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Recall and application skill enhancement in Genetics with working memory through segmented multimedia instruction at higher secondary level

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Abstract: *This study attempts to explore the mediating effects of working memory capacity and the segmentation principle of multimedia instruction in the Genetics of Higher Secondary students. The sample of the research consisted of 250 higher secondary students who opted for Biology. Based on the scores of the OSPAN Task, students were assigned to low (n=42), average (n=120) and, high (n=88) working memory capacity. Students from each category were randomly assigned to control and experimental groups. The experimental group received a segmented version of multimedia instruction and the control group received a non-segmented version of multimedia instruction in Genetics. To test the hypotheses, the statistical techniques such as ANOVA, factorial design (2 × 3), Cohen's d, contrast analysis in between-subject designs, simple effects contrasts were applied based on the scores of Recall and Application Test. The findings of the study showed a significant and positive effect for working memory capacity and Segmenting principle of multimedia instruction on the score of Recall Test as well as Application Test.*

Key Words: *working memory capacity, multimedia, segmentation principle, recall, application.*

1. INTRODUCTION:

Learning and memory are very closely related. Without memory, learning would not be sustainable. Learners must accomplish all the processing necessary for learning within the capacity limits of working memory. Learning of various concepts are enormously cognitive processes, as students always try to understand some inherently complex concepts, terminologies, and processes. For learning new concepts and content in any subject, the new information must be held temporarily, processed, and then saved in memory for later. Each of these three steps is most important for learning to occur. The first involves simple storage of information which is called short-term memory. The third step includes long-term memory, from which information can be retrieved hours, days, or years later for further mental reprocessing.

An understanding of working memory, and of a related concept called a cognitive load, is critical in designing and implementing the curriculum to provide students with the best opportunity to learn. One of the domains of multimedia learning is the higher-order cognitive tasks that have been studied extensively, resulting in the cognitive theory of multimedia learning and a series of design principles.

The efficacy of learning depends on both, instructional designers creating effective multimedia instructions, and individual learners actively participate in constructing understanding and transfer of knowledge. The present research study evaluates this interaction, specifically, the interaction between segmentation principle of multimedia instruction, and working memory capacity.

2. NEED AND SIGNIFICANCE OF THE STUDY:

Various studies indicated that the teaching of Genetics needs considerable review and strengthening. Because the abstract nature of Genetics is difficult to conceptualize, other teaching aids—photographs, film and video, time-lapse phase-contrast microscopy, models, etc.—could be introduced to explain the dynamic nature of the various processes, such as protein synthesis. The emphasis in teaching and learning Genetics should not be confined to covering the topics and having students memorize them by rote. Instead, Genetics teaching should aim to inculcate a conceptual understanding of the subject area and encourage thinking during learning activities. Only then will students be able to assimilate and accommodate the related information in real-life situations.

Therefore, multimedia instructions are more effective and beneficial to improve the ability to recall and the application of knowledge in Genetics compared to the traditional methods of learning. Prior research studies on multimedia instruction with segmentation principle, however, did not take into consideration the individual difference variables, particularly the working memory capacity that may influence the academic performance of the learner.

Keeping these points in view, the researcher felt the need to evaluate the mediating effects of working memory capacity with the segmentation of multimedia instruction in Genetics of Higher Secondary Students.
The application of segmented multimedia instruction (SI) in Genetics represents one of the ways to enhance the teaching effectiveness of this subject to streamline and improve the quality of the educational process. It would help the students with variable WMC to learn & clarify the difficult as well as higher-level concepts in Genetics with proper background, understanding & capability. This research study is an attempt to provide a meaningful & practical instructional strategy for learning and to enhance the ability of students with varying WMC to recall and to apply knowledge of various units in Genetics.

3. OPERATIONAL DEFINITION OF KEY TERMS:

❖ **Mediating effect**

For the present study, the mediating effect is an effect that acts as an intermediate influencing agent in learning various concepts of Genetics to enhance recall and application skill of Higher secondary students.

❖ **Segmentation Principle**

For the present study, the segmentation principle includes a multimedia tutorial based on small segments (modules) of various topics in Genetics that provide the user with pacing control, through the use of a start or stop button or continue button.

❖ **Multimedia Instruction**

For the present study, multimedia Instruction means it is an interactive instructional method that uses a computer to present various concepts of Genetics by using a combination of text, graphics, sound, animations, videos, and tutorials.

❖ **Working memory capacity**

Operationally working memory capacity is a vital ability for storing short-term information, words, and meanings required to carry out learning, reasoning, recalling, and application of knowledge in Genetics.

