Spatial	83.43	1	83.43	6.59	.011*
A x B	9.84	2	4.92	.38	.684
Within	1251.90	99	12.64		

*$p < .05$

Table 27

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Delayed, Cued Recall Test

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	21	6.95	3.93	15	5.06	3.69
Generated-Synthesizer	16	5.87	3.40	17	4.88	2.45
No-Synthesizer	18	6.67	3.07	18	4.16	3.07
Maximum Score		18.00			18.00	

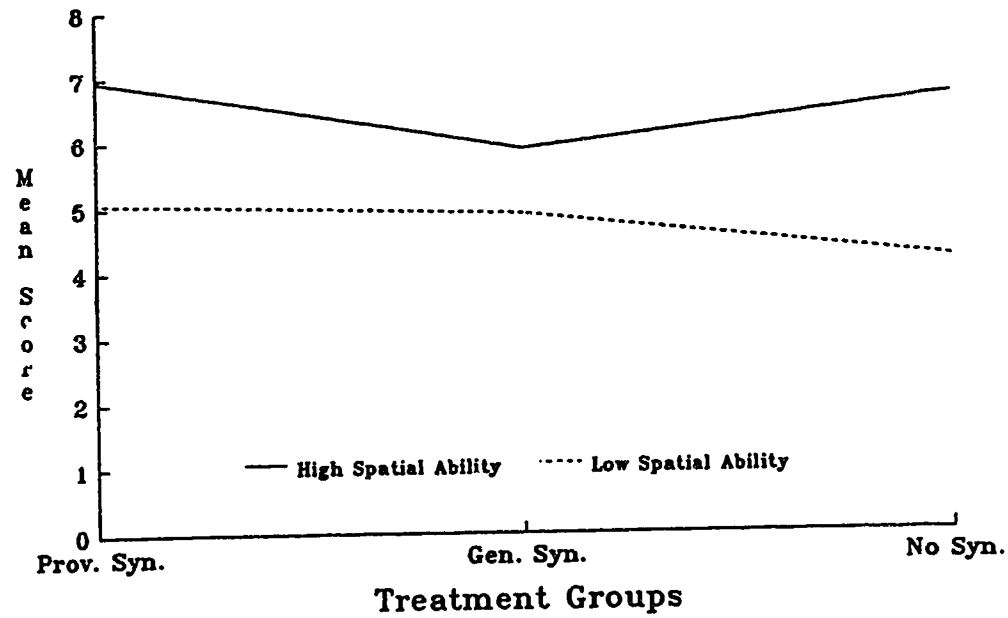


Figure 12. *Mean Score for High and Low Spatial Ability Levels on the Delayed, Cued Recall Test for the Unrelated Course Passage.*

On the delayed, comprehension test, there was no significant interaction between spatial ability level and treatment group, $F(2,99) = .78$, $p > .05$. Also, there was no significant main effect for spatial ability level, $F(1,99) = 2.38$, $p > .05$ on the delayed, comprehension test. Table 28 gives the summary of the analysis of variance for the delayed, comprehension test. Refer to Table 29 for the means and standard deviations and Figure 13 for a graph of the means. Hypothesis 6 was rejected for the delayed, comprehension test since high spatial ability subjects did not benefit more from the spatial synthesizer than did low spatial ability subjects.

Table 28

Analysis of Variance for Spatial Ability Level by Treatment Group on the Delayed, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	.59	2	.29	.08	.914
B. Spatial	8.79	1	8.79	2.38	.121
A x B	5.79	2	2.89	.78	.462
Within	356.20	99	3.68		

Table 29

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Delayed, Compre[illegible]on Test

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	21	3.24	2.43	15	2.00	1.25
Generated-Synthesizer	16	2.81	1.94	17	2.47	1.81
No-Synthesizer	18	2.55	1.85	18	2.39	1.85
Maximum Score		14.00			14.00	

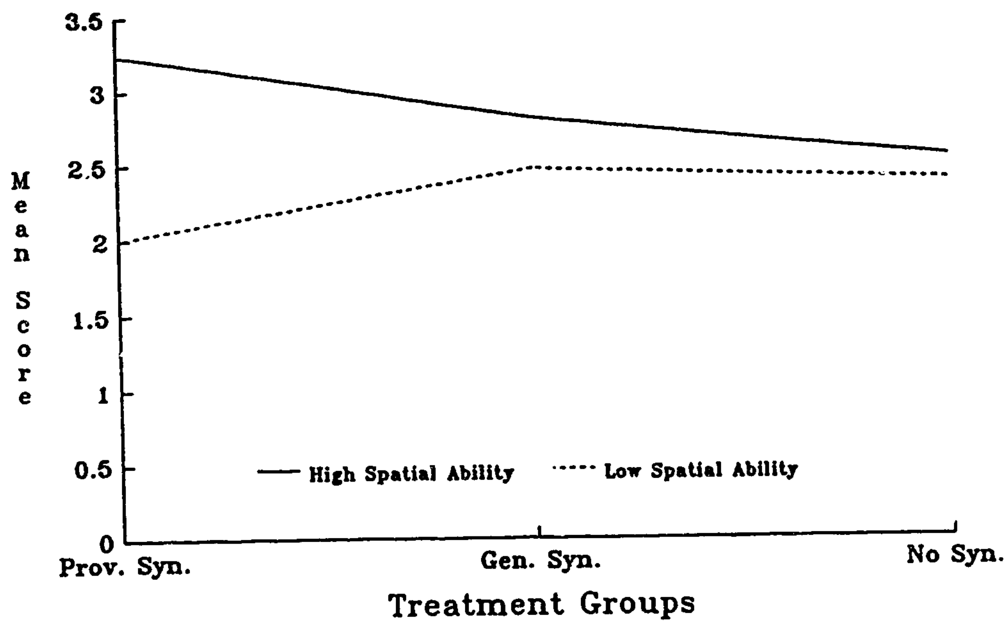


Figure 13. Mean Score for High and Low Spatial Ability Levels on the Delayed, Comprehension Test for the Unrelated Course Passage.

Related Course Passage

A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and spatial ability level (high and low). The dependent variables were the immediate, cued recall and comprehension tests. On the immediate, cued recall test, there was no significant interaction between spatial ability level and treatment group, $F(2,124) = .01, p > .05$. Also, there was no significant main effect for spatial ability level, $F(1,124) = .00, p > .05$ on the immediate, cued recall test. Refer to Table 30 for a summary of the analysis of variance for the immediate, cued recall test. Refer to Table 31 for the means and standard deviations and Figure 14 for a graph of the means. Hypothesis 6 was rejected for the immediate, cued recall tests since high spatial ability subjects did not benefit more from the spatial synthesizer than did low spatial ability subjects.

Table 30

Analysis of Variance for Spatial Ability Level by Treatment Group on the Immediate, Cued Recall Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1234.79	2	617.39	11.38	.001
B. Spatial	.02	1	.02	.00	.931
A x B	1.39	2	.69	.01	.975
Within	6723.72	124	54.22		

Table 31

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Immediate, Cued Recall Test for the Related Course Passage

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	17	26.53	7.76	25	26.60	7.42
Generated-Synthesizer	24	21.17	6.62	21	21.43	6.36
No-Synthesizer	16	19.06	7.77	27	18.81	8.12
Maximum Score		56.00			56.00	

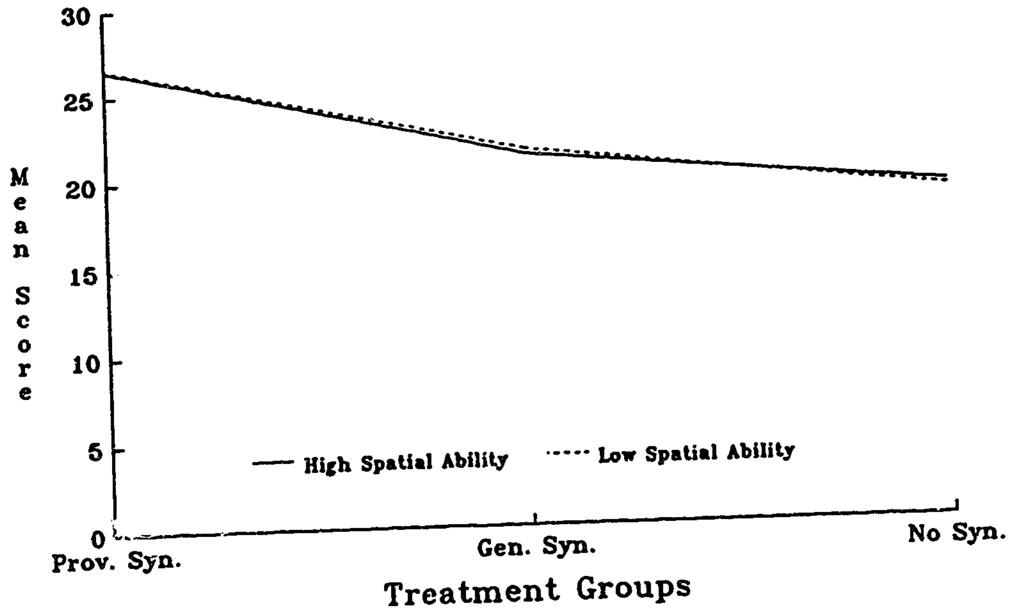


Figure 14. *Mean Score for High and Low Spatial Ability Levels on the Immediate, Cued Recall Test for the Related Course Passage.*

On the immediate, comprehension test, there was no significant interaction between spatial ability level and treatment group, $F(2,124) = .21$, $p > .05$. However, there was a significant main effect for spatial ability, $F(1,124) = 4.71$, $p < .05$. Refer to Table 32 for the analysis of variance summary for the immediate, comprehension test. High spatial ability subjects performed better on the immediate, comprehension test than did low spatial ability subjects. Refer to Table 33 for the means and standard deviations and Figure 15 for a graph of the means. Part of hypothesis 6 was accepted for the immediate, comprehension test since high spatial ability subjects benefitted more from the spatial synthesizer than did low spatial ability subjects.

Table 32

Analysis of Variance for Spatial Ability Level by Treatment Group on the Immediate, Comprehension Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	5.84	2	2.92	.20	.815
B. Spatial	67.42	1	67.42	4.71	.029*
A x B	6.11	2	3.05	.21	.808
Within	1772.34	124	14.29		

*$p < .05$

Table 33

Means and Standard Deviations for the Treatment Groups and Spatial Ability Levels on the Immediate, Comprehension Test for the Related Course Passage

	Spatial Ability					
	High			Low		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	17	8.35	4.36	25	6.36	3.49
Generated-Synthesizer	24	7.54	3.44	21	6.62	3.90
No-Synthesizer	16	7.56	4.53	27	6.07	3.34
Maximum Score		34.00			34.00	

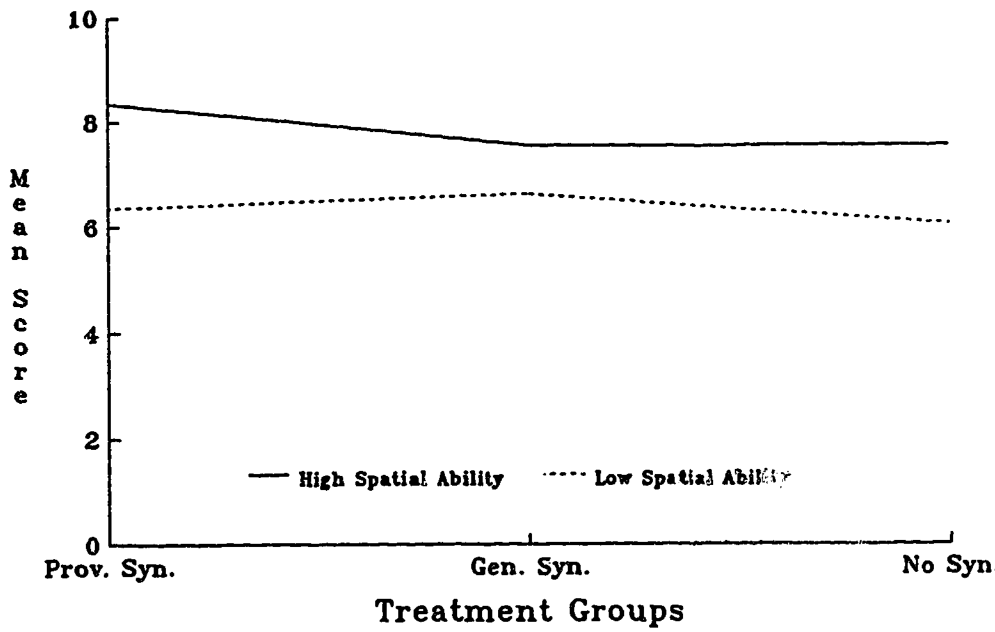


Figure 15. *Mean Score for High and Low Spatial Ability Levels on the Immediate, Comprehension Test for the Related Course Passage*

Hypothesis 7

There is a significant gender difference on the immediate, and delayed, cued recall and comprehension tests.

Unrelated Course Passage

A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and gender (male and female). The dependent variables were the immediate, and delayed, cued recall and comprehension tests' scores. There was no significant interaction between gender and treatment groups on the immediate, cued recall test, $F(2,147) = .04$, $p > .05$; on the immediate, comprehension test, $F(2,147) = .61$, $p > .05$; on the delayed, cued recall test, $F(2,96) = .16$, $p > .05$; or on the delayed, comprehension test, $F(2,96) = .57$, $p > .05$. Also, there was no significant main effect for gender on the immediate, cued recall test, $F(1,147) = .21$, $p > .05$; on the immediate, comprehension test, $F(1,147) = 1.74$, $p > .05$; on the delayed, cued recall test, $F(1,96) = .24$, $p > .05$; or on the delayed, comprehension test, $F(1,96) = 2.44$, $p > .05$. Refer to Tables 34 to 37 for the analysis of variance summaries. Refer to Tables 38 to 41 for the means and standard deviations and Figures 16 to 19 for graphs of the means. Hypothesis 7 was rejected since there was no significant difference between males and females on the immediate, and delayed, cued recall and comprehension tests.

