



# Effects of matching multiple memory strategies with computer-assisted instruction on students' statistics learning achievement

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In the era when digitalization is pursued, numbers are the major medium of information performance and statistics is the primary instrument to interpret and analyze numerical information. For this reason, the cultivation of fundamental statistical literacy should be a key in the learning area of mathematics at the stage of compulsory education. The emphasis on the expression and communication of charts, the understanding of preliminary concepts of sampling and probability, and the accurate application of statistical data to real life should be the blueprint of the thematic instruction. To effectively achieve the research objectives and test the research hypotheses, the nonequivalent pretest posttest control group design model is utilized for the experimental research. Total 208 students in Nanjing Auditing University are sampled for the 15-week experimental instruction, 3hr per week for total 45 hours. The research results are summarized as below. 1. Multiple memory strategies reveal significant effects on learning outcomes. 2. Multiple memory strategies appear remarkable effects on learning gains. 3. Computer-assisted instruction presents notable effects on learning outcomes. 4. Computer-assisted instruction shows significant effects on learning gains. 5. Matching multiple memory strategies with computer-assisted instruction could remarkably promote learning outcomes. 6. Matching multiple memory strategies with computer-assisted instruction could notably enhance learning gains. According to the analyses, suggestions are proposed to help the statistics instruction in mathematics and promote students' statistics learning achievement.

*Keywords:* multiple memory strategies, computer-assisted instruction, statistics, learning achievement, learning gains

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## INTRODUCTION

In modern multiple societies, a lot of tasks are related to statistics, including politics, economics, biology, industry and commerce, agriculture and forest, education, insurance, medicine, meteorology, and justice. Statistics therefore is regarded as the practical mathematics in daily life. Statistics, covering data collection, data arrangement, data analysis, and interpretation of statistical results, could help people master the meaning and connotation of enormous numbers to make correct interpretation. Statistical data are everywhere on daily journalism, e.g. opinion poll for election, survey of television ratings, and development and test of epidemic diseases. The idea of statistics presents the importance with the advancing society. People have to be able to read and interpret the complicated and sometimes inconsistent message in life; and, to become a knowledgeable person, the knowledge related to probability and statistics should be comprehended. Accordingly, a modern citizen should be able to read, interpret, evaluate, and analyze the statistical information in journalism in order to acquire accurate message and knowledge.

In the new era with technology progress, people often face diversified information. In this case, acquiring meaningful information for interpretation and analyses to become useful assets is a primary ability in the time to pursue knowledge economy. The ability to apply statistical knowledge could be enhanced with the habits of inspecting surrounding matters from the viewpoint of statistics and cultivating to observe the statistics meaning, characteristics, and relationship among problems and represent problems with statistical problems for solutions. Cultivating students' use of memory strategies allows the message in the short-term memory smoothly getting into the long-term memory in order not to be replaced by the successive message. Moreover, it could enhance or reinforce the extraction of clues in the long-term memory so that the message could be properly kept and the extraction failure could be reduced. The learning and memory process requires three phases of message processing model, short-term memory, and long-term memory. Good remembers would automatically or actively apply proper memory strategies to have the message get into the memory system or be deeply processed in order to assist students in experiencing the link between everyday life and statistics and deepen students' comprehension of statistical concepts when developing problem-solving strategies. In this case, guiding learners to use multiple memory strategies allows the newly learnt

### **State of the literature**

- Good remembers would automatically or actively apply proper memory strategies to have the message get into the memory system or be deeply processed in order to assist students in experiencing the link between everyday life and statistics and deepen students' comprehension of statistical concepts when developing problem-solving strategies.
- This study aims to investigate the effects of matching multiple memory strategies with computer-assisted instruction on students' statistics learning achievement.
- Computer-assisted instruction did not completely replace all instructional activities, but, with the advantage of computer technology, presented multimedia technology with text, sound, and images, compensated the loss in traditional instruction, offer diversified learning experiences and assist teachers in enhancing the teaching quality, and immediately provide students with feedbacks