❖ **Genetics**

Genetics is a science which deals with the study of the transmission of characters from one generation to the next and differences among individuals.

❖ **Higher Secondary students**

For the present study, Higher Secondary students are the students of the first and second year who opt for science faculty with Biology of Higher Secondary program.

4. OBJECTIVES OF THE RESEARCH STUDY:

- To study the interaction effect of WMC and segmentation principle of multimedia instruction tutorials for recall of content.
- To study the interaction effect of WMC and segmentation principle of multimedia instruction tutorials for application of content.

HYPOTHESES:

H_{O1}: There is no significant difference between the treatment effects for students with high, average, and low WMC instructed Genetics using a segmented and a non-segmented version of multimedia instruction on the Recall Test scores.
H_{O2}: There is no significant difference between the performance of students with high, average, and low WMC instructed Genetics using a segmented and a non-segmented version of multimedia instruction on the Application-Test scores.
H_{O3}: There is no significant difference between the treatment effects for students with high, average, and low WMC instructed Genetics using a segmented and a non-segmented version of multimedia instruction on the Application-Test scores.

5. METHODOLOGY OF THE STUDY:

This quasi-experimental study was conducted by using “The Pre-Test-Post-Test Equivalent groups design”. Out of 300, 250 students were selected and assigned randomly to the experimental and control groups.

SAMPLE:

The sample comprised of a total number of 250 higher secondary students who opted for Biology. 176 students from KES Mehendale High school and Jr. College, Roha, and 74 students from Private High school and Jr. College, Pen were randomly selected and divided into control and experimental groups. Each group constituted 125 students.

TOOLS USED:

The data for the present study was collected from higher secondary students using following tools.

OSPAN TASK:

Operation Span Task Tutorial: - Based on **'Turner and Engle's (1989) [1]** operation span test, which was designed to measure the combined processing and storage capacity of working memory during the performance of simple mathematical computations. Operation span task (OSPAN), which involves remembering words (storage component) while solving arithmetic operations (processing component). To develop this tool, the researcher has prepared a blue-print that includes 3 sets. Two software engineers have prepared this OSPAN task application in Python version **3.7.2**. Three-span sub scores were calculated for each participant, corresponding to the first, second, and third presentations of the sets of each size. **The Cronbach's alpha coefficient** for these three measurements was **0.73** as an index of internal consistency. The **Test-Retest reliability** was also found out by **Pearson product moment correlation** (Pearson's r) =**0.97** and the content validity was found out as **0.874**. The control and experimental groups were subjected to the OSPAN Task and were assigned to the high WMC group if they score in the upper quartile, the low WMC group if they scored in the lower quartile and average WMC if they scored between upper and lower quartile of the total scores.

SEGMENTED VERSION OF MULTIMEDIA INSTRUCTION:
This study followed the steps of **"Interactive media design: from concept to reality"** module proposed by **Camillan Huang (2004) [2]** for the development of multimedia instruction package with segmenting principle for the five units of Genetics. i.e. Introduction of Genetics, Principles of Inheritance & variations, Gene: -its nature, expression & regulation, Chromosomal Basis of Inheritance; Genetic Engineering & Genomics. Whole content was divided into 5 modules. Wherever it is necessary the modules were further sub-divided in a simpler and understandable form. A pilot study was conducted with a small group of higher secondary students. The students were asked to provide feedback on content and other matters such as graphic design formats. Based on the suggestions and evaluations, various modifications were done in the package. After redesigning, the segmented version of multimedia instruction package was ready for implementation.

RECALL TEST (POST-TEST) AND **APPLICATION TEST (POST-POST-TEST):**
Both the multiple-choice tests were developed by the researcher. All the test items were based on the text of the five Units of Genetics taught to the sample students. As a result of the reviews by the domain experts and lecturers, it is stated that the content validity of the test has been provided, and is suitable for the purpose and level of higher secondary students. The coefficient of reliability was determined for the Post-Test and Post-Post-Test and it was found to be **+ 0.85** and **+ 0.83** respectively.

PROCEDURE:
The experimental group received a segmented version of multimedia instruction in the computer laboratory by the researcher and the control group received a non-segmented version of multimedia instruction in the computer laboratory by Biology teacher as usual, during the same period in the Jr. College time table. The experiment continued over a period of 8 weeks. The Recall Test was administered immediately after the treatment was over. Application Test was administered after 15 days of Recall-Test. Then the opinionnaire was administered to the students of the experimental group to elicit their opinion about the segmented version of Multimedia Instruction. Final data were collected from 250 students -125 from each group who remained almost regular throughout the experiment.