Table 34

Analysis of Variance for Gender by Treatment Group on the Immediate, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	509.129	2	254.56	14.00	.000
B. Gender	3.84	1	3.84	.21	.651
A x B	1.74	2	.87	.04	.942
Within	2671.84	147	18.17		

Table 35

Analysis of Variance for Gender by Treatment Group on the Immediate, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	16.45	2	8.22	1.13	.323
B. Gender	12.64	1	12.64	1.74	.185
A x B	8.83	2	4.41	.61	.549
Within	1063.76	147	7.23		

Table 36

Analysis of Variance for Gender by Treatment Group on the Delayed, Cued Recall Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	18.19	2	9.09	.66	.519
B. Gender	3.34	1	3.34	.24	.627
A x B	4.54	2	2.27	.16	.844
Within	1306.59	96	13.61		

Table 37

Analysis of Variance for Gender by Treatment Group on the Delayed, Comprehension Test for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1.09	2	.54	.14	.861
B. Gender	9.17	1	9.17	2.44	.116
A x B	4.31	2	2.15	.57	.569
Within	359.84	96	3.74		

Table 38

Means and Standard Deviations for the Treatment Groups and Gender on the Immediate, Cued Recall Test for the Unrelated Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	35	11.40	4.03	19	12.00	2.76
Generated-Synthesizer	26	8.57	5.00	24	8.87	4.02
No-Synthesizer	26	7.19	4.39	23	7.26	4.76
Maximum Score		18.00			18.00	

Table 39

Means and Standard Deviations for the Treatment Groups and Gender on the Immediate, Comprehension Test for the Unrelated Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	35	4.25	2.42	19	4.31	2.64
Generated-Synthesizer	26	5.03	2.10	24	3.91	3.26
No-Synthesizer	26	4.03	2.67	23	3.34	3.02
Maximum Score		14.00			14.00	

Table 40

Means and Standard Deviations for the Treatment Groups and Gender on the Delayed, Cued Recall Test for the Unrelated Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	23	5.95	3.73	12	6.50	4.48
Generated-Synthesizer	18	5.00	2.99	14	5.78	3.04
No-Synthesizer	20	5.35	3.26	15	5.13	4.65
Maximum Score		18.00			18.00	

Table 41

Means and Standard Deviations for the Treatment Groups and Gender on the Delayed Comprehension Test for the Unrelated Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	23	2.78	1.90	12	2.41	2.46
Generated-Synthesizer	18	2.77	1.51	14	2.50	2.31
No-Synthesizer	20	3.00	1.62	15	1.80	1.97
Maximum Score		14.00			14.00	

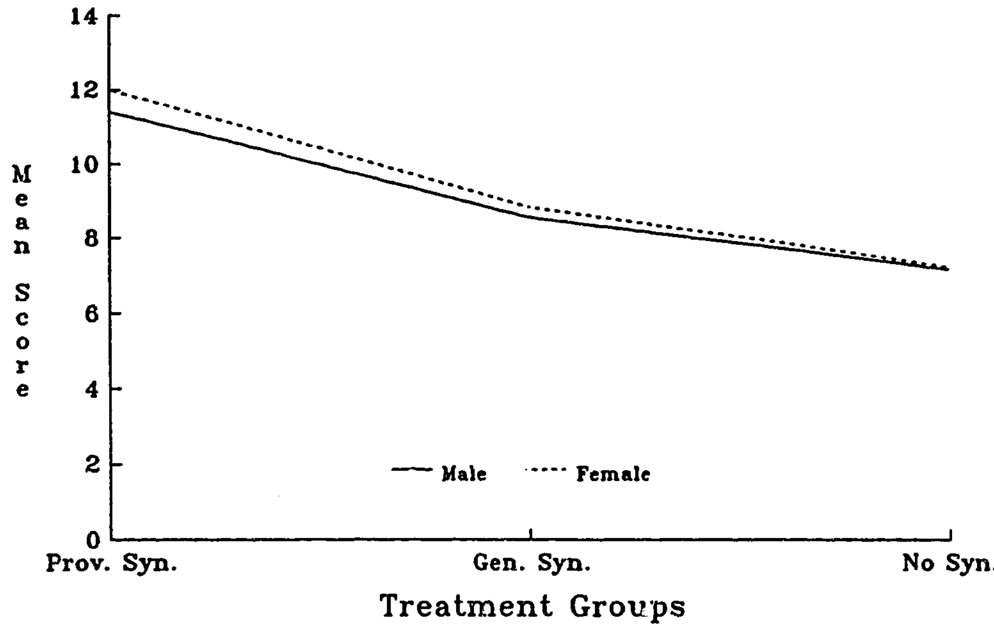


Figure 16. *Mean Score for Male and Female on the Immediate, Cued Recall Test for the Unrelated Course Passage.*

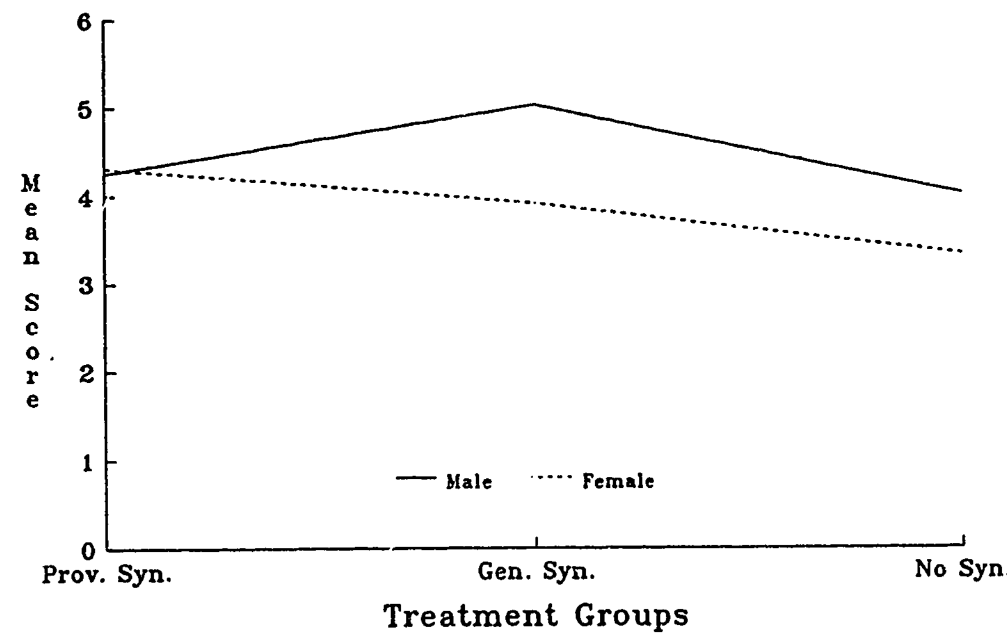


Figure 17. *Mean Score for Male and Female on the Immediate, Comprehension Test for the Unrelated Course Passage.*

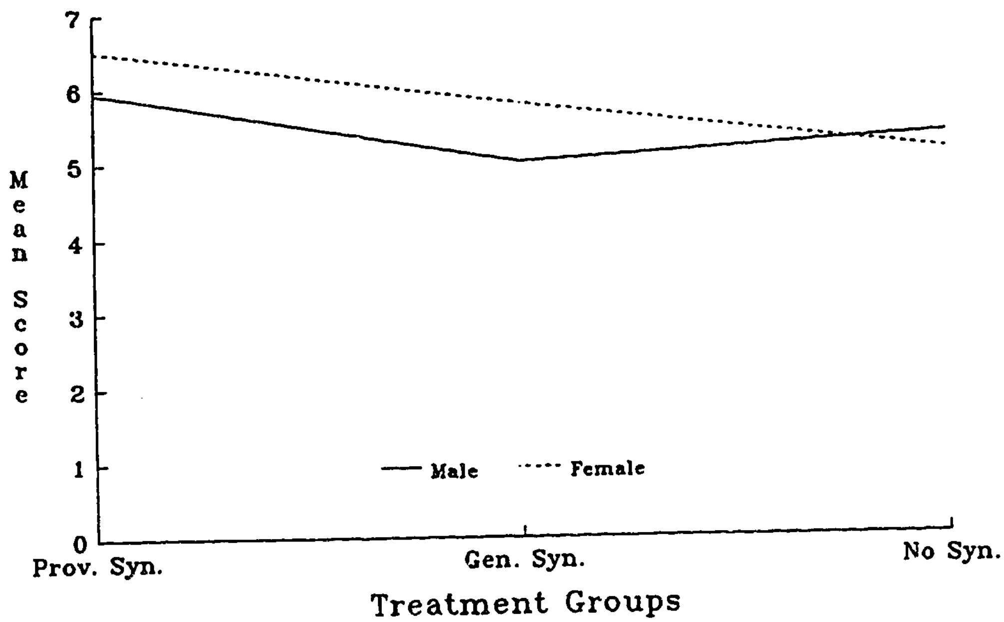


Figure 18. *Mean Score for Male and Female on the Delayed, Cued Recall Test for the Unrelated Course Passage.*

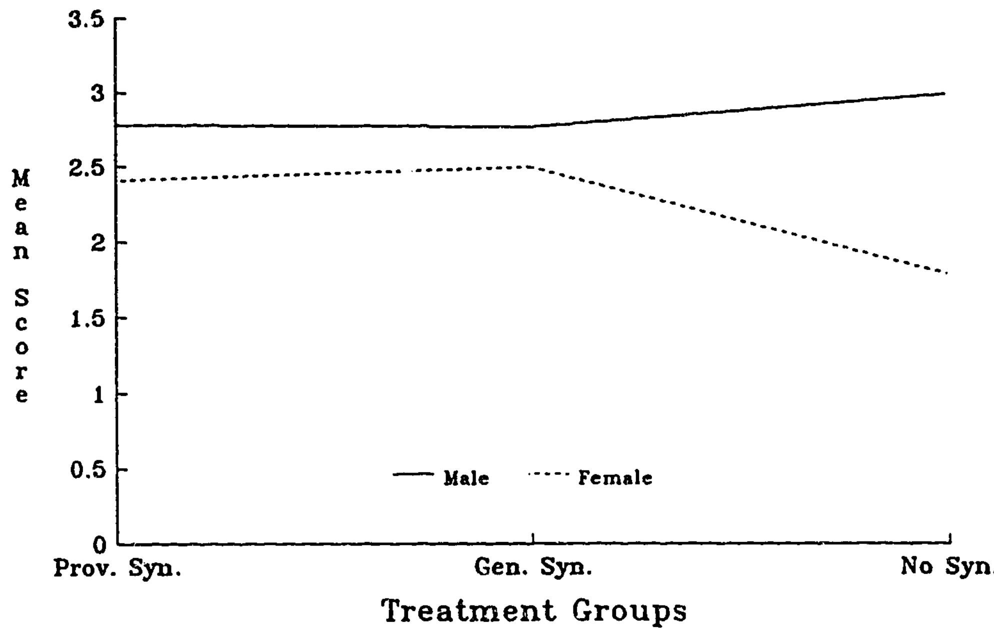


Figure 19. *Mean Score for Male and Female on the Delayed, Comprehension Test for the Unrelated Course Passage.*

Related Course Passage

A 3 x 2 analysis of variance was used for the analysis. The independent variables were treatment group (provided-synthesizer, generated-synthesizer, and no-synthesizer) and gender (male and female). The dependent variables were the immediate, cued recall and comprehension test scores. There was no significant interaction between gender and treatment group on the immediate, cued recall test, F(2,110) = .39, p > .05 and on the immediate, comprehension test, F(2,110) = 1.09, p > .05. Also, there was no significant main effect for gender on the immediate, cued recall test, F(1,110) = .80, p > .05 or on the immediate, comprehension test, F(1,110) = 1.04, p > .05. Refer to Tables 42 to 43 for the analysis of variance summaries for the tests. Refer to Tables 44 to 45 for the means and standard deviations and Figures 20 and 21 for graphs of the means. Hypothesis 7 was rejected since there was no significant difference between males and females on the immediate, and delayed, cued recall and comprehension tests.

Table 42

Analysis of Variance for Gender by Treatment Group on the Immediate, Cued Recall Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	1036.53	2	518.26	10.34	.000
B. Gender	40.56	1	40.56	.80	.373
A x B	40.40	2	20.02	.39	.677
Within	5513.30	110	50.12		

Table 43

Analysis of Variance for Gender by Treatment Group on the Immediate, Comprehension Test for the Related Course Passage

Source	SS	DF	MS	F	P
A. Treatment	.37	2	.18	.01	.975
B. Gender	15.15	1	15.15	1.04	.310
A x B	31.96	2	15.98	1.09	.337
Within	1601.54	110	14.55		

Table 44

Means and Standard Deviations for the Treatment Groups and Gender on the Immediate, Cued Recall Test for the Related Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	25	26.64	8.14	15	26.60	6.58
Generated-Synthesizer	23	22.65	6.87	16	19.81	4.15
No-Synthesizer	18	19.82	8.01	19	19.10	7.15
Maximum Score		56.00			56.00	

Table 45

Means and Standard Deviations for the Treatment Groups and Gender on the Immediate, Comprehension Test for the Related Course Passage

	Gender					
	Male			Female		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	25	8.16	4.17	15	6.13	2.97
Generated-Synthesizer	23	7.52	4.07	16	6.75	3.19
No-Synthesizer	18	6.72	4.22	19	7.31	3.63
Maximum Score		34.00			34.00	

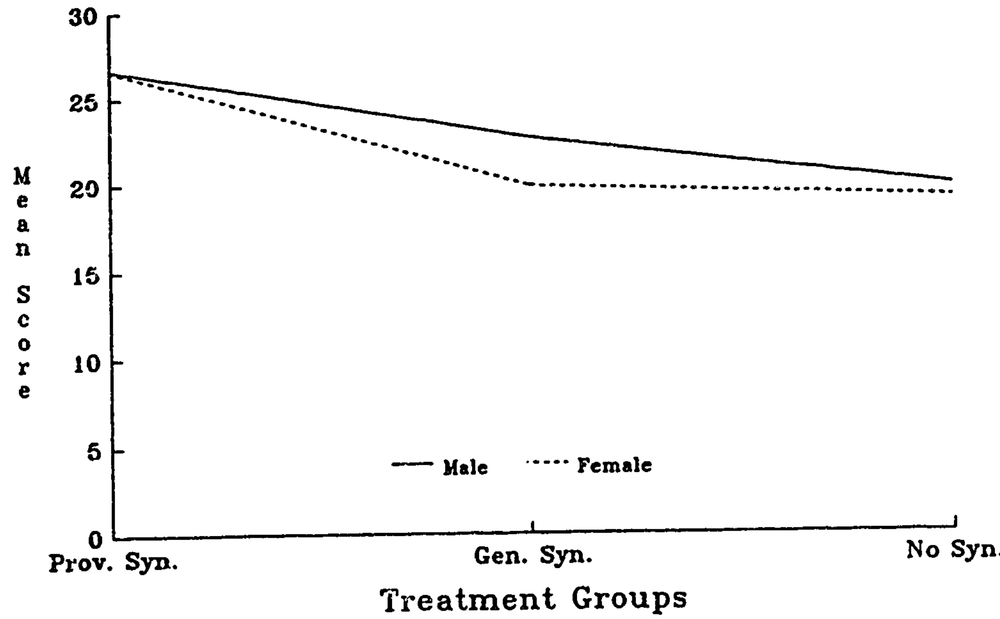


Figure 20. *Mean Score for Male and Female on the Immediate, Cued Recall Test for the Related Course Passage.*

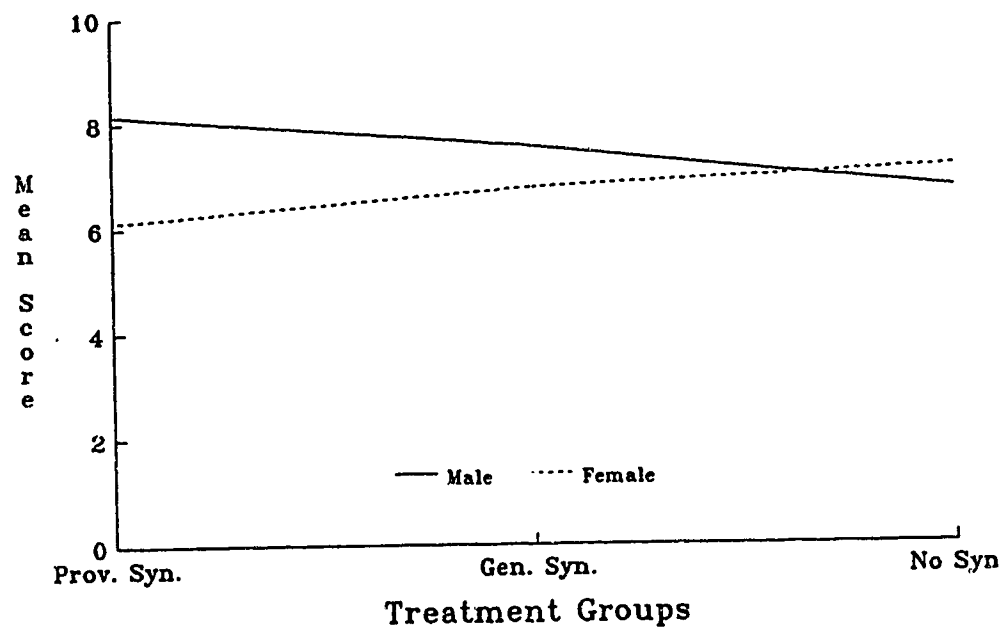


Figure 21. *Mean Score for Male and Female on the Immediate, Comprehension Test for the Related Course Passage.*

Hypothesis 8

High spatial ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low spatial ability subjects.