### **Contribution of this paper to the literature**

- Teachers should prompt students memorizing multiple memory strategies for such knowledge and have students understand the relationship between multiple memory strategies and statistics learning as well as the effectiveness and meaning of strategies so as to achieve the actual effects
- Teachers could make computer-assisted instruction by matching the curriculum contents of the learning area of statistics with multiple memory strategies for students learning at home. It could be students' rehearsal materials or individual computer-assisted instruction at free time.
- Computer-assisted instruction could be used as the remedial instruction offering interesting, individual, and self-controllable learning environments for students who could not follow the schedule or appear worse learning achievement.

knowledge getting into the long-term memory and forming the memory network with other existing items to help reinforce students' ability of applying statistical knowledge and concepts to daily life. This study therefore aims to investigate the effects of matching multiple memory strategies with computer-assisted instruction on students' statistics learning achievement.

## **LITERATURE REVIEW**

### **Multiple memory strategies**

Memory is an important function of human brain as well as the foundation of all learning and creation (Madan & Spetch, 2012). However, mechanical repeated memory could not enhance the learning power; contrarily, well utilizing memory strategies could enhance the learning power and reduce time (Semrud-Clikeman et al., 2010). For this reason, guiding learners to use memory strategies to have the newly learnt knowledge get into the long-term memory and form the memory network with other existing items could help promote the learning outcomes. Castel et al. (2011) proposed three functions of memory strategies, including 1. offering organizational structure to assist in learning and acquire message, 2. systematically storing learning materials into the memory structure to help remain learning materials in the memory without being forgotten, and 3. providing clues to assist in message extraction (Hsu et al., 2013).

Roderer et al. (2012) pointed out multiple memory strategies as a practical magic to have memory become accurate and rapid after the application. Sonuga-Barke & Fairchild (2012) defined multiple memory strategies as the involved behaviors and thinking in the encoding process when learners engaging in learning. Hsu et al. (2015) considered that people would look for human contact with the materials to enhance the memory effects when the memorizing materials were meaningless or remembers did not comprehend the meaning of materials. Madan & Spetch (2012) regarded multiple memory strategies as the technique to reinforce memory with certain special methods (Karamustafaoglu, & Mamlok-Naaman, 2015). There were several skills and methods for memory strategies, and multiple memory strategies were referred to offer several memory strategies for students' selection and application. Castel et al. (2011) classified rehearsal strategies, organizational strategies, and elaboration strategies. Storm & White (2010) concluded the remedial strategies for enhancing the memory of people with mental retardation, containing rehearsal, material organization, imagery, attention reinforcement, and control of forgetting. Hsu et al. (2015) proposed the training of multiple memory strategies for students, including labeling and item repetition, grouping of stimuli, cuing, cumulative rehearsal, imagery, and verbal elaboration. In sum, the following strategies are organized for enhancing memory.

- (1) Repeating message for several times: Repetition is the commonest memory strategy. The saying, "strangers at the first meeting and friends at the second", is the effect of repetition. Constantly repeating message could remain the message in the short-term memory and turn it into the long-term memory.
- (2) Systematically organizing learning materials: Memorizing ten data with rich contents and more correlations is easier than memorizing ten trivial matters with poor contents.
- (3) Making meaningful connection of message: Such a method is called elaboration. Adding some beneficial message into the learning

process could meaningfully connect newly learnt contents with existing knowledge so as to enhance the memory.

(4) Assisting in memory with imagery: Imagery refers to the psychological representation of matters, without actual presentation, but forming the memory materials to an image in the brain (Semrud-Clikeman et al., 2010).

(5) Practicing the extraction process: In addition to effective storage, memory could be effectively extracted and applied; the practicing method could be utilized for enhancing individual ability to extract memory.

## Computer-assisted instruction

Computers could present diversified information, interact with students, provide feedback for students, and even do instructional management. As a result, computers are considered as a highly valuable teaching medium (Bahadorfar, 2013). A lot of research proved the effectiveness of computer-assisted instruction enhancing students' learning achievement. Computer-assisted instruction was a practical teaching method as it could enhance students' learning achievement and promote students' learning interests and attitudes. Besides, computer-assisted instruction could reduce students' learning time (Alcoholado et al., 2012).