DATA ANALYSIS:
To test the hypotheses, the statistical techniques such as ANOVA, factorial design (**2 × 3**), Cohen's d, contrast analysis in between-subject designs, simple effects contrasts were applied based on the scores of Recall and Application Test.

6. RESULT AND INTERPRETATION:
This research intended to find out the mediating effects of high, average and, low WMC of students on content recall and application of knowledge as well as to evaluate the segmentation effect of multimedia instruction on content recall and application skills of the students with low, average and, high WMC. These two questions were analysed using the factorial design (**2 × 3**), Cohen's d, contrast analysis in between-subject designs, simple effects contrasts were applied based on the scores of Recall and Application Test.

TESTING OF HYPOTHESIS 1:
Table 1 shows the relevant statistics for it.
Table 1: - ANOVA (2 × 3) showing the difference between the treatment effects for the students with HWMC, AWMC, and LWMC of EG and CG on Recall Test scores.

***Significant at 0.05**

Source of variance	Df	Sum of squares	Mean square variance	F- value	F-Critical values
Sum square of 1st factor (Treatment)	1	22988.2	22988.2	514.04*	3.88
Sum square of 2nd factor (WMC)	2	12314.82	6157.41	137.69*	3.03
Sum of square of both factor	2	5919.36	2,959.68	66.18*	
Total square within	244	10910.64	44.72		
Sum of square of total	249	52133.02			

The null hypothesis no. $\mathbf{H_{01}}$ is **rejected** at **0.05** level.

INTERPRETATION: -

Table No. 1 indicates the following results: -

Main effect for segmentation**: F (1, 224) = 514.04, p < 0.05**
Main effect for Working Memory Capacity: **F (2, 224) = 137.69, p < 0.05**
Working Memory Capacity by segmentation interaction**: F (2, 244) = 66.18, p < 0.05**

There is a main effect for WMC and Segmenting principle of multimedia instruction on the score of the Recall Test. The interaction effect between WMC and treatment is statistically significant at the 0.05 level. Therefore, the null hypothesis, "There is no significant difference between the treatment effects for students with high, average, and low WMC instructed Genetics using a segmented and a non-segmented version of multimedia instruction on the Recall Test scores**"** is **rejected.** Hence, there is a significant difference between the treatment effects for students with high, average, and low WMC of the experimental and the control group on the Recall Test scores.

TESTING OF HYPOTHESIS 2:

Table 2 shows the relevant statistics for it.

Table 2: - Significance of difference between the mean scores of the students with **HWMC, AWMC** and, **LWMC** of experimental and control groups on Application Test.

Source of variance	df	Sum of squares	Mean square variance	F – value	F – Critical value
Among the means of condition	5	45291.02	9058.20	174.18*	2.25
Within condition	244	12689.08	52.00		
Total	249	57980.10			

***Significant**

For df 5 & 244, at 0.05 level F=**2.25** and at 0.01 level F = **3.09**
The hypothesis no. $\mathbf{H_{02}}$ is **rejected** at **0.05** level.

INTERPRETATION: -

It appears from **Table 2** that the probability of this result, assuming the null hypothesis, is **174.18.** As the 'F' value is significant, the null hypothesis is **rejected.** "There is no significant difference between the performance of students with high, average, and low WMC instructed Genetics using a segmented and a non-segmented version of multimedia instructions on the Application Test scores." is **rejected**. Hence, there is a significant difference between the performance of students with high, average, and low WMC of the experimental and the control group on the Application Test scores.

TESTING OF HYPOTHESIS 3:

Table 3 shows the relevant statistics for it.

Table 3: - ANOVA (2 × 3) showing a difference between the treatment effects for the students with HWMC, AWMC, and LWMC of EG and CG on Application Test scores.
***Significant at 0.05**

Source of variance	df	Sum of squares	Mean square variance	F- value	F-Critical values
Sum square of 1st factor (Treatment)	1	33091.76	33091.76	771.55*	3.88
Sum square of 2nd factor (WMC)	2	9281.16	4640.58	108.20**	3.03
Sum of square of both factor	2	6597.73	3298.87	76.91***	
Total square within	244	10464.45	42.89		
Sum of square of total	249	59435.11			

INTERPRETATION: -
Table No. 3 indicates the following results: -

Main effect for segmentation**: F (1, 224) = 771.55, p < 0.05**
Main effect for Working Memory Capacity: **F (2, 224) = 108.20, p < 0.05**
Working Memory Capacity by segmentation interaction**: F (2, 244) = 76.91, p < 0.05**

There is a main effect for WMC and Segmenting principle of multimedia instruction on the score of Application Test. Therefore, the interaction effect between WMC and treatment is statistically significant at the 0.05 level. As a result, the null hypothesis, **"There is no significant difference between the treatment effects for students with high, average and low WMC instructed Genetics using a segmented and non-segmented version of multimedia instructions on Application Test scores"** is **rejected**. Hence, there is a significant difference between the treatment effects for students with high, average and, low WMC of the experimental and control groups on Application Test scores.