Unrelated course passage. Fifty-three subjects (96 percent) in the generated-synthesizer group followed the procedure to construct the synthesizer. Analysis of variance was used to determine if there was any significant difference between high and low spatial ability subjects on the generated-synthesizer score. There was no significant difference between high and low spatial ability subjects on the generated synthesizer score, $F(1,51) = .25$, $p > .05$. Table 46 shows the summary of the analysis of variance for the generated-synthesizer score. Refer to Table 47 for the means and standard deviations. Hypothesis 8 was rejected since there was no significant difference between high spatial ability and low spatial ability subjects on the generated-synthesizer score.

Related course passage. All subjects in the generated-synthesizer group used the procedure to construct the spatial synthesizer for the related course passage. Analysis of variance showed no significant difference between high and low spatial ability subjects on the spatial synthesizer score, $F(1,46) = .79$, $p > .05$. Refer to Table 48 for the analysis of variance summary for the generated-synthesizer score. Refer to

Table 47 for the means and standard deviations. Hypothesis 8 was rejected since there was no significant difference between high spatial ability and low spatial ability subjects on the generated-synthesizer score.

Table 46

Analysis of Variance for High and Low Spatial Ability Subjects in the Generated-Synthesizer Group on the Synthesizer Score for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Spatial	7.72	1	7.72	.25	.627
Within	1597.56	51	31.32		

Table 47

Means and Standard Deviations for Spatial Ability Levels on the Spatial Synthesizer Score

	Spatial Ability					
	High			Low		
Passage	n	M	SD	n	M	SD
Unrelated Passage (Max = 26)	27	10.85	5.49	26	11.61	5.71
Related Passage (Max = 62)	26	31.92	11.43	22	28.86	12.29

Table 48

Analysis of Variance for High and Low Spatial Ability Subjects in the Generated-Synthesizer Group on the Synthesizer Score for the Related Course Passage

Source	SS	DF	MS	F	P
A. Spatial	111.54	1	111.54	.79	.380
Within	6436.43	46	139.92		

Hypothesis 9

High verbal ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low verbal ability subjects.

Unrelated course passage. Analysis of variance was used to determine if there was any significant difference between high and low verbal ability subjects on the generated-synthesizer score. There was no significant difference between high and low verbal ability subjects on synthesizer score, $F(1, 51) = .01$, $p > .05$. Refer to Table 49 for the analysis of variance summary for the generated-synthesizer score. Refer to Table 51 for the means and standard deviations. Hypothesis 9 was rejected since there was no significant difference between high verbal and low verbal ability subjects on the generated-synthesizer score.

Table 49

Analysis of Variance for High and Low Verbal Ability Subjects in the Generated-Synthesizer Group on the Synthesizer Score for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Verbal	.50	1	.50	.01	.867
Within	1604.78	51	31.46		

Related course passage. Analysis of variance showed no significant difference between high and low verbal ability subjects on synthesizer score, $F(1,46) = 2.51$, $p > .05$. Refer to Table 50 for the analysis of variance summary for the generated-synthesizer score. Refer to Table 51 for the means and standard deviations. Hypothesis 9 was rejected since there was no significant difference between high verbal and low verbal ability subjects on the generated-synthesizer score.

Table 50

Analysis of Variance for High and Low Verbal Ability Subjects in the Generated-Synthesizer Group on the Synthesizer Score for the Related Course Passage

Source	SS	DF	MS	F	P
A. Spatial	338.81	1	338.81	2.51	.116
Within	6209.16	46	134.98		

Table 51

Means and Standard Deviations for Verbal Ability Levels on Spatial Synthesizer Score

	Verbal Ability					
	High			Low		
Passage	n	M	SD	n	M	SD
Unrelated Passage (Max = 26)	29	11.14	5.49	24	11.33	5.74
Related Passage (Max = 62)	22	33.41	11.90	26	28.07	11.36

Relationship Between the Generated-Synthesizer Scores and Tests' Scores

Scores on the generated-synthesizer and the immediate, and delayed, cued recall and comprehension tests were correlated to determine whether there were any significant relationships between the scores. For the unrelated course passage, there were significant relationships between the generated-synthesizer scores and the immediate, cued recall test scores ($r = .62$, $p < .05$) and the delayed, cued recall test scores ($r = .41$, $p < .05$). There was no significant relationship between the generated-synthesizer scores and scores on the immediate, comprehension test ($r = .13$, $p > .05$) and the delayed, comprehension test ($r = .00$, $p > .05$).

For the related course passage, there were significant relationships between the generated-synthesizer scores and scores on the immediate, cued recall test ($r = .55$, $p < .05$) and on the immediate, comprehension test ($r = .38$, $p < .05$).

Attitude Questionnaire

Subjects' responses to the questionnaire were analyzed to determine if there were any differences between the three treatment groups. The following section summarizes the results from the questionnaire data.

Used the synthesizer to summarize the materials?

Subjects were asked whether they used the synthesizer to summarize the prose materials. Subjects responded yes or no to the question.

Unrelated course passage. For the no-synthesizer group, only six percent of subjects claimed that they used the synthesizer to summarize the materials. This result is not surprising since the no-synthesizer group was not instructed to use the synthesizer. For the provided-synthesizer group, 89 percent of the subjects used the synthesizer to summarize the materials, while for the generated-synthesizer group, 66 percent used the synthesizer to summarize the materials. Chi-square analysis, showed that the percent of subjects who used the synthesizer to summarize the materials was significantly different for the treatment groups, $x^2(2, N = 157) = 76.10$, $p < .05$.

Related course passage. For the no-synthesizer group, only two percent of subjects claimed that they used the synthesizer to summarize the materials. For the provided-synthesizer group, 86 percent of the subjects said that they used the synthesizer to summarize the passage while 75 percent of the subjects in the generated-synthesizer said they used the synthesizer to summarize the passage. Chi-square analysis showed that there was a significant difference between the groups, $x^2(2, N = 131) = 69.90, p < .01$.

How helpful was the synthesizer to learn the materials?

Subjects were asked how helpful was the synthesizer to learn the materials. Subjects were asked to respond on a scale of 1 to 5 with 5 representing very helpful and 1 representing not helpful.

Unrelated course passage. Analysis of variance showed a significant difference between the three treatment groups, $F(2,128) = 28.14, p < .05$ on the helpfulness of the synthesizer. Refer to Table 52 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the no-synthesizer group mean response (M = 1.67, SD = 1.24) was significantly lower than the provided-synthesizer (M = 3.61, SD = 1.03) and generated-synthesizer group means (M = 2.57, SD = 1.12). The no-synthesizer group found the synthesizer least helpful compared to the provided and generated-synthesizer groups. This finding was not surprising since the no-synthesizer group subjects were not instructed to use the synthesizer. Post hoc analysis revealed that the provided-synthesizer group mean (M = 3.61, SD = 1.03) was significantly higher than the generated-synthesizer group mean (M = 2.57, SD = 1.12). The provided-synthesizer group found the synthesizer the most helpful while the generated-synthesizer group found the synthesizer somewhat helpful. Refer to Table 53 for the means and standard deviations.

Table 52

Analysis of Variance for How Helpful was the Synthesizer? for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Helpful	69.11	2	34.55	28.14	.000*
Within	157.18	128	1.22		

*$p < .05$

Related course passage. There was a significant difference between the three treatment groups, $F(2,109) = 19.82$, $p < .05$ on the helpfulness of the synthesizer. Refer to Table 54 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer (M = 3.59, SD = 1.06) and generated-synthesizer (M = 3.17, SD = 1.16) groups obtained significantly higher mean score than did the no-synthesizer group (M = 1.79, SD = 1.21). There was no significant difference between the provided-synthesizer and generated-synthesizer groups. The provided-synthesizer group and the generated-synthesizer group found the synthesizer most helpful while the no-synthesizer group found the synthesizer the least helpful. Refer to Table 53 for the means and standard deviations.

Table 53

Means and Standard Deviations for the Treatment Groups on How Helpful was the Synthesizer?

	Course Passage					
	Unrelated			Related		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	54	3.61	1.03	42	3.59	1.06
Generated-Synthesizer	53	2.57	1.12	46	3.17	1.16
No-Synthesizer	24	1.67	1.24	24	1.79	1.21
Minimum Score (Not Helpful)		1.00			1.00	
Maximum Score (Very Helpful)		5.00			5.00	

Table 54

Analysis of Variance for How Helpful was the Synthesizer? for the Related Course Passage

Source	SS	DF	MS	F	P
A. Helpful	51.17	2	25.58	19.82	.000*
Within	140.68	109	1.29		

*p < .05

Familiarity With the Passage

Subjects were asked to indicate on a scale of 1 to 5 how familiar they were with the information in the reading passages. One represented not familiar while five represented very familiar.

Unrelated course passage. Analysis of variance revealed no significant difference between the three treatment groups, $F(2, 156) = .41$, $p > .05$ on the familiarity of the reading passage. Refer to Table 55 for the summary of the analysis of variance. The means indicated that all three treatment groups were not familiar with the reading passage. Refer to Table 57 for the means and standard deviations.

Related course passage. There was no significant difference between the treatment groups, $F(2,128) = 1.47$, $p > .05$ on the familiarity of the reading passage. Refer to Table 56 for the summary of the analysis of variance. The means indicated that subjects in all three treatment groups were somewhat familiar with the information in the passage. Refer to Table 57 for the means and standard deviations.

Table 55

Analysis of Variance for How Familiar Was the Reading Passage? for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Familiar	.61	2	.30	.41	.664
Within	114.86	156	.73		

Table 56

Analysis of Variance for How Familiar Was the Reading Passage? for the Related Course Passage

Source	SS	DF	MS	F	P
A. Familiar	3.29	2	1.64	1.47	.230
Within	142.58	128	1.11		

Table 57

Means and Standard Deviations for the Treatment Groups on How Familiar was the Reading Passage?

	Course Passage					
	Unrelated			Related		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	54	1.59	0.88	43	2.76	1.31
Generated-Synthesizer	54	1.57	1.00	46	3.15	0.87
No-Synthesizer	51	1.45	0.64	42	2.97	0.95
Minimum Score (Not Familiar)		1.00			1.00	
Maximum Score (Very Familiar)		5.00			5.00	

Difficulty Using the Synthesizer to Summarize the Information

Subjects were asked to rate how difficult it was to use the synthesizer to summarize the information. One represented very difficult while five represented not difficult.

Unrelated course passage. Analysis of variance showed that there was a significant difference between the treatment groups, $F(2,126) = 17.33$, $p < .05$ on the difficulty level for using the synthesizer. Refer to Table 58 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer mean score (M = 3.74, SD = .97) was significantly higher than the generated-synthesizer (M = 2.76, SD = 1.06) and no-synthesizer (M = 2.30, SD = 1.49) groups mean score. There was no significant difference between the generated-synthesizer and no-synthesizer groups. The provided-synthesizer group found the use of the synthesizer the least difficult while the no-synthesizer group found it the most difficult. The generated-synthesizer group found the use of the synthesizer somewhat difficult. Refer to Table 60 for the means and standard deviations.

Table 58

Analysis of Variance for How Difficult Was It to Use the Synthesizer? for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Difficult	41.97	2	20.98	17.33	.000*
Within	152.50	126	1.21		

*$p < .05$

Related course passage. There was a significant difference between the treatment groups, $F(2,104) = 29.88$, $p < .05$ on the difficulty level for using the synthesizer. Refer to Table 59 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer ($M = 4.02$, $SD = 1.05$) and generated-synthesizer ($M = 3.55$, $SD = .87$) groups mean was significantly higher than was the no-synthesizer group mean ($M = 2.00$, $SD = 1.02$). There was no significant difference between the provided-synthesizer and generated-synthesizer groups. The provided and generated-synthesizer groups found the synthesizer the least difficult to use while the no-synthesizer group found the synthesizer the most difficult. Refer to Table 60 for the means and standard deviations.

Table 59

Analysis of Variance for How Difficult Was It to Use the Synthesizer? for the Related Course Passage

Source	SS	DF	MS	F	P
A. Difficult	56.38	2	28.19	29.88	.000*
Within	98.08	104	.94		

*$p < .05$

Table 60

Means and Standard Deviations for the Treatment Groups on How Difficult was it to Use the Synthesizer?

	Course Passage					
	Unrelated			Related		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	55	3.74	0.97	42	4.02	1.05
Generated-Synthesizer	54	2.76	1.06	45	3.55	0.87
No-Synthesizer	20	2.30	1.49	20	2.00	1.02
Minimum Score (Not Difficult)		1.00			1.00	
Maximum Score (Very Difficult)		5.00			5.00	

Used Synthesizer before in Previous Studies?