Computer-assisted instruction (CAI) refers to using computers as a teaching tool to assist teachers' instruction and students' learning in the instruction process (Koizumi, 2013), where teachers' instruction is emphasized. Giulio et al. (2011) explained computer-assisted instruction (CAI) as an interactive teaching method utilizing computers for directly helping learners' learning as well as providing curriculum contents with computers and using drills and practice, tutorials, and simulation in order to achieve the instructional objectives. Nonetheless, "computer" in computer-assisted instruction was a general meaning of instructional activities using computers as the control machine. In this case, multimedia-assisted instruction and intelligent tutoring system (ITS) were covered in computer-assisted instruction. AbuSeileek & Abu Sa'aleek (2012) proposed a similar term, multimedia computer-assisted instruction, which was called multimedia in short in education. It generally indicated the combination of computer-assisted instruction and multimedia technology to achieve more effective instruction and learning outcomes. Multimedia was the integration of several media in a computer-assisted instruction program, commonly including text, graphics, audio, and video. Bahrani (2011) pointed out "computer-assisted instruction" as an interactive teaching method with computer systems directly assisting in students' learning, utilizing the characteristics of computer systems for instructional situations, presenting curriculum contents, controlling instructional progress according to students' levels, and proceeding instruction with tutorial, drills and practice, tutorials, problem solving, games, and simulation to achieve the instructional goal.

## Learning achievement

Learning refers to the process of individual behaviors generating permanent changes after certain practice or experiences (Baz & Tekdal, 2014). Huang et al. (2010) regarded it as students' overall performance on learning achievement and learning attitudes after instructional activities. Learning achievement generally indicated various evaluations of learners after completing certain learning activities and the achievement of anticipated effect (Laufer, 2013). Lan (2013) indicated it as students' affirmation of personal learning abilities in the teachers' instruction process. Learning achievement is an indicator to measure instructors' outcomes and

teaching quality as well as learners' learning outcomes. Learning achievement would be affected by teaching strategies, curriculum design, and curriculum contents. Ahmed & Khurshid (2012) regarded it as an indicator to evaluate students' learning outcomes and the major items to evaluate teaching quality. Learning achievement would be influenced by curriculum design, teaching methods, and learning behaviors, and students' learning objectives were to monitor self-learning, review the learnt knowledge, and learn how to learn; learning achievement therefore was the most direct presentation of learning outcomes. In other words, it could be learners' changes in knowledge, skills, behaviors, and attitudes after the end of instruction (Weng et al., 2013). Purrazzella & Mechling (2013) considered that learning achievement was the cognition of acquired knowledge, skills, and reasoning abilities, after practicing and learning for a period of time, to change the behaviors or behavior models, apply and solve problems, enhance working abilities, and improve life. Nevertheless, learning achievement would be affected by learners' personal factors, teaching quality, learning styles, curriculum design, and learning environments (Chiu, 2013). Referring to Chiu (2013), learning achievement should cover the following dimensions.

(1) Learning outcomes, including test results, completion of schedule, and term results.

(2) Learning gains, containing learning satisfaction, achievement, and preference.

## **METHODOLOGY**

### **Research hypothesis**

Roderer et al. (2012) indicated that selecting memory strategies suitable for learners could achieve the learning outcomes and reduce time. Sonuga-Barke & Fairchild (2012) revealed that students' use of memory strategies was significantly correlated with the performance of learning achievement. Madan & Spetch (2012) indicated that students regarded the memory strategy of teachers' demonstration as the most effective learning. Storm & White (2010) studied computer-assisted instruction with computer multimedia and multiple memory strategies and found out the immediacy, maintenance, and generalization effects on participants' skills.

Asdam (2015) mentioned that computer-assisted instruction did not completely replace all instructional activities, but, with the advantage of computer technology, presented multimedia technology with text, sound, and images, compensated the loss in traditional instruction, offer diversified learning experiences and assist teachers in enhancing the teaching quality, and immediately provide students with feedbacks (Douglas et al., 2011). Larsen-Freeman & Marti (2011) indicated that learners could achieve the learning goal by directly interacting with computers. For instance, English listening required frequent practice to be skilled and learners could increase the practice by the diversified question design with computers. Computers were a learning channel for learners' self-learning. Learners could personally arrange learning time and location, control the learning process, and promptly acquire feedbacks and guidance from computers for any learning questions. For example, learners making mistakes in online test systems could immediately know the mistake. Furthermore, teachers could present abstract concepts, which students could not easily comprehend, with pictures or sound through the assistance of computers. For instance, animation could be utilized for explaining the factors and phenomenon of tsunamis. Finally, teachers could mater learners' learning situations through computers (Lazaros, 2012). The following hypotheses are therefore proposed in this study.