WMC EFFECT SIZE:
Table 4: Means and standard deviations of segmented and non-segmented multimedia instruction on recall and application scores

Working Memory Capacity	Recall			Application		
	Treatment	Mean	SD	Mean	SD	N
HWMC	SIM	86.23	3.99	84.57	4.12	44
	NSIM	67.27	12.14	59.43	10.79	44
	Total	76.75	13.10	72	15.03	88
AWMC	SIM	76.78	3.96	76.47	4.23	60
	NSIM	62.63	7.46	55.20	7.29	60
	Total	69.71	9.26	65.83	12.21	120
LWMC	SIM	62.29	5.14	62.57	4.72	21
	NSIM	41.05	8	39.76	10.76	21
	Total	51.67	12.63	51.17	14.16	42
Total	SIM	77.67	9.15	76.98	8.59	125
	NSIM	60.64	13.06	54.10	11.39	125
	Total	69.16	14.12	65.54	15.26	250

Maximum Recall score = 94 Maximum Application score = 92

The WMC effect was confirmed for recall as well as for application skills. As high WMC students recalled more than average and low WMC students, resulting in a **significant main effect** for WMC, (see **Table 4**) **F (5, 244) = 136.97, p = 0.00, Cohen's d** (between HWMC & AWMC**) = 0.64, Cohen's d** (between AWMC & LWMC**) = 1.76,** and **Cohen's d (**between LWMC & HWMC**) = 1.94.** These results show that effect size is medium between HWMC and AWMC while effect size is large between AWMC and LWMC as well as for HWMC and LWMC on the score of Recall Test.

Similarly, based on the application data, the high WMC students performed better than average and low WMC students, resulting in a **significant main effect** for WMC, (see **Table 4**) **F (5, 244)** = **174.18**, **p = 0.00**, and **Cohen's d** (between HWMC & AWMC**) = 0.46, Cohen's d** (between AWMC & LWMC**) = 1.15,** and **Cohen's d (**between LWMC & HWMC**) = 1.87**. These results show that effect size is medium between HWMC and AWMC while effect size is large between AWMC and LWMC as well as for HWMC and LWMC on the score of Application Test.

SEGMENTATION EFFECT:

The ANOVA for recall data resulted in a significant main effect for segmentation, **F** (**2, 224**) = **66.18**, **p = 0.00**, and **Cohen's d** = **1.51** (see **Table 4**). Similarly, based on the application data, there was a significant main effect for segmentation, **F (2, 244)** = **76.91**, **p = 0.03**, and **Cohen's d** = **2.27**. These results are consistent with the predictions of the WMC hypothesis as well as with prior research (**Mayer & Chandler, 2001) [3]; (Danielle L. Lusk, Amber D. Evans, Thomas R. Jeffrey, Keith R. Palmer, Chris S. Wikstrom and Peter E. Doolittle, 2008**) **[4]** and provide support for the segmentation effect of multimedia instructions.

WMC AND SEGMENTATION INTERACTION:

The result of **contrast analysis in between-subject designs** for Recall as well as Application Test reveals that:
- There is a main effect for working memory capacity and Segmenting principle of multimedia instruction on the score of Recall Test, **F (2, 244) = 4.829, MSE= 53.450, p = 0.009** as well as Application Test, **F (2, 244) = 4.206, MSE=52.004, p = 0.016.**

The presence of the interaction indicates that the main effect for high, average and low working memory capacity is not equal across segmented version of multimedia instructions in Genetics on the score of Recall Test. as well as Application Test. The specific learners particularly, LWMC and AWMC may not be benefited from specific multimedia instructions i.e. non-segmented versions of multimedia instructions but both, LWMC and AWMC of experimental groups when taught genetics with segmented version are benefited and performed better on Recall and Application Tests.