Subjects were asked to respond, yes or no, whether they had used synthesizer as a learning strategy in previous learning activities.

Unrelated course passage. For the no-synthesizer group, 91 percent of the subjects said they had never used a synthesizer before. For the provided-synthesizer group, 87 percent of subjects said they had never used a synthesizer before while 83 percent of subjects in the generated-synthesizer group had never used a synthesizer in previous studies. Chi-square analysis indicated that the difference between the groups was not significant. Hence, it can be concluded that the groups were equivalent with regards to previous experience with spatial synthesizers.

Related course passage. For the no-synthesizer group, 92 percent of the subjects said that they had never used a spatial synthesizer before. For the provided-synthesizer group, 74 percent said they had never used a spatial synthesizer before while 78 percent in the generated-synthesizer group said they had never used spatial synthesizers before. Chi-square analysis revealed no significant difference between the groups on the number of subjects with previous experience on the use of spatial synthesizers as learning strategies.

Use Spatial Synthesizers in the Future

Subjects were asked to respond, yes or no, whether they would use spatial synthesizers in the future when they read other passages.

Unrelated course passage. Seventy-six percent of subjects in the no-synthesizer group said they will use spatial synthesizers in the future while 75 percent of subjects in the provided-synthesizer group and 71 percent in the generated group said they will use spatial synthesizer in the future. Chi-square analysis revealed no significant difference between the groups on the number of subjects who said they will use spatial synthesizers in the future.

Related course passage. For the no-synthesizer group, 56 percent of subjects said they will use spatial synthesizer in the future. Seventy-five percent of subjects in the provided-synthesizer group said they will use spatial synthesizer in the future while 64 percent from the generated-synthesizer group said they will use spatial synthesizer in the future. Chi-square analysis revealed no significant difference between the groups on the number of subjects who said they will use spatial synthesizers in the future.

Satisfaction with the Synthesizer as a Learning Tool

Subjects were asked to rate their satisfaction on a scale of 1 (not satisfied) to 5 (very satisfied) with the spatial synthesizer as a learning tool.

Unrelated course passage. Analysis of variance showed a significant difference between the treatment groups, $F(2,130) = 9.78$, $p < .05$ on satisfaction with the spatial synthesizer. Refer to Table 61 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer (M = 3.64, SD = .97) group mean was significantly higher than that of both the generated-synthesizer group (M = 2.96, SD = 1.07) and no-synthesizer group (M = 2.60, SD = 1.26). There was no significant difference between the generated-synthesizer and no-synthesizer group means. The provided-synthesizer group was the most satisfied followed by the generated-synthesizer group and the no-synthesizer group which was the least satisfied. Refer to Table 63 for the means and standard deviations.

Table 61

Analysis of Variance for the Satisfaction Level With the Synthesizer as a Learning Tool for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Satisfied	22.37	2	11.18	9.78	.000*
Within	148.65	130	1.14		

*p < .05

Related course passage. When asked to rate their satisfaction with the spatial synthesizer, analysis of variance revealed a significant difference between the groups, $F(2,109) = 8.36$, $p < .05$. Refer to Table 62 for the summary of the analysis of variance. Post hoc analysis using the Scheffé test revealed that the provided-synthesizer (M = 3.67, SD = .98) and the generated-synthesizer (M = 3.41, SD = 1.00) groups obtained significantly higher means than did the no-synthesizer group (M = 2.58, SD = 1.25). There was no significant difference between the provided-synthesizer and generated-synthesizer groups. The provided-synthesizer and generated-synthesizer groups were the most satisfied while the no-synthesizer group was the least satisfied. Refer to Table 63 for the means and standard deviations.

Table 62

Analysis of Variance for the Satisfaction Level With the Synthesizer as a Learning Tool for the Related Course Passage

Source	SS	DF	MS	F	P
A. Satisfied	18.45	2	9.22	8.36	.000*
Within	120.31	109	1.10		

*$p < .05$

Overall Questionnaire Score

The scores for the questions that had the Likert scale format were totalled to get an overall score for the questionnaire for each subject. Analysis of variance was then conducted to determine whether there was any difference between the groups on the overall questionnaire score.

Unrelated course passage. There was no significant difference between the provided-synthesizer, generated-synthesizer, and the no-synthesizer groups on the overall questionnaire score, $F(2,70) = .41, p > .05$. Refer to Table 64 for the analysis of variance summary. Refer to Table 66 for the means and standard deviations.

Related course passage. There was a significant difference between the provided-synthesizer, generated-synthesizer, and the no-synthesizer groups on the overall questionnaire score, $F(2,101) = 13.94$, $p < .05$. Post hoc analysis using the Scheffé test indicated that the provided-synthesizer (M = 25.30, SD = 4.82) and generated-synthesizer (M = 24.82, SD = 3.72) groups obtained a significantly higher overall mean score than did the no-synthesizer group (M = 18.82, SD = 5.34). Refer to Table 65 for the analysis of variance summary. Refer to Table 66 for the means and standard deviations.

Table 63

Means and Standard Deviations for the Treatment Groups on Satisfaction with the Spatial Synthesizer as a Learning Tool

	Course Passage					
	Unrelated			Related		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	55	3.64	0.97	42	3.67	0.98
Generated-Synthesizer	53	2.96	1.07	46	3.41	1.00
No-Synthesizer	25	2.60	1.26	24	2.58	1.25
Minimum Score (Not satisfied)		1.00			1.00	
Maximum Score (Very Satisfied)		5.00			5.00	

Table 64

Analysis of Variance for the Overall Questionnaire Score for the Unrelated Course Passage

Source	SS	DF	MS	F	P
A. Overall	10.88	2	5.44	.41	.667
Within	917.16	70	13.10		

Table 65

Analysis of Variance for the Overall Questionnaire Score for the Related Course Passage

Source	SS	DF	MS	F	P
A. Overall	557.82	2	278.91	13.94	.000*
Within	2020.02	101	20.00		

*$p < .05$

Table 66

Means and Standard Deviations for the Treatment Groups on the Overall Questionnaire Score

	Course Passage					
	Unrelated			Related		
Treatment Groups	n	M	SD	n	M	SD
Provided-Synthesizer	27	17.00	3.58	42	25.30	4.82
Generated-Synthesizer	33	16.84	3.69	45	24.82	3.72
No-Synthesizer	13	15.92	3.49	17	18.82	5.34
Maximum Score		30.00			35.00	

Summary of Results

The following section lists each hypothesis and summarizes the results for each hypothesis.

Hypothesis 1

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on an immediate, cued recall and comprehension test than will subjects with no spatial synthesizer.

Hypothesis 1 Result

Unrelated Course Passage

Immediate, Cued Recall. Provided-Synthesizer Group > Generated-Synthesizer Group = No-Synthesizer Group.

Immediate, Comprehension. Provided-Synthesizer Group = Generated-Synthesizer Group = No-Synthesizer Group.

Related Course Passage

Immediate, Cued Recall. Provided-Synthesizer Group > Generated-Synthesizer Group = No-Synthesizer Group.

Immediate, Comprehension. Provided-Synthesizer Group = Generated-Synthesizer Group = No-Synthesizer Group.

Hypothesis 2

Subjects who generate a spatial synthesizer and subjects provided with a spatial synthesizer will perform better on a delayed, cued recall and comprehension test than will subjects with no spatial synthesizer.

Hypothesis 2 Result

Unrelated Course Passage

Delayed, Cued Recall. Provided-Synthesizer Group = Generated-Synthesizer Group = No-Synthesizer Group.

Delayed, Comprehension. Provided-Synthesizer Group = Generated-Synthesizer Group = No-Synthesizer Group.

Hypothesis 3

There is a significant relationship between spatial ability scores and the immediate, and delayed, cued recall and comprehension tests' scores.

Hypothesis 3 Result

There was no significant relationship between spatial ability scores and scores on the immediate, and delayed, cued recall and comprehension tests.

Hypothesis 4

There is a significant relationship between verbal ability scores and the immediate, and delayed, cued recall and comprehension tests' scores.

Hypothesis 4 Result

For the unrelated course passage, there was no significant relationship between verbal ability scores and immediate and delayed tests' scores for the provided synthesizer group. For the generated-synthesizer group, the only significant relationship was between verbal ability scores and the delayed, cued recall test scores.

For the generated-synthesizer group in the related course passage, the only significant relationship was between verbal ability scores and the immediate, cued recall test scores.

Hypothesis 5

Low verbal ability subjects who used synthesizers will perform better on the immediate, and delayed, cued recall and comprehension tests than will high verbal ability subjects who used synthesizers.

Hypothesis 5 Result

For the unrelated course passage, there was a significant interaction between treatment and verbal ability level on the immediate, cued recall test. High verbal ability subjects in the generated-synthesizer group obtained significantly higher scores on the immediate, cued recall test than did low verbal ability subjects. In addition, the following significant main effects were obtained from the analysis. On the delayed, cued recall and the delayed, comprehension tests for the unrelated course passage, high verbal ability subjects performed better than did low verbal ability subjects. On the immediate, comprehension test for the related course passage, high verbal ability subjects performed better than did low verbal ability subjects.

Hypothesis 6

High spatial ability subjects who used synthesizers will perform better on the immediate, and delayed, cued recall and comprehension tests than will low spatial ability subjects who used synthesizers.

Hypothesis 6 Result

There was no significant interaction between treatment and spatial ability level. However, two significant main effects were obtained. High spatial ability subjects performed better on the delayed, cued recall test than did low spatial ability subjects for the unrelated course passage. Also, high spatial ability subjects performed better on the immediate, comprehension test than did low spatial ability subjects for the related course passage.

Hypothesis 7

There is a significant gender difference on the immediate, and delayed, cued recall and comprehension tests.

Hypothesis 7 Result

There was no significant difference between males and females on the immediate, and delayed, cued recall and comprehension tests.

Hypothesis 8

High spatial ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low spatial ability subjects.

Hypothesis 8 Result

There was no significant difference between high and low spatial ability subjects on the synthesizer score.

Hypothesis 9

High verbal ability subjects will generate higher quality spatial synthesizer as measured by the score on the generated-synthesizer than will low verbal ability subjects.

Hypothesis 9 Result

There was no significant difference between high and low verbal ability subjects on the synthesizer score.

The next chapter discusses the result obtained, outlines the implications for education, and makes recommendations for future studies.

CHAPTER 5

Discussion

This chapter discusses the results obtained from the present study, identifies the delimitation of the study, proposes educational implications, and suggests further research that should be conducted to extend the study.

Effectiveness of Synthesizers

The hypothesis that the provided and generated-synthesizer groups will perform better than will the no-synthesizer group was supported for the provided-synthesizer group on the immediate, cued recall test. The provided-synthesizer group performed better on the immediate, cued recall test than did the generated-synthesizer and no-synthesizer groups. The facilitative effects on the immediate, cued recall test of the provided-synthesizer over the generated-synthesizer and no-synthesizer supported the findings of previous studies (Jonassen & Hawk, 1984; Kiewra, Dubois, Christian, McShane, 1988; Kiewra, Mayer, DuBois, Christensen, Kim, & Risch, 1990; Lambiotte & Dansereau, 1990) that providing students with learning strategies facilitated recall of information. It appears that the provided-synthesizer allowed subjects to store the information from the prose passage for easy retrieval on the cued recall test for both the related and unrelated passages. The provided-synthesizer facilitated recall by either (a) activating existing schema to assimilate the information in the prose passages, (b) providing the framework to accommodate the information into memory, or (c) facilitated subjects to store the information in the spatial and verbal subsystems in memory. The superiority of the provided-synthesizer group over the generated-synthesizer group can also be explained by the data from the questionnaire in the present study. Eighty-nine percent of subjects in the provided-synthesizer group claimed that they used the synthesizer to review the materials in the prose passage while only 66 percent of the subjects from the generated-synthesizer group claimed that they used the synthesizer to summarize the prose materials. It appears that a smaller number of subjects in the generated-synthesizer group, when compared to the provided-synthesizer group, made use of the generated-synthesizer to review the prose materials. As a result, subjects in the generated-synthesizer group did not recall as much information as did subjects in the provided-synthesizer group. Also, the questionnaire data indicated that the provided-synthesizer group, when compared to the generated-synthesizer group, found the synthesizer less difficult and more useful.

The results of the present study revealed that the generated-synthesizer group did not perform better on the cued recall and comprehension tests than did the no-synthesizer group. Hence, the results from the present study did not support other studies (Brody & Legenza, 1980; Carrier, Joseph, Krey, & LaCroix, 1983; Corkill, Bruning, Glover, & Krug, 1988; Dean & Kulhavy, 1981; McGuinness, 1986; Skaggs, Rocklin, Dansereau, Hall, O'Donnell, Lambiotte, & Young, 1990) which claimed that asking students to generate learning strategies facilitated recall and comprehension of textual information. Four possible explanations for the same level of performance for the generated and no-synthesizer groups on the immediate, cued recall test are as follows. (a) Subjects in the generated-synthesizer group may have focused their attention on the mechanics of constructing the synthesizer. As a result, less attention may have been given to the use of the generated-synthesizer as a learning strategy to encode the materials (Dansereau, 1989). (b) Too much time may have been spent generating the synthesizer. As a result, limited time may have been left to use the generated-synthesizer effectively as a learning strategy (Armbruster & Anderson, 1984; Winn, 1987). The limited amount of time to use the spatial synthesizer by the generated-synthesizer group was supported by the data from the questionnaire. Although all subjects in the generated-synthesizer group developed the synthesizer, only 66 percent of subjects for the unrelated passage and 75 percent of subjects for the related course passage claimed that they used the synthesizer to study the prose passage. The percent of subjects in the generated-synthesizer group who made use of the synthesizer to review the prose material was significantly lower than the percent of subjects in the provided-synthesizer group. For the provided-synthesizer group, 89 percent of the subjects from the unrelated passage and 86 percent from the related passage claimed that they used the synthesizer to review the prose passage. (c) The synthesizer generated by subjects may not have been of the same quality as that of the provided-synthesizer to facilitate recall of information from the prose passage. When the generated-synthesizer was compared to the provided-synthesizer, the mean score for the unrelated passage generated-synthesizer was 11.24 out of a total score of 26. For the related course passage, the mean score for the generated-synthesizer was 30.74 out of a total score of 62. The mean scores for the generated-synthesizers were slightly below 50 percent of the total score for the provided-synthesizer. Perhaps, subjects required more training in the use and generation of spatial synthesizers to use the synthesizers as effective learning strategies. (d) Subjects in the no-synthesizer group, anticipating a recall test and having time to rehearse, may have developed a conceptual synthesizer or used other learning strategies to facilitate recall of information from the prose passage.