- H1: Multiple memory strategies present significant effects on learning outcomes.
- H2: Multiple memory strategies reveal remarkable effects on learning gains.
- H3: Computer-assisted instruction shows notable effects on learning outcomes.
- H4: Computer-assisted instruction appears significant effects on learning gains.
- H5: Multiple memory strategies matching with computer-assisted instruction could remarkably enhance learning outcomes.
- H6: Multiple memory strategies matching with computer-assisted instruction could notably promote learning gains.

### Research subject and research design

To effectively achieve the research objective and test the research hypotheses, the nonequivalent pretest posttest control group design model is applied to this experimental research. Total 208 students of Nanjing Audit University are sampled for the multiple memory strategy integrated computer-assisted instruction 2×2 experiment. The experiment is divided into computer-assisted instruction (computer-assisted instruction; traditional general instruction) × multiple memory strategies (multiple memory strategies; traditional general instruction) for the 15-week instruction, with three hours per week (total 45 hours).

### Analysis method

Analysis of Variance is applied to discuss the effects of multiple memory strategies on statistics learning achievement and further understand the effects of matching multiple memory strategies with computer-assisted instruction on statistics learning achievement.

## EMPIRICAL DATA AND ANALYSIS

### Variance analysis of multiple memory strategies and statistics learning achievement

Applying Analysis of Variance to discuss the effects of multiple memory strategies on learning outcomes and learning gains, Table 1, multiple memory strategies and traditional general instruction appear remarkable differences on learning outcomes, and multiple memory strategies show higher learning outcomes than traditional general instruction does that H1 is supported. Furthermore, multiple memory strategies and traditional general instruction present notable differences on learning gains, and multiple memory strategies reveal higher learning gains than traditional general instruction does that H2 is supported.

**Table 1.** Variance analysis of multiple memory strategies

Variable		F	P	Scheffe post hoc
Multiple memory strategies	Learning outcomes	8.463	0.000**	multiple memory strategies>traditional general instruction
	Learning gains	7.539	0.000**	multiple memory strategies>traditional general instruction

\* stands for  $p < 0.05$ , \*\* for  $p < 0.01$

**Table 2.** Variance analysis of multiple memory strategies

Variable		F	P	Scheffe post hoc
Computer-assisted instruction	Learning outcomes	15.374	0.000**	computer-assisted instruction>traditional general instruction
	Learning gains	17.921	0.008**	computer-assisted instruction>traditional general instruction

\* stands for  $p < 0.05$ , \*\* for  $p < 0.01$

**Variance analysis of computer-assisted instruction and statistics learning achievement**

Applying Analysis of Variance to discuss the effect of computer-assisted instruction on learning outcomes and learning gains, Table 2, computer-assisted instruction and traditional general instruction show significant differences on learning outcomes, and computer-assisted instruction appears higher learning outcomes than traditional general instruction does that H3 is supported. Moreover, computer-assisted instruction and traditional general instruction present remarkable differences on learning gains, and computer-assisted instruction reveals higher learning gains than traditional general instruction does that H4 is supported.

**RESULTS AND DISCUSSION**

**Effect analysis of integrating computer-assisted instruction into multiple memory strategies**

Analysis of Variance is utilized for investigating the effect of multiple memory strategy integrated computer-assisted instruction on statistics learning achievement and the interaction of computer-assisted instruction and multiple memory strategies to test the promotion effect of computer-assisted instruction. From the interaction in Table 3, multiple memory strategies appear the highest integration on learning outcomes and the highest interaction on learning gains in the computer-assisted instruction, Figure 1. The margin mean in Figure 2 shows remarkable interaction that H3 and H4 are supported.