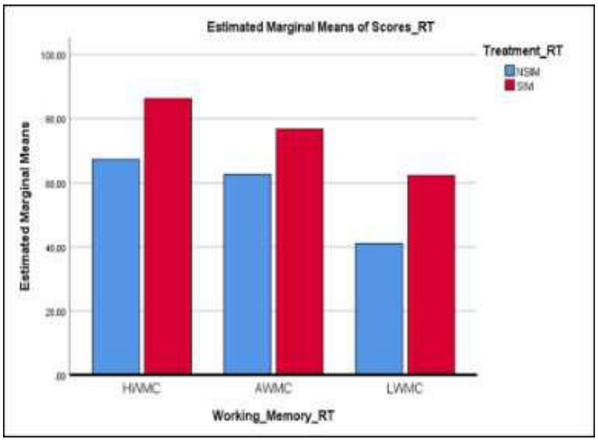

Figure 1: The interaction effect for Recall

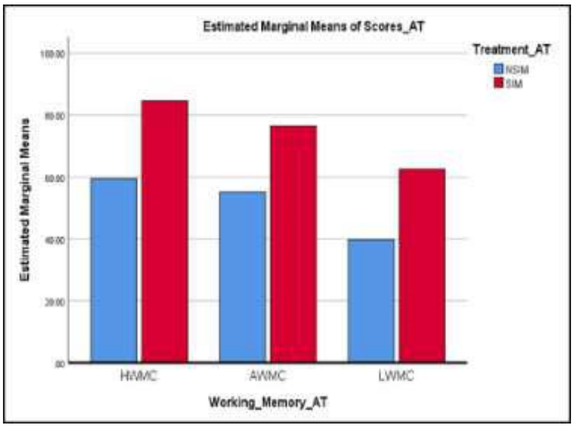

Figure 2: The interaction effect for Application

This appearance was statistically confirmed using a **simple effects contrast** comparing the LWMC-NSI to LWMC-SI, AWMC-SI to AWMC-NSI and, HWMC-NSI to HWMC-SI. **The test of the simple effect of**: -

- ❖ **The high working memory capacity** of students with segmented and non-segmented version of multimedia instructions states that students of **HWMC** when taught Genetics with segmented version were performed exceptionally better on **Recall** [**t (244) = 12.160, p < .001]** as well as **Application** Test [**t (244) = 16.349, p < .001]** than those taught with non-segmented version.
- ❖ **An average working memory capacity** of students with segmented and non-segmented version of multimedia instruction states that students of **AWMC** when taught Genetics with segmented version were performed remarkably better on **Recall** [**t (244) = 10.601,**

p < .001] as well as **Application** Test [**t (244) = 16.153, p < .001]** than those taught with non-segmented version.

- **The low working memory capacity** of students with segmented and non-segmented version of multimedia instructions states that students of **LWMC** when taught Genetics with segmented version were performed much better on **Recall** [**t (244) = 9.413, p < .001]** as well as **Application** Test [**t (244) = 10.249 p < .001]** than those taught with non-segmented version.

7. DISCUSSION:

This finding clearly indicates that the main effect for high, average, and low working memory capacity is not equal across a segmented version of multimedia instructions in Genetics on the score of Recall Test as well as Application Test. The specific learners particularly, LWMC and AWMC may not be benefited from specific multimedia instructions i.e., non-segmented versions of multimedia instructions, but both, LWMC and AWMC of experimental groups when taught Genetics with segmented version are benefited and performed better on Recall and Application Tests.

On a positive note, however, the results also indicate that the use of a segmentation version of multimedia instruction, benefits AWMC individuals to the point where students with AWMC and HWMC perform equally better on Recall and Application Tests when taught Genetics with a segmented version of multimedia instruction.

8. CONCLUSIONS:

The results of the present study are consistent with the opinion that students with low working memory capacity will have difficulty learning from complex or non-segmented multimedia instructions and that segmentation is one of the effective strategy to overcome this difficulty. The results of the present study also support the previous findings that individuals with higher working memory capacity performed exceptionally better than the individuals with lower working memory capacity on tasks demanding recall and application of knowledge. These findings are significant as they provide evidence for an individual difference variable that affects learning in a multimedia instructional environment. Previous research has shown that prior knowledge (Cooper, Tindall-Ford, Chandler & Sweller, 2001) [5] and spatial ability (Moreno & Mayer, 1998) [6] function as individual difference variables that affect multimedia learning to which working memory capacity can now be added.

Eventually, the present study provides meaningful evidences for the educators and multimedia developers to design and construct new knowledge in relation to multimedia learning for students with variable working memory capacity.

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