The facilitative effect of the provided-synthesizer on the immediate, cued recall test, when compared to the effects of the generated-synthesizer and no-synthesizer, was not repeated on the immediate, comprehension test. The provided, generated, and no-synthesizer groups all had similar scores on the immediate, comprehension test. The lack of effectiveness of the generated-synthesizer on recall and comprehension contradicts Hall, Dansereau, and Blair's (1990) [illegible] that it is the process of generating the synthesizer rather than the accuracy [illegible] entation that has an impact on learning.

One [illegible] hypothesize that both the provided-synthesizer and generated-synthesizer did not allow subjects to build elaborate schema to respond to the comprehension questions. According to Anderson (1987) and Rumelhart (1980), for comprehension to occur, one has to select a schema that provides a suitable account of the information to assimilate the information into the schema. Possibly, the synthesizers may not have activated the appropriate schema to assimilate the information or they did not provide the framework to accommodate the information to promote comprehension. Also, it appears that the provided-synthesizer facilitated recall of the information in the passage, but not the relationships among the separate pieces of information. Perhaps more or different training on synthesizer generation and use would have enhanced comprehension of the passage.

Although the generated-synthesizer group did not perform better than did the no-synthesizer group, results revealed that for the generated-synthesizer group, there were statistically significant positive correlations between the generated-synthesizer scores and scores on the cued recall and comprehension tests. For the related course passage, there were statistically significant positive correlations between the generated-synthesizer scores and scores on the immediate, cued recall and comprehension tests. When subjects in the generated-synthesizer group were divided into high and low synthesizer score levels, subjects who obtained high scores on the generated-synthesizer performed better on the immediate and delayed cued recall tests than did subjects who obtained low scores on the generated-synthesizer. It appears that for the generated-synthesizer group, the better the quality of the generated-synthesizer, as measured by the completeness of the generated-synthesizer, the better subjects performed on the cued recall and comprehension tests. Perhaps, the type and amount of training on synthesizer generation and use was not effective for all subjects. As a result, there was a large variation in the quality of the generated-synthesizer. The variation in synthesizer quality was confirmed when the generated-synthesizer scores were examined. The range of the scores for the related passage generated-synthesizer was 9 to 50 while the range for the unrelated passage generated-synthesizer was 2 to 20.

The hypothesis that the generated and provided-synthesizer groups will perform better on the delayed, cued recall and comprehension tests than did the no-synthesizer group was not supported. The provided, generated, and no-synthesizer groups performed at the same level on the delayed, cued recall and comprehension tests. There was no ceiling effect on the tests that were used in the present study. It appears that the provided-synthesizer and the generated-synthesizer, when compared to the no-synthesizer, did not facilitate permanent storage of the information in long-term memory for delayed cued recall and comprehension. The resulting cognitive structure, after the information was assimilated, may not have been integrated efficiently to facilitate delayed, cued recall and comprehension. Also, the spatial synthesizer may not have provided the framework to accommodate the new information from the prose passage into permanent storage to facilitate delayed, cued recall and comprehension.

Spatial Ability and Use of Synthesizers

The hypothesis that there will be a significant positive relationship between spatial ability scores and scores on the immediate and delayed comprehension tests was rejected by the present study. There was no significant relationship between spatial ability scores, as measured by the General Aptitude Test Battery (GATB) spatial subtest, and scores on the immediate and delayed, cued recall and comprehension tests for both the related and unrelated course passages. It appears that spatial ability scores were not associated with whether or not subjects used the spatial synthesizer effectively to study the prose passage to facilitate performance on the cued recall and comprehension tests.

The hypothesis that high spatial ability subjects will perform better than will low spatial ability subjects was supported on the delayed, cued recall and immediate, comprehension tests. On the delayed, cued recall test for the unrelated course passage and on the immediate, comprehension test for the related course passage, high spatial ability subjects outperformed low spatial ability subjects in the provided-synthesizer, the generated-synthesizer, and no-synthesizer groups. It appears as if high spatial ability subjects in the provided and generated-synthesizer groups were able to use their superior spatial ability to process the spatial synthesizer and build a permanent store to facilitate retention of information from the prose passage. As a result, high spatial ability subjects recalled more on the delayed, cued recall test than did low spatial ability subjects. The superior performance by high spatial ability subjects over low spatial ability subjects in the no-synthesizer group, may be explained in two ways. Firstly, high spatial ability subjects in the no-synthesizer group may have used the training on how to construct a synthesizer as a conceptual synthesizer review strategy while they were waiting for further instructions after reading the passage. The questionnaire data indicated that six percent of subjects in the no-synthesizer group claimed they used the synthesizer as a review strategy for the prose passage. Because subjects were told that they would be given a test to determine how much they remembered from the prose passage, subjects may have used a learning strategy to review the information in the prose passage. Secondly, high spatial ability subjects in the no-synthesizer group may have used better study strategies than did low spatial ability subjects. Superior study strategies by high general ability subjects have been demonstrated by some research studies (Swing & Petersen, 1988). As a result, high spatial ability subjects in the no-synthesizer group were able to store the information more efficiently to facilitate delayed, cued recall.

On the immediate, cued recall test for both the related and unrelated course passages and the comprehension test for the unrelated course passage, high spatial ability subjects did not perform better than did low spatial ability subjects. For unrelated course information, high spatial ability subjects were not able to take advantage of their superior spatial ability to use the synthesizer to build elaborate schema to facilitate recall and comprehension when compared to low ability subjects.

Verbal Ability and Use of Synthesizers

The hypothesis that there will be a significant positive relationship between verbal ability scores and scores on the immediate, and delayed, cued recall and comprehension tests was partially supported by the present study. For the provided-synthesizer group, there was no significant relationship between verbal ability scores and scores on the immediate and delayed, cued recall and comprehension tests for both the related and unrelated course passages. For the generated-synthesizer group on the unrelated course passage, there was a significant relationship between verbal ability scores and scores on the delayed, comprehension test. It appears that when the learning material is unfamiliar to learners, high verbal ability subjects who generated the synthesizer were able to use the synthesizer to process the information to facilitate delayed comprehension.

For the generated-synthesizer group on the related course passage, there was a significant relationship between verbal ability scores and scores on the immediate, cued recall test. There was no significant relationship between verbal ability scores and scores on the immediate, comprehension test. One explanation for the nonsignificant relationship between verbal ability scores and immediate, comprehension scores is that when subjects encountered familiar and related course materials, they did not see a need to use the spatial synthesizer. Hence, comprehension of the information in the prose passage was not facilitated.

The hypothesis that low verbal ability subjects will perform better on the immediate, cued recall test than will high verbal ability subjects was supported for the provided-synthesizer group. On the immediate, cued recall test for the unrelated course passage, low verbal ability subjects in the provided-synthesizer group performed better than did high verbal ability subjects. This is consistent with other research findings (Dees & Dansereau, 1990; Holley, Dansereau, McDonald, Garland, & Collins, 1979; McCombs & McDaniel, 1983) that low verbal ability subjects tend to benefit more from provided learning strategies. One explanation is that low verbal ability subjects did not have the skills to spontaneously use their own strategies to determine the structure of the prose materials. As a result, low verbal ability subjects took advantage of the provided-synthesizer to help process the information in the prose passage. On the other hand, high verbal ability subjects may have ignored the provided-synthesizer and used their own learning strategy which may not have been as effective as the provided-synthesizer.

On the immediate, cued recall test, high verbal ability subjects performed better than did low verbal ability subjects in the generated-synthesizer group. One possible explanation for this occurrence could be that the process of generating the synthesizer was too demanding for the low verbal ability subjects. Low verbal ability subjects may have spent too much mental resources trying to identify the main ideas and the relationship between the ideas in the passage. As a result, low verbal ability subjects did not effectively use the instructions to generate the synthesizer. When the generated-synthesizer score for the related course passage was examined, the mean score for high verbal ability subjects was 33.41 while the mean score for low verbal ability subjects was 28.07. Perhaps, low ability subjects did not benefit sufficiently from the training to generate the spatial synthesizer. On the other hand, it could be postulated that high verbal ability subjects may have used their own strategy or may have made better use of the instructions to generate and process the synthesizer to learn the material.

On the immediate, comprehension test for the unrelated course passage and the immediate, cued recall test for the related course passage, both high and low verbal ability subjects had similar scores in all three treatment groups. High verbal ability subjects may not have been able to utilize the synthesizer to build the appropriate cognitive structure necessary for comprehension. According to Anderson (1977) and Rumelhart (1980), comprehension requires that the information be assimilated or accommodated into existing cognitive structures. Because of the spatial nature of the synthesizer, high verbal ability subjects may not have been able to take advantage of their superior verbal ability to use the spatial synthesizer effectively.

On the delayed, cued recall and comprehension tests for the unrelated course passage, and the immediate, comprehension test for the related course passage, high verbal ability subjects outperformed low verbal subjects. It appears for high verbal ability subjects, compared to low verbal ability subjects, the provided-synthesizer and the generated-synthesizer may have facilitated a more permanent and elaborate store of the information to facilitate comprehension. However, for the no-synthesizer group, high verbal ability subjects compared to low verbal ability subjects, used their superior ability to study the prose passage. One could postulate that the facilitative effect of the provided-synthesizer for low verbal ability subjects was only temporary to influence performance on the immediate, cued recall test. The superior performance of high verbal ability subjects over low verbal ability subjects in the no-synthesizer group is not surprising since high verbal ability subjects tend to take advantage of their superior ability to process the prose material.

When the generated-synthesizer scores were examined, high verbal ability subjects did not generate better quality synthesizers than did low verbal ability subjects. Because of the spatial nature of the synthesizer, high verbal ability subjects were not able to use their superior verbal ability to generate better quality spatial synthesizer than did low verbal ability subjects.

Gender and the Use of Spatial Synthesizer

The hypothesis that there is a significant gender difference on immediate, and delayed cued recall and comprehension tests was rejected by the present study. For both the related and unrelated course passages and in all three treatment groups, females performed as well as males on both the immediate and delayed, cued recall and comprehension tests. In addition, when the generated-synthesizer scores were examined, there was no significant difference between males and females on the generated-synthesizer. One could hypothesize simply that males and females possess the same skills requisite for constructing and using a spatial synthesizer. Also, Alderton (1989) claimed that gender differences in spatial ability can be eliminated by practice. These observations are consistent with those made by Linn and Petersen (1986). The absence of a significant difference between males and females was not in agreement with other studies (Kail, Stevensen, & Black, 1984; Maccoby & Jacklin, 1974) which claimed that males are superior to females on spatial tasks. Four possible explanations for the nonsignificant difference between males and females on the tests and the generated-synthesizer scores are as follows. (a) The training to generate and use the spatial synthesizer may have eliminated any gender differences that might have existed in using the spatial synthesizer. (b) The spatial aptitude test may not have been sensitive enough to identify male and female differences in spatial ability. (c) Males and females who attend the technical institute where the present study was conducted may have equivalent spatial ability because of their background and interest. (d) Because subjects used in the present study were adults, previous training and experience may have eliminated gender differences on spatial tasks (Alderton, 1984; Maccoby & Jacklin, 1974).

Delimitation of the Study

The present study used technical institute students as subjects. As a result, one should use caution when generalizing the results to other students. Younger students may not have the skills and ability to study and generate spatial synthesizers. Also, the subjects involved in the present study were business students. As a result, some of the results may not apply to students enrolled in engineering or the hard sciences. Engineering and science students may have developed high spatial ability because of the nature of their training or previous work experience.

In the present study, the training on how to generate and study the spatial synthesizer was fifteen minutes in duration. The amount of training may not have been enough to allow all of the subjects in the present study to generate high quality spatial synthesizers to facilitate recall and comprehension of the prose material. When the generated-synthesizer scores were examined, the range for the related and unrelated passages generated-synthesizers were 9 to 50 (M = 30.74) and 2 to 20 (M = 11.24), respectively. Although all subjects had the same training to generate the synthesizer, there was a large variation in the quality of the generated-synthesizers. Hence, the type of training for generating the synthesizer may not have benefitted all subjects. The present study did not evaluate the effectiveness of the training for generating and using the synthesizer.

The no-synthesizer (control) group in the present study received training on synthesizer generation and use. As a result, subjects in the no-synthesizer group may have used the knowledge they gained from the training to develop a conceptual synthesizer to review the prose materials. When the questionnaire data was analyzed, results indicated that six percent of subjects in the no-synthesizer group claimed that they had used the synthesizer to review the prose passage. Also, the no-synthesizer group, while waiting for further instructions, may have used other learning strategies (spontaneous strategies) to rehearse and review the prose materials.

A related and an unrelated course passage was used in the present study to determine whether the same results will be obtained for both passages. However, the passages differed in length, difficulty level, the type of information, and the style of presentation. Perhaps, if the passages were similar in length, difficulty level, and style of presentation, different results would have been obtained. Also, the results section presented the unrelated course passage results followed by the related course passage results. This sequence may have resulted in an order effect which may have caused some readers to compare the results for the passages.

Implications for Education

With the increased emphasis on "education for all", educators have to accommodate students with large individual differences (McNabb & Welch, 1990). Learning strategies such as spatial synthesizers could help eliminate some of the individual differences. As this study indicated, providing a spatial synthesizer for learners after reading a passage, improved performance on a cued recall test.

For both unrelated, difficult course materials and related course materials, the provided spatial synthesizer facilitated recall of the materials. Textbook authors, course developers, and teachers should use spatial synthesizers to enhance recall. The spatial synthesizers should be placed at the end of lessons or chapters of textual material.

Subjects were asked to rate the usefulness of the synthesizer and their satisfaction with the synthesizer for both the related and unrelated course passages. For the unrelated course passage, the generated-synthesizer group did not find the synthesizer as useful as did the provided-synthesizer group. Also, subjects in the generated-synthesizer group, when compared to the provided-synthesizer group, were not as satisfied with the synthesizer. As a result, for unfamiliar and difficult reading materials, teachers and course developers may derive benefit by providing more training to students on methods of generating and using spatial synthesizers.

The present study did not find any significant differences between males and females on the immediate and delayed, cued recall and comprehension tests. As a result, educators may use the same spatial learning strategies for both males and females. When the level of learning required is recall of information, the results from the present study suggest that a provided spatial synthesizer may be employed.

Recommendations for Future Research

According to Weinstein (1984), spatial learning strategies tend to be content independent. Subjects trained to generate spatial learning strategies in one content area should be able to transfer the skills for generating spatial learning strategies in other content areas. In the present study, subjects were trained to generate and use a spatial synthesizer in a business communication course. More studies are needed to determine whether subjects trained to generate and use a spatial synthesizer in one subject area will transfer the skills to other subject areas. In addition, the research should look at how spatial synthesizers are used over time. Do students improve over time with the use of spatial synthesizers?

Results from the present study indicated that a provided spatial synthesizer facilitated the cued recall from a prose passage. More research is needed to determine how students process spatial synthesizers to facilitate the recall of information (Dees & Dansereau, 1990).