**Table 3.** Variance analysis of multiple memory strategies and statistics learning achievement

Variable	Learning outcomes			Learning gains		
	F	P	Scheffe post hoc	F	P	Scheffe post hoc
Multiple memory strategies	8.463	0.000**	multiple memory strategies>traditional general instruction	7.539	0.000**	multiple memory strategies>traditional general instruction
Computer-assisted instruction	15.374	0.000**	computer-assisted instruction>traditional general instruction	17.921	0.008**	computer-assisted instruction>traditional general instruction
Multiple memory strategies*computer-assisted instruction	27.195	0.000**	11>21>22>12	31.426	0.000**	21>11>12>22

**CONCLUSIONS**

This study intends to discuss the effect of multiple memory strategies on students' statistics learning achievement. The results reveal that good remembers would automatically or actively apply effective memory strategies to have the message get into the memory system for deeper processing ( Craik & Lockhart, 1972). The results also show that the instruction with multiple memory strategies could help students apply strategies to enhance the memory. In this case, teachers should timely guide the memory strategies of students, who would like to enhance the knowledge memory abilities, and provide them with practice opportunities. For the best learning outcomes, students have to learn the use of multiple memory strategies as well as understand the relationship between multiple memory strategies and learning as well as the effectiveness and meaning of strategies so as to achieve the actual effects.