The present study used fifteen minutes to train subjects on how to generate and use the spatial synthesizer. Future studies should train students to meet a predefined criterion on generating and learning from spatial synthesizers. Also, the subjects used in the present study were enrolled in business administration. Future studies should use engineering students as subjects. Because of their training, engineering students may have developed high spatial ability which may be beneficial in the generation and use of spatial synthesizers.

Results from the present study indicated that subjects asked to generate a synthesizer did not perform better on the cued recall and comprehension tests than did subjects given no synthesizer. More research should be conducted to determine what type of spontaneous learning strategies students use when they are not provided with learning strategies or asked to generate learning strategies. In addition, research is needed to determine if there are any differences in quality between student-generated spatial learning strategies and expert-generated spatial learning strategies.

The present study found that subjects reacted more positively when using the synthesizer with the related course passage. More study should be conducted to determine whether there is any relationship between level of satisfaction with using spatial synthesizers and benefits from spatial synthesizers. At the same time, more research is needed to determine how effective synthesizers are for learning new and difficult materials.

Results from the attitude questionnaire indicated that although subjects in the generated and no-synthesizer groups had a low satisfaction level with the spatial synthesizer, they claimed that they will use synthesizers in future studies. More research is needed to determine if subjects use spatial synthesizers after an initial encounter with synthesizers.

A higher percentage of subjects in the related course passage, when compared to the unrelated course passage, used the generated-synthesizer to review the prose passage. It seems as if for new and difficult materials, students do not use the synthesizer they generate. More research is needed to ascertain whether it is more effective to provide subjects with spatial synthesizers for new and unfamiliar materials.

Finally, because the present study is one of a few recent studies that investigated the effectiveness of spatial learning strategies, more research should be conducted to assist educators to make effective use of spatial learning strategies. The present study provided some of the ground work for future studies on spatial learning strategies.

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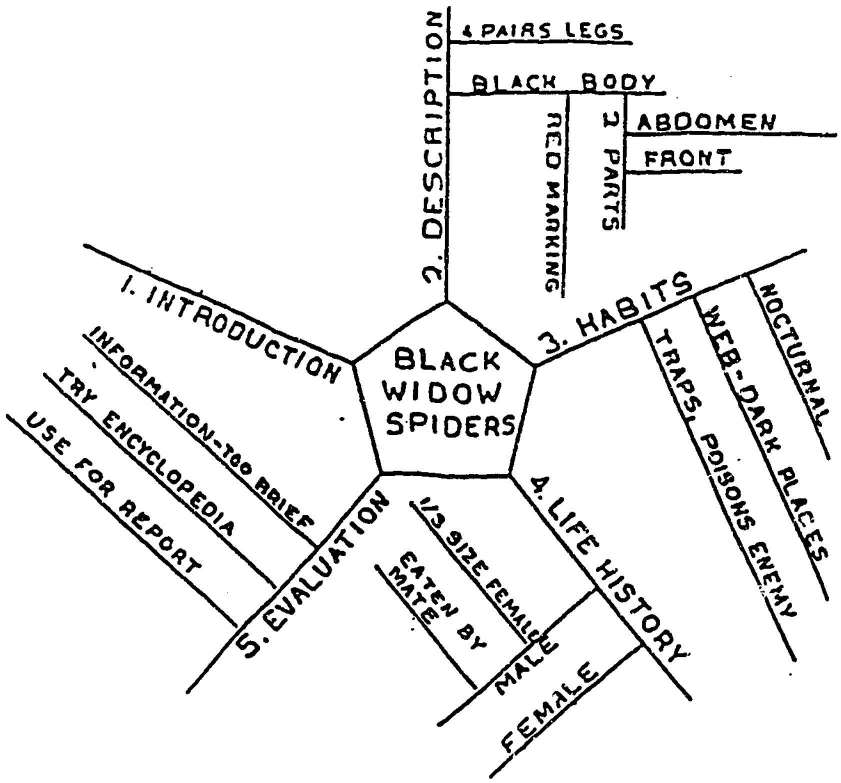
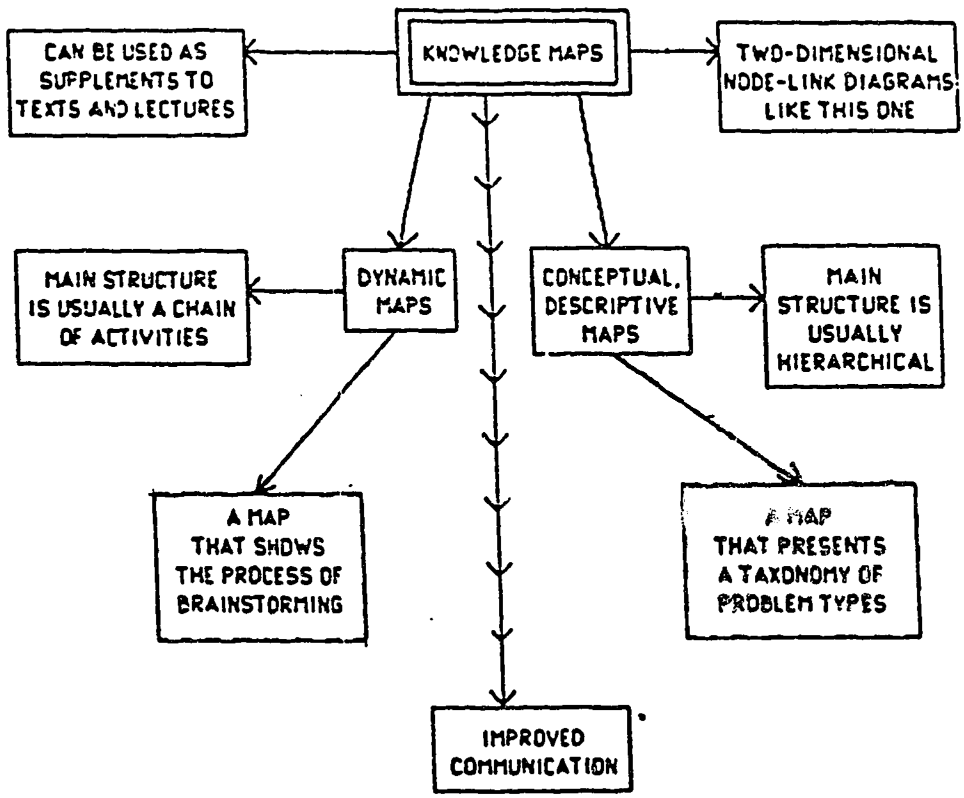
APPENDIX 1

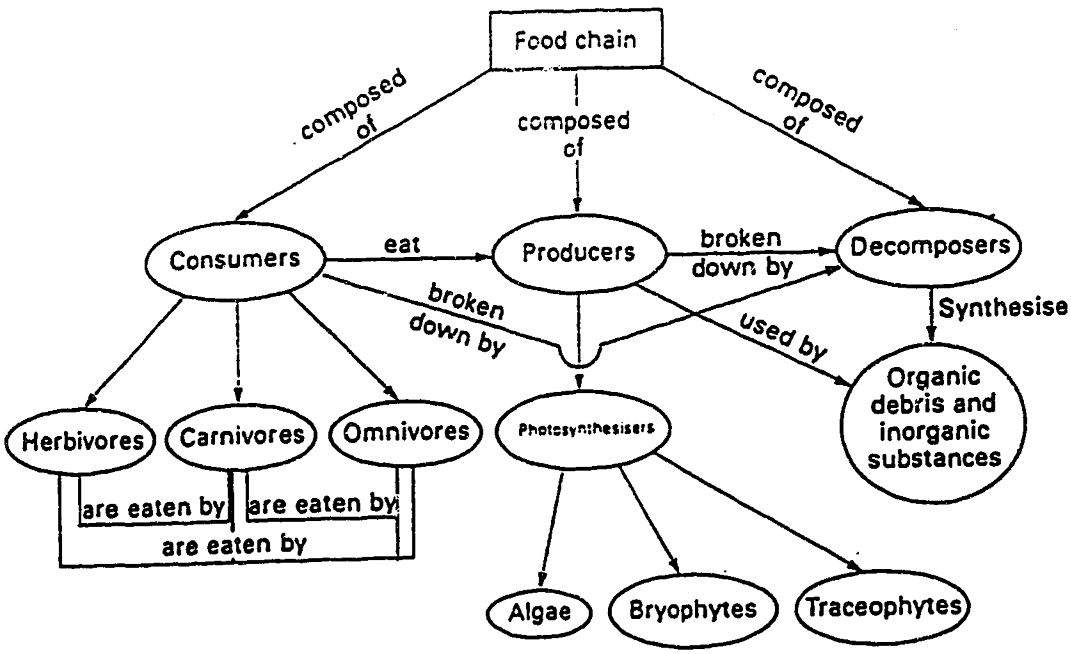
Examples of Spatial Learning Strategies



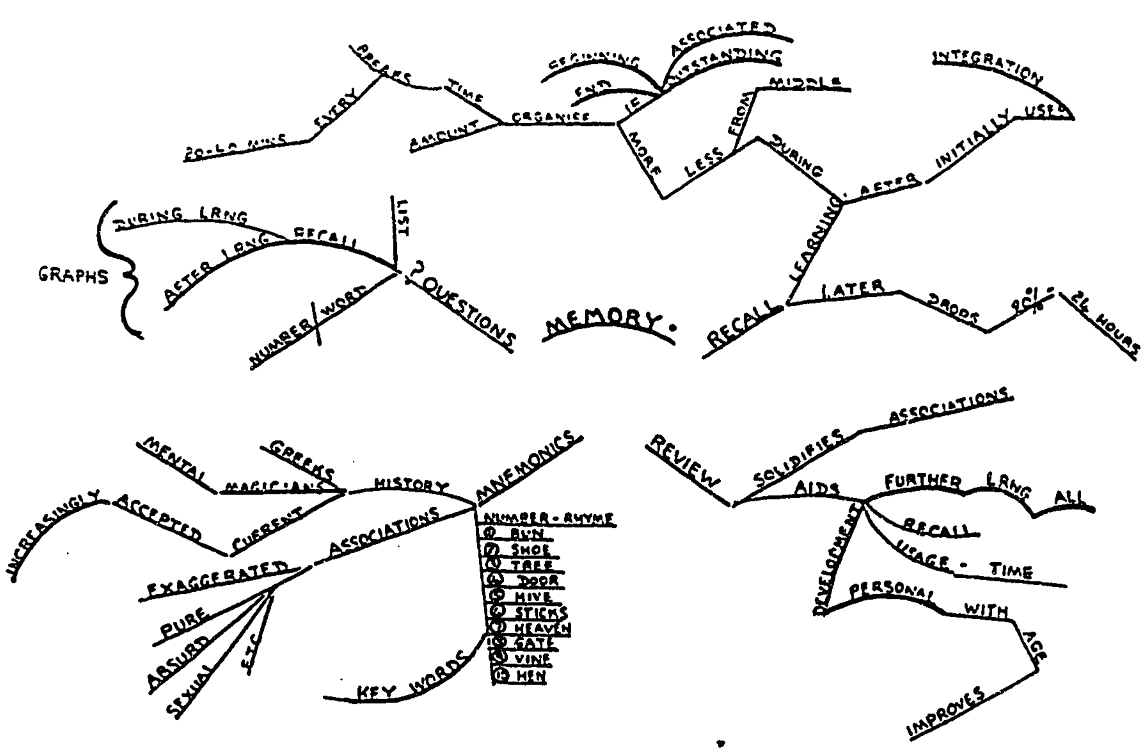
Example of a Map (Hanf, 1971, adapted)



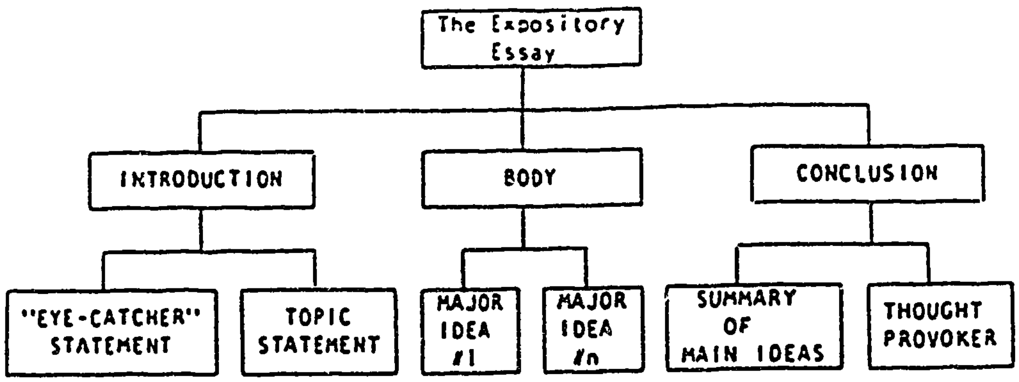
Example of a Network (Dansereau, 1989, adapted)



Example of a Concept Map (Novak & Gowin, 1984, adapted)



Example of a Mind Map (Buzan, 1983, adapted)



Example of a Synthesizer (Van Patten, Chao, & Reigeluth, 1986, adapted)

APPENDIX 2

Training Materials

Reading Passage Used for the Training

Note. From Business Communication Today (p. 455-458) by C.L. Bovee and J.V. Thill, 1989. New York: Random House. Reprinted with permission from McGraw-Hill, Inc.

Informational Reports

Informational reports have one basic purpose: to explain something in straightforward terms. Informational reports, which have hundreds of uses in business, include reports for monitoring and controlling operations, statements of policies and procedures, most compliance reports, most personal activity reports, some justification reports, some reports documenting client work, and some proposals.

In structuring an informational report, you can let the nature of whatever you're describing serve as the point of departure. If you're describing a machine, each component can correspond to a part of your report. If you're describing an event, you can approach the discussion chronologically, and if you're explaining how to do something, you can describe the steps in the process.

Informational reports take many forms, but the two examples that follow, a brief periodic report and a personal activity report on a conference, will give you an idea of the typical organization and tone.

A Periodic Report

A periodic report is a monitor/control report that describes what has happened in a department or division during a particular period. The purpose of these recurring documents, which are sometimes called status reports, is to provide a picture of how things are going so that managers will be up-to-date and can take corrective action if necessary.

Periodic reports are usually written in memo format and do not need much of an introduction; a subject line on the memo is adequate. They should follow the same general format and organization from period to period. Most are organized in this sequence:

- o Overview of routine responsibilities. A brief description of activities related to each of the writer's normal responsibilities.
- o Discussion of special projects. A description of any new or special projects that have been undertaken during the reporting period.
- o Plans for the coming period. A schedule of activities planned for the next reporting period.
- o Analysis of problems. Although often included in the overview of routine or special activities, it is sometimes put in a separate section to call attention to areas that may require high-level intervention.

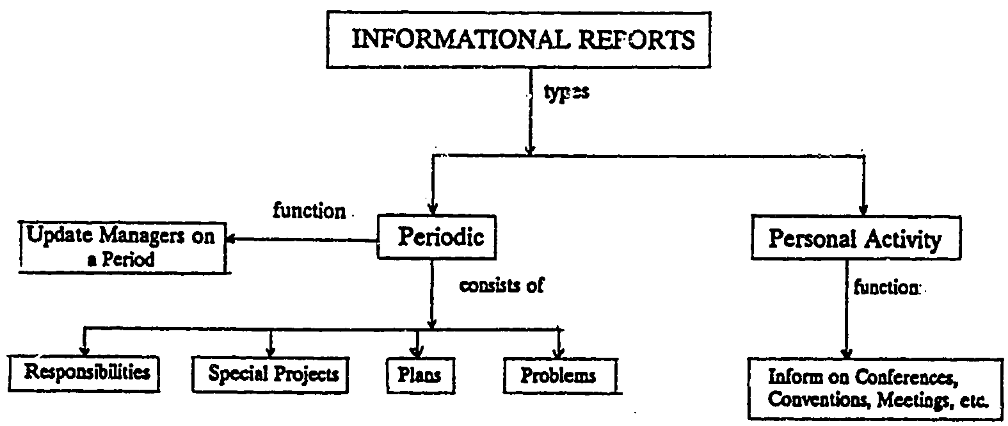
The important thing to remember in writing periodic reports is to be honest about problems as well as accomplishments.

A Personal Activity Report

A personal activity report is a form of monitor/control report that calls for an individual's description of what occurred during a conference, convention, or trip, for example. It is intended to inform management of any important information or decisions that emerged.

Personal activity reports are ordinarily written in memo format. Because they are nonrecurring documents, they require more of an introduction than a periodic report does. They are often organized chronologically, but some are organized around topics that reflect the reader's interests.

Spatial Synthesizer for the Training Passage



Synthesizer for the Informational Reports Passage

Procedure for Generating the Spatial Synthesizer

Generating the Synthesizer

Start with a blank piece of paper.

1. Write the title of the passage at the top of the page.
2. Visualize and write the major sections or topics in the passage.
   a. This is usually obtained from headings and topic sentences.
   b. Use one word or a short phrase to describe each section.
   c. Refer back to the passage if needed.
3. Visualize the structure of the passage.
4. On another piece of paper, place the concept/idea in an order that reflects the structure of the passage. Use the title of the passage as the highest level.
5. Visualize the relationship between two concepts/ideas.
6. Draw a line between concepts/ideas that are related.
7. Label the line with a word or short phrase to describe the relationship between the two concepts/ideas.
8. Visualize the relationship between all of the concepts/ideas.
9. Draw lines to connect all concepts/ideas that are related.
10. Label each line with a word or short phrase to describe the relationship.
11. Visualize the structure of the passage and check to determine that the synthesizer reflects the structure of the passage.
12. Study the synthesizer using the following procedure.

a. Start reading the synthesizer from top to bottom.

b. If there is a line connecting more than one box, place the relationship in the form of a sentence and read the sentence quietly in your mind.

c. Repeat the above step (b) for all of the relationships in the synthesizer.

d. For each box try to recall the information from the passage that is related to that box.

e. If you cannot recall the details for a box, go back to the passage and look for the details.

f. Take a final look at the synthesizer to get an overall picture of the content.

APPENDIX 3

Reading Passages

Unrelated Course Passage

Shannon's Communication Theory

Shannon's Communication Theory

The communication system proposed by Shannon consists of an information source, a transmitter, a communication channel, a noise source, a receiver, and a message destination.

The information source and the message destination are usually human beings. As an example, a human being may type a message consisting of letters and spaces on the keyboard of a teletypewriter. The teletypewriter serves as a transmitter that encodes each character as a sequence of electrical pulses, which may be "on" or "off", "current" or "no current". These electrical pulses are transmitted by a pair of wires to another teletypewriter that acts as a receiver and prints out the letters and spaces, which are in turn read by the human being serving as the message destination.

As the pulses travel from the teletypewriter that serves as the receiver to the teletypewriter, an intermittent connection or an extraneous current may alter or mutilate them so that the receiver teletypewriter prints out some wrong characters. Shannon sums up such alterations or mutilations of the signal by including a noise source in his communication system. Ordinarily the signal is an electrical signal, and the noise is an unpredictable interfering signal that is added to the desired signal.

The noise can cause the received message to differ from the message the source wished to transmit. The greater the ratio of the power of the signal to the power of the noise is, that is, the greater the signal-to-noise ratio, the less effect the noise will have on the operation of the communication system.

In a voice communication system based on the automatic speaking machines known as vocoders, the transmitter part of such a system analyzes a speech signal and obtains data to control a speaking machine at the remote receiver. The control signals so obtained are the signals that are sent from the transmitter to the receiver. These control signals operate the distant speaking machine. Excessive noise in the transmission path may cause errors of articulation in the speech the message destination hears. Using this example, we come to another concept introduced by Shannon. The vocoder and its control signals must be complex enough to produce speech that meets a fidelity criterion set by the message destination. If we fail to meet the fidelity criterion, the purposes of the communication system will not be fulfilled. If we produce better speech than is necessary, the system will be inefficient.

Shannon also showed how to measure the capacity of a communication channel in bits per second. A bit (short form for "binary digit") is a unit of uncertainty between "yes" or "no", or "heads" or "tails". The capacity of a communication channel is a quantity that is referred to as the entropy or entropy rate of the source. The entropy rates of different message sources vary widely. The entropy of English text is probably about one bit per character. The entropy rate of speech is not known. Experiments with vocoders indicate that it is less than 1,000 bits per second. In contrast, we routinely use a channel (the telephone) capable of transmitting 60,000 bits per second of high-quality speech. A channel capable of transmitting some 60 million bits per second is generally used in transmitting television pictures.

Shannon contributed a great deal in establishing the bit as a measure of the complexity of message sources and the capabilities of channels. In addition, he proved an extraordinary theorem. He showed that if the entropy rate of a message source does not exceed the capacity of a communication channel, then in principle messages from the source can be transmitted over the channel with a vanishingly small probability of error.

Related Course Passage

Developing Formal Presentations

Note. From Business Communication Today (p. 567-573) by C.L. Bovee and J.V. Thill, 1989. New York: Random House. Reprinted with permission from McGraw-Hill, Inc.

DEVELOPING FORMAL PRESENTATIONS

In oral communication, there is interaction between you and the audience. When you speak before a group, you can receive information as well as transmit it. As a consequence, you can adjust both the content and the delivery of your message as you go along, editing your speech or presentation to make it clearer and more compelling. Instead of simply expressing your ideas, you can draw out the audience's ideas and use them in reaching a mutually acceptable conclusion. You can also capitalize on nonverbal signals to convey information to and from your audience.

But in order to get the benefits of oral communication, you have to make a few sacrifices. The biggest price you pay is loss of control. Dealing with an audience requires flexibility; the more you plan to interact, the more flexible you must be. Halfway through your presentation, an unexpected comment from someone in the audience may force you to shift to a new line of thought, which requires a good deal of skill. At the same time, you must also accommodate the limitations of listeners. To prevent the audience from losing interest or getting lost, you must use special techniques in developing the various elements of the presentation: the introduction, the body, the final summary, the question-and-answer period.

The Introduction

You have a lot to accomplish during the first few minutes of your speech or presentation: You need to arouse the audience's interest in your topic, establish your credibility, and prepare the audience for what will follow. That's why the introduction often requires a disproportionate amount of your attention.

Arousing Interest

Some subjects are naturally more interesting than others. If you happen to be discussing a matter of profound significance that will personally affect the members of your audience, chances are they will listen regardless of how you begin. Other subjects, however, call for more imagination.

The best approach when you are dealing with an uninterested audience is to appeal to human nature. Encourage people to take the subject personally. Show them how they as individuals will be affected.

Experienced speakers use several other tried-and-true techniques for connecting their subject to the audience's personal concerns. However, they always make sure that the introduction matches the tone of the speech or presentation. If the occasion is supposed to be fun, you may begin with something light; but if you are talking business to a group of executives, don't waste their time with cute openings. Avoid jokes and personal anecdotes when you are discussing a serious problem. If you are giving a routine oral report, don't be overly dramatic. Most of all, be natural. Nothing turns off the average audience faster than a trite, staged beginning.

Building Credibility

One of the chief drawbacks of overblown openings is that they damage the speaker's credibility, and building credibility is probably even more important than arousing interest. Communication research clearly shows that acceptance of a message depends on the audience's confidence in the speaker. Thus you must establish a good relationship with the audience - and quickly, because people will decide within a few minutes whether you are worth listening to. You want the audience to like you as a person and to respect your opinion.

Establishing credibility is relatively easy if you are speaking to a familiar, open-minded audience. As long as you avoid sticking your foot in your mouth, you can coast on your reputation. The real difficulty arises when you must earn the confidence of strangers, especially those who are predisposed to be skeptical or antagonistic.

One way to handle the problem is to let someone else introduce you. This solution enables you to present your credentials without appearing boastful. Be certain, however, that the person doesn't exaggerate your qualifications. Some members of the audience are likely to bristle if you're billed as being the world's greatest authority on the subject.

If you're introducing yourself, keep your comments simple. But don't be afraid to mention your accomplishments. Your listeners are curious about you. They want to know your qualifications, so tell them very briefly who you are and why you're there. Generally speaking, one or two aspects of your backgrou... are all you need to mention: your position in an organization, your profession, the name of your company.

Previewing the Presentation

Giving your audience a preview of what's ahead adds to your authority and more importantly, helps people understand your message. A reader can get an idea of the structure of a report by looking at the table of contents and scanning the headings. But in oral presentation, the speaker must provide the framework. Otherwise, the audience may be unable to figure out how the main points of the message fit together.

Your introduction should summarize your basic message (the main idea), identify the supporting points, and indicate the order in which those points will be developed. Tell your listeners in so many words, "This is the subject, and these are the points I will cover." Once you have established the framework, you can move into the body of the presentation, confident that the audience will understand how the individual facts and figures relate to your main idea.

The Body

The bulk of your speech or presentation should be devoted to a discussion of the three or four main points on your outline. You can use the same organizational patterns that you use in a letter, memo, or report, but strive for simplicity. You want the structure of your speech or presentation to be clear, and you don't want to lose the audience's attention.

Emphasizing Structure

A written report uses typographical and layout clues - headings, paragraph indentions, white space between sections, lists - to show how ideas are related. For oral presentation, however, you must rely more on words.

For small links between sentences and paragraphs, one or two transitional words are enough: therefore, because, in addition, in contrast, moreover, for example, consequently, nevertheless, finally. But to link major sections of the speech or presentation, you need complete sentences or paragraphs. Every time you shift topics, stress the connection between ideas. Summarize what's been said: preview what's to come.

The longer the speech or presentation, the more important the transitions become. When you present many facts and ideas, the audience has trouble absorbing them and seeing the relationship among them. Listeners need clear transitions to guide them to the most important points. Furthermore, they need transitions to pick up ideas they may have missed. If you repeat key ideas in the transition, you can compensate for lapses in the audience's attention. You might also want to call attention to the transitions by using gestures, changing your tone of voice, or introducing a visual aid.

Holding the Audience's Attention

Throughout a speech or presentation, you must continue trying to maintain the audience's interest. Here are a few helpful tips for creating memorable speeches:

- Relate your subject to the audience's needs. People are most interested in things that affect them personally. Present every point in light of the audience's needs and values.
- Use clear, vivid language. People become bored very quickly when they don't understand the speaker. If your presentation involves abstract ideas, try to show how those abstractions connect with everyday life. Use familiar words, short sentences, and concrete examples.
- Explain the relationship between your subject and familiar ideas. By showing how your subject relates to ideas the audience already understands, you give people a way to categorize and remember your points.

You can also maintain the audience's interest by introducing variety into your speech or presentation. One especially useful technique is to pause occasionally for questions or comments from the audience. Not only do you get a chance to determine whether the audience understands key points before launching into another section, but the audience also gets a chance to switch for a time from listening to participating. Visual aids are another source of both clarification and stimulation. Variety in your tone of voice and gestures helps too.

The Final Summary

When you have finished covering the main points, you may be tempted to wrap things up quickly. Avoid temptation. The ending of a speech or presentation is almost as important as the beginning, because audience attention peaks at this point. Plan to devote about 10 percent of the total time to the ending.

Begin your conclusion by telling listeners that you are about to finish so they will make one final effort to listen intently. Don't be afraid to sound obvious. Say something like "In conclusion" or "To sum it all up". You want people to know that this is the home stretch.

Restating the Main Points

Once you have everyone's attention, repeat your main idea. Be sure to emphasize what you want the audience to do or think. Then state the key motivating factor.

Reinforce your theme by repeating the three or four main supporting points. A few sentences are generally enough to refresh people's memories.

Outlining the Next Steps

Some speeches and presentations require the audience to reach a decision or agree to take specific action. In those cases, the final summary must provide a clear wrap-up.

If the audience has reached agreement on an issue handled in the speech or presentation, review the consensus in a sentence or two. If not,make the lack of consensus clear by saying something like "We seem to have some fundamental disagreement on this question". You can go on to suggest a method of resolving the differences.

If you expect any action to occur, you must explain who is responsible for doing what. One very effective technique is to list the action items, with an estimated completion date and the name of the person responsible. This list should be presented in a visual aid that can be seen by the entire audience. Each person on the list should be asked to agree to accomplish his or her assigned task by the target date. This public commitment to action is the best insurance that something will happen.

If the required action is likely to be difficult, make sure everyone understands the problems involved. You don't want people to leave the presentation thinking "This will be easy as pie", only to discover later that the job is a major undertaking. If that happens, they are likely to become discouraged and fail to complete their assignments. You want everyone to have a realistic attitude and be prepared to handle whatever arises. So use the final summary to point up pitfalls; alert people to potential difficulties.

Ending on a Positive Note

Your final remarks should be enthusiastic and memorable. Even if parts of your speech or presentation have been downbeat, you should try to close on a positive note. For example, you might point out the benefits of action or express confidence in listeners' ability to accomplish the work ahead. An alternative is to end with a question or with a statement that will leave your audience thinking.

Remember that your final words should round out the presentation. You want to leave the audience with a satisfied feeling, a feeling of completeness. The final summary is not the place to introduce new ideas or to alter the mood of the presentation. Although you want to close on a positive note, avoid a staged finale. Keep it natural.

The Question-and-Answer Period

In addition to having an introduction, a body, and a final summary, your speech or presentation should include an opportunity for questions and answers. Otherwise, you might just as well write a report. If you don't plan to interact with the audience, you waste the chief advantage of an oral format.