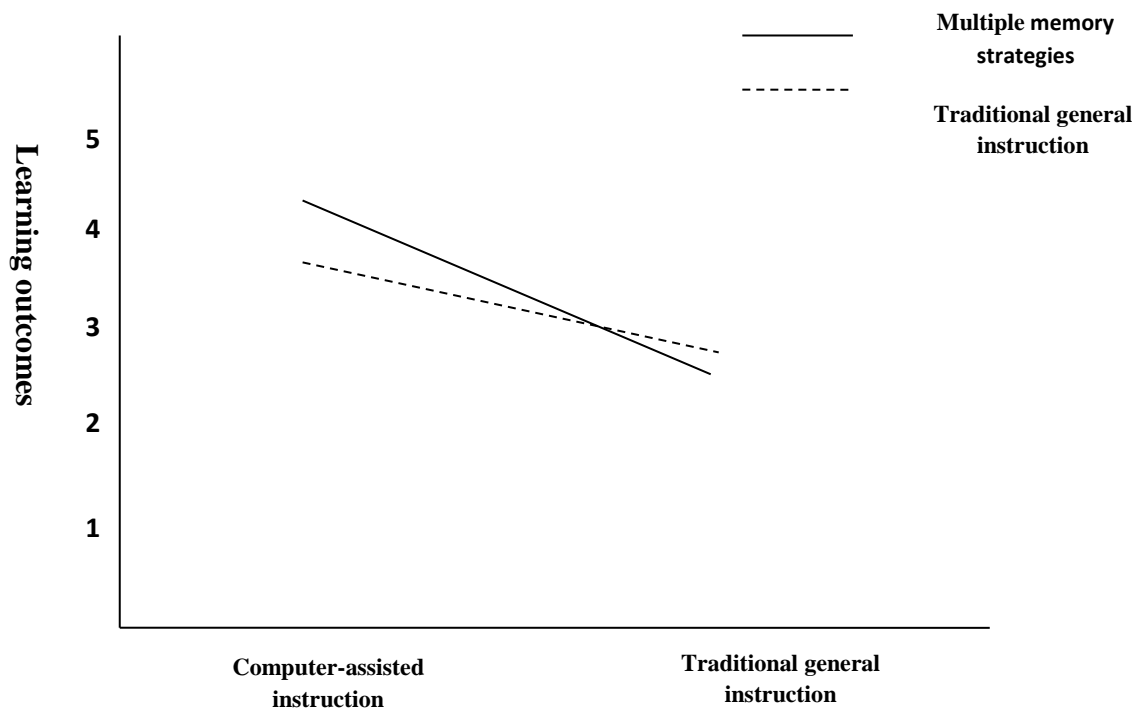


Figure 1: Margin mean

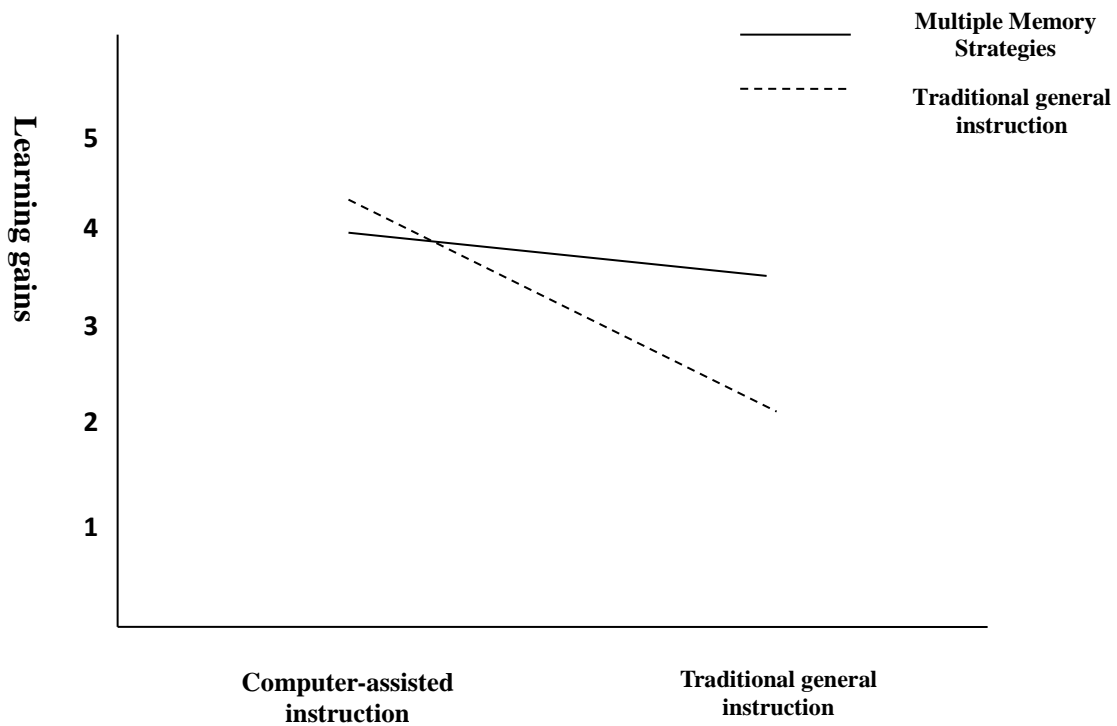


Figure 2: Margin mean



For the long-term and generalization effects, the comprehensive guidance of strategy objectives (why), strategy contents (what), use opportunities (when), and use situations (where) should be paid attention to in the guiding process of multiple memory strategies, and the students are led to do active mental construction of multiple memory strategies. In other words, the motivation, in addition to the guidance of multiple memory strategies, should be concerned. According to the research conclusion, the following suggestions are proposed in this study.

1. In addition to arranging active and vivid learning methods, teachers should prompt students memorizing multiple memory strategies for such knowledge and have students understand the relationship between multiple memory strategies and statistics learning as well as the effectiveness and meaning of strategies so as to achieve the actual effects. It is discovered in this study that the participants are interested in the contents and pictures in computer-assisted instruction, and most students concentrate on the computer screens for learning and present great interests in the game-based practice. It is suggested that teachers could design computer-assisted instruction with audio and video effects matching with game-based memory strategies in the computer-assisted instruction to attract students' attention and induce the motivation.

2. Teachers could make computer-assisted instruction by matching the curriculum contents of the learning area of statistics with multiple memory strategies for students learning at home. It could be students' rehearsal materials or individual computer-assisted instruction at free time.

3. Computer-assisted instruction could be used as the remedial instruction offering interesting, individual, and self-controllable learning environments for students who could not follow the schedule or appear worse learning achievement. Most of students' learning problems are strategic deficits that the statistics learning outcomes could be largely enhanced by strategic instruction or training. Consequently, teachers making multiple memory strategy integrated computer-assisted instruction not only provide strategy guidance and training for students with low abilities, but also offer them with individual and unlimited learning opportunities to immediately help the statistics learning achievement.

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