Although you should generally interact with the audience, think carefully about the nature and timing of that interaction. Responding to questions and comments during the presentation interrupts the flow of your argument and reduces your control of the situation. If you are addressing a large group, particularly a hostile or unknown group, questions can be dangerous. Your best bet in this case is to ask people to hold their questions until after you have concluded your remarks. But if you are working with a small group and need to draw out ideas, you should encourage comments from the audience throughout the presentation.

Regardless of when you respond to questions, remember that they are one of the most important parts of your presentation. Questions give you a chance to obtain important information, to emphasize your main idea and supporting points, and to build enthusiasm for your point of view.

APPENDIX 4

Instructions to the Provided-Synthesizer Group and the Provided-Synthesizers

Instructions to the Provided-Synthesizer Group

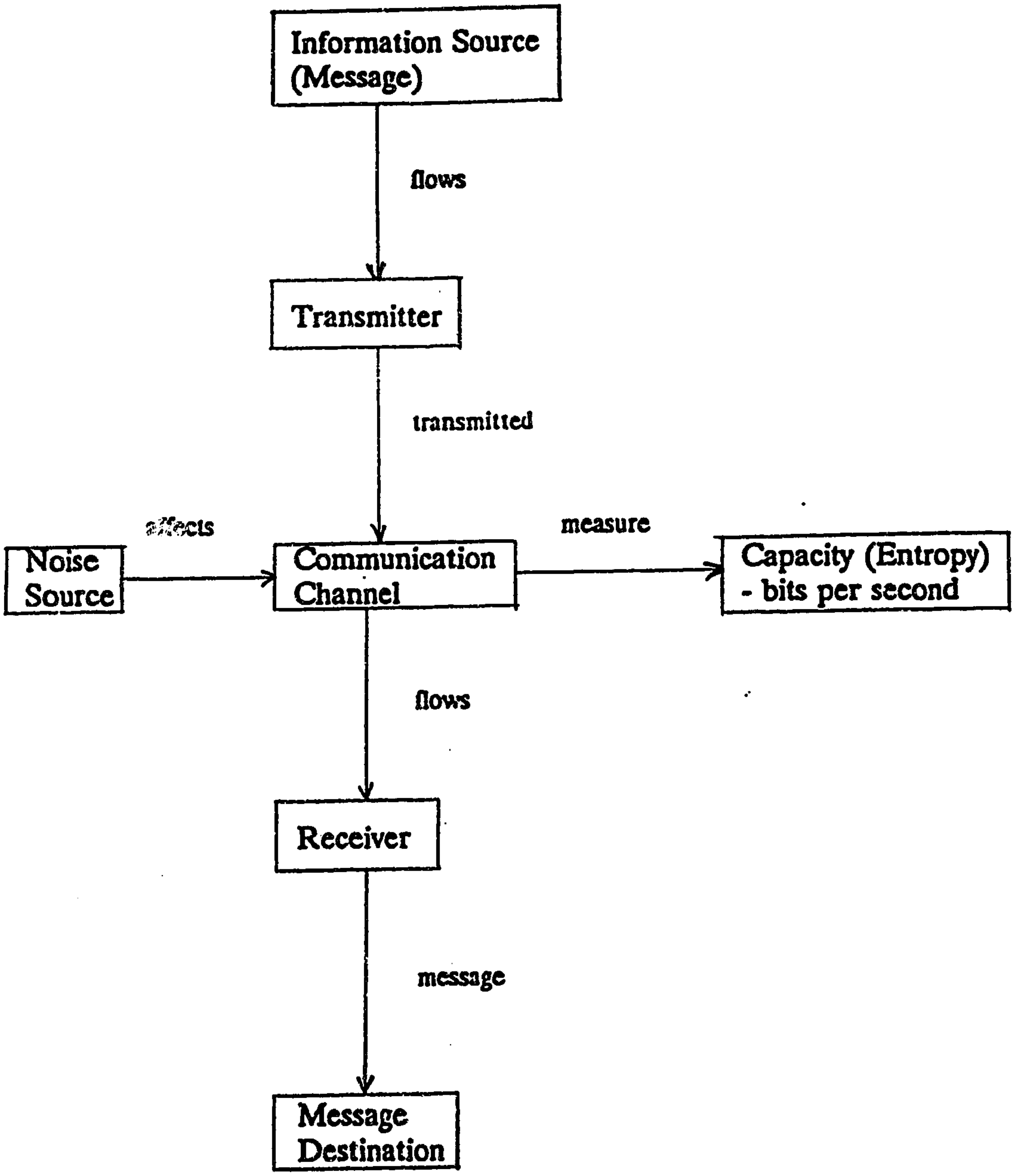
Instructions

You will be given a test to determine how much you have learned from the passage. Please study the following synthesizer which shows the structure of the passage you have just read. The synthesizer will help you review the materials. You have 15 minutes to study the synthesizer.

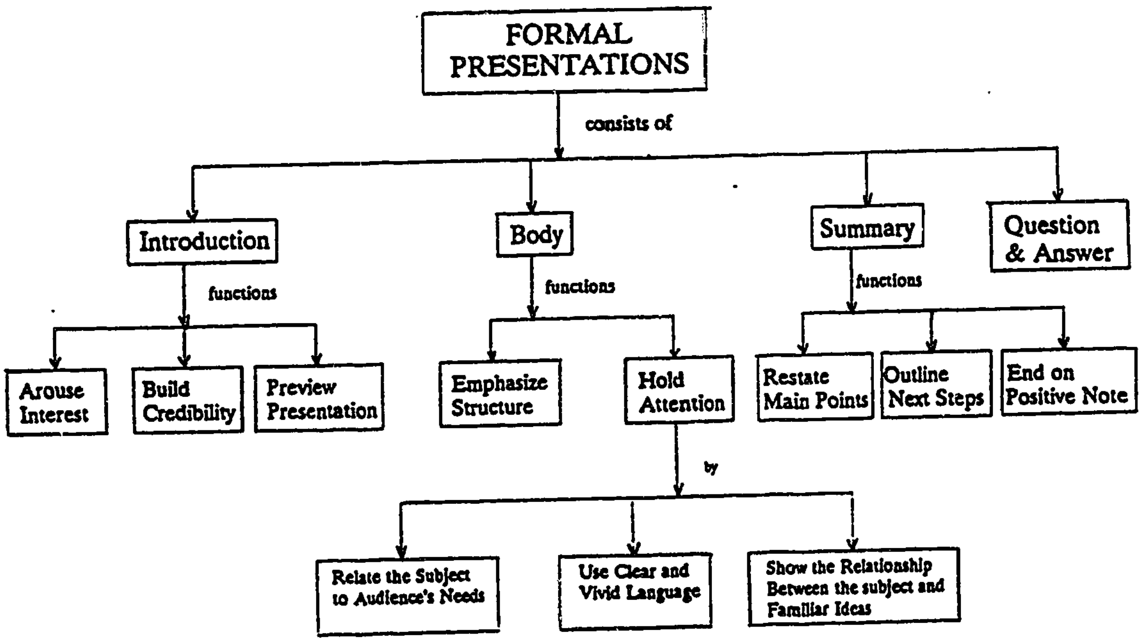
Procedure for Studying the Synthesizer

1. Start reading the synthesizer from top to bottom.
2. If there is a line connecting more than one box, place the relationship in the form of a sentence and read the sentence quietly.
3. Repeat the above step (2) for all of the relationships in the synthesizer.
4. For each box, try to recall the information from the passage that is related to that box.
5. If you cannot recall the details for a box, go back to the passage and look for the details.
6. Take a final look at the synthesizer to get an overall picture of the content.

Provided-Synthesizers



Synthesizer for the Unrelated Course Passage (Shannon's Theory)



Synthesizer for the Related Course Passage (Formal Presentation)

APPENDIX 5

Instructions to the Generated Synthesizer Group

Instructions

You will be given a test to determine how much you have learned from the passage. Please use the following procedure to generate a synthesizer to show the structure of the passage you have just read. Use the blank pages provided to generate the synthesizer. The synthesizer generation is a good strategy to help you review the materials in the passage.

You have fifteen minutes to generate and study the synthesizer.

Start with a blank piece of paper.

1. Write the title of the passage at the top of the page.
2. Visualize and write the major sections or topics in the passage.
    a. This is usually obtained from headings and topic sentences.
    b. Use one word or a short phrase to describe each section.
    c. Refer back to the passage if needed.
3. Visualize the structure of the passage.
4. On another piece of paper, place the concept/idea in an order that reflects the structure of the passage. Use the title of the passage as the highest level.
5. Visualize the relationship between two concepts/ideas.
6. Draw a line between the two concepts/ideas that are related.
7. Label the line with a word or short phrase to describe the relationship between the two concepts/ideas.

8. Visualize the relationship between all of the concepts/ideas.

9. Draw lines to connect all concepts/ideas that are related.

10. Label each line with a word or short phrase to describe the relationship.

11. Visualize the structure of the passage and check to determine that the synthesizer reflects the structure of the passage.

12. Study the synthesizer using the following procedure.

    a. Start reading the synthesizer from top to bottom.

    b. If there is a line connecting more than one box, place the relationship in the form of a sentence and read the sentence quietly in your mind.

    c. Repeat the above step (b) for all of the relationships in the synthesizer.

    d. For each box, try to recall the information from the passage that is related to that box.

    e. If you cannot recall the details for a box, go back to the passage and look for the details.

    f. Take a final look at the synthesizer to get an overall picture of the content.

APPENDIX 6

Instructions to the No-Synthesizer Group

Instructions

Please wait for further instructions.

APPENDIX 7

Tests for the Reading Passages

Unrelated Passage (Shannon's Passage) Cued Recall and Comprehension Tests

Unrelated Course Passage Tests

Please answer the following questions to determine how much you have learned from the passage. The test consists of 10 questions. You have 5 minutes to complete the test. Write the answer below each question.

Cued Recall Test

1. List the major parts of Shannon's Communication system.
2. What unit is used to measure the capacity of the communication channel?
3. What term is used to describe the capacity of a communication channel?
4. Which of the following two pieces of information needs more capacity for transmission?
   a. speech
   b. pictures

Comprehension Test

5. Which two parts of Shannon's system are humans?
6. What will happen to the information if there is an intermittent connection in the system?
7. What is the effect of having noise in the communication system?
8. If the signal-to-noise ratio is increased, would the noise have less or more effect on the operation of the communication system?
9. What will happen if the fidelity criterion is not met?

10. According to Shannon's theorem, what is a requirement for transmitting over a channel so that there is a small probability of error?

Related Passage (Formal Presentation) Cued Recall and Comprehension Tests

Formal Presentation Tests

Please answer the following questions to determine how much you have learned from the passage. The test consists of 25 questions. You have 15 minutes to complete the test. Write the answer below each question.

Cued Recall Test

1. What are the four elements of a formal presentation?
2. What are three major parts of the introduction for a presentation?
3. What are three approaches you could use in your introduction to arouse interest in an uninterested audience?
4. According to communications research, what factor determines the acceptance of a message?
5. What are two reasons why you should preview your presentation?
6. What are the two major functions of the body of the presentation?
7. How would you link sentences and paragraphs in your presentation?
8. What are three main tips for holding the audience's attention?
9. What are three major functions of the summary of a presentation?
10. How would you reinforce the theme of the presentation in the summary?
11. What are three methods for summarizing a presentation on a positive note?
12. Why would you ask your audience to hold questions until the question and answer period?

13. What is one instance in which you will need to outline the next steps after a presentation?

14. What is the major purpose of the question and answer period?

15. Name one situation where you will prefer to do a formal presentation instead of using a written report?

16. How can you tell whether you have done a good job in your introduction?

17. One of your colleagues is planning to make a presentation to some executives in her company. What is some advice you will give her with regards to arousing interest in the audience?

18. Give one reason why an introduction to a presentation could lose the audience's confidence in the speaker?

19. What part of a formal written report is the equivalent of the preview of a presentation?

20. What are the two benefits for having a well organized body for a presentation?

21. If your presentation has a major shift in topic, how would you make the transition?

22. Audience attention tends to peak after covering the body of a presentation. What would you say to get the audience to listen to the summary for the presentation?

in the summary?

24. After giving a presentation on a serious topic, you found that the audience cannot agree on what action to take. How would you handle this situation?

25. During your summary, you realized that you should have covered an additional point in your presentation. What would you do in this situation?

APPENDIX 8

Attitude Questionnaires

Unrelated Passage (Shannon) Questionnaire

Shannon Passage Attitude Questionnaire

Please respond to the following statements to indicate your feelings toward the material and process for this study.

1. Did you use the synthesizer to help you summarize the materials?

   Yes ____ No ____

2. How helpful was the synthesizer to learn the materials?

   5 4 3 2 1

   Very Helpful Not Helpful

3. How familiar were you with the information in the passage? (Did you know it before?)

   5 4 3 2 1

   Very Familiar Not Familiar

4. How difficult was it to use the synthesizer to summarize the information?

   5 4 3 2 1

   Not Difficult Very Difficult

5. Did you ever use the synthesizer outlined in this study in your previous studies?

   Yes ____ No ____

6. Would you use synthesizers in the future when you read other passages?

   Yes ____ No ____

7. How easy was the passage to read?

5 4 3 2 1

Easy Difficult

8. Overall, rate your satisfaction with the synthesizer as a learning tool.

5 4 3 2 1

Very Satisfied Not Satisfied

9. How helpful was the synthesizer to answer the questions on the tests?

5 4 3 2 1

Very Helpful Not Helpful

Related Passage (Formal Presentation) Questionnaire

Formal Presentation Passage Attitude Questionnaire

Please respond to the following statements to indicate your feelings toward the material and process for this study.

1. Did you use the synthesizer to help you summarize the materials?

   Yes ____ No ____

2. How helpful was the synthesizer to learn the materials?

   5 4 3 2 1

   Very Helpful ... Not Helpful

3. How important was the reading passage to your course?

   5 4 3 2 1

   Very Important ... Not Important

4. How familiar were you with the information in the passage? (Did you know it before?)

   5 4 3 2 1

   Very Familiar ... Not Familiar

5. How difficult was it to use the synthesizer to summarize the information?

   5 4 3 2 1

   Not Difficult ... Very Difficult

6. Did you ever use the synthesizer outlined in this study in your previous studies?

   Yes ____ No ____

7. Would you use synthesizers in the future when you read other passages?

Yes ____ No ____

8. How easy was the passage to read?

5	4	3	2	1
Easy				Difficult

9. Overall, rate your satisfaction with the synthesizer as a learning tool.

5	4	3	2	1
Very Satisfied				Not Satisfied

10. How helpful was the synthesizer to answer the questions on the tests?

5	4	3	2	1
Very Helpful				Not Helpful

11. Did you read Chapter 18 in the textbook for this course?

Yes ____ No ____

12. Did you take the training on how to construct the synthesizer?

Yes ____ No ____