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ABSTRACT

The purpose of this study was to compare the Gilbertian mathetical sequence (MS) with the Skinnerian logical sequence (LS) methodologies in their effectiveness for language teaching. A series of 3 experiments were designed to investigate the effect of MS and LS on the teaching of Japanese Kanji characters to 24 Japanese fifth-graders. The students were divided into two groups and received instruction on three consecutive Saturdays following either the MS or LS method. During each session, the students learned three Kanji characters. The study found that after the first session students in the MS group recalled fewer characters than the LS group. After the second and third sessions, however, the MS group recalled more characters than the LS group. These findings suggest that MS might be preferable to LS as a potential method for language teaching. (MDM)

A COMPARATIVE STUDY OF THE SEQUENCE EFFECT IN LEARNING JAPANESE KANJI CHARACTERS: MATHETICAL VS. LOGICAL SEQUENCES

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A COMPARATIVE STUDY OF THE SEQUENCE EFFECT IN LEARNING JAPANESE KANJI CHARACTERS: MATHETICAL VS. LOGICAL SEQUENCES

BY Harumitsu MIZUNO

The purpose of this study is to compare the backward Gilbertian mathetical sequence (MS) with the forward Skinnerian logical sequence (LS) in their effectiveness for language teaching. A series of three consecutive experiments was designed to investigate the effect of MS vs. LS on teaching of Japanese Kanji characters in a real classroom setting.

A total of 24 Japanese 5th graders were divided into two equal subgroups matched for their achievement in 4th grade. On each of the three consecutive Saturdays, one subgroup ("the MS group") was given instruction following the MS, while the other subgroup ("the LS group") was given instruction following the LS. Each day, the groups learned three Japanese Kanji characters.

In the first session of this study subjects in the MS group recalled fewer characters on the reproduction test. However, as the course of instruction proceeded, students in the MS group received higher scores on the reproduction test. The results of this study suggest that subjects receiving the MS instruction initially did worse because of the unfamiliarity of the method. The later success of the MS method may be attributable to initially showing the entire Kanji to the students, and the constant repetition of the Kanji. These findings suggest that MS might be preferable to LS as a potential method for language teaching, specifically for the teaching of characters or other linguistic signs.

INTRODUCTION

During the past quarter century, instructional theory has developed remarkably. Advances occurred like clockwork at ten year intervals. They were linked sometimes to technological developments, sometimes to particular theorists, and sometimes to social changes. One of the biggest developments in this field has been research on programmed instruction. This paper will focus on the effectiveness of sequencing. We will first review the existing research as a prelude to the present study; and then, a report of a study conducted to test the effectiveness of the mathetical sequence and the logical sequence follows; and finally, we will discuss implications of the effectiveness of sequencing for language teaching.

OVERVIEW OF THE RESEARCH

Pressy's introduction of the teaching machine as a technological aid at Ohio State

University in 1926 created a great stir in the educational world. It was not until the early sixties, however, that programmed instruction and teaching machines came on the scene as a response to Skinner's behaviorism.

If audiovisual specialists responded to programmed instruction with caution and reserve, some teachers rejected it almost completely. Their resistance stemmed from suggestions by some advocators of programmed instruction that programs were "teacher-proof" and that teachers could be replaced. Audiovisual specialists and teachers, however, generally supported the idea of instructional systems, encouraging teachers to help write behavioral objectives and incorporating new media formats.

In the late 1960's atomosphere of student revolts, technology and systems were seen in a negative light, and no technological inventions appeared; attention to programmed learning disappeared. The period confused and frustrated teachers, media specialists, and educational technologists, as student pressures forced them to retreat

Table 1

Changing emphases of programmed learning (Reproduced from Davis, I. K.,) Competency Based Learning: Technology, Management, and Design. New York; McGraw-Hill, 1973)

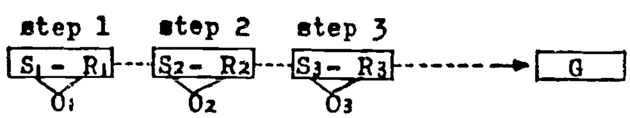
1960	1963	1966	1970
Small steps Overt responses Immediate feedback of results Self-pacing Validation	Task analysis Behavioural objectives Small steps Logical sequencing Active responding Immediate feedback Self-pacing Validation	Task analysis Behavioural objectives Subject analysis Flowcharts Small steps Active responding Presentation as a communication problem Validation	Systems analysis Task analysis Contrast analysis Behavioural objectives Structuring material (via analysis and synthesis) Appropriate teaching strategy Controlled interaction via: digestible steps appropriate stimulus content relevant response modes reinforcement Presentation as a communication problem Appropriate instrumentation Validation and evaluation Installation and implementation

from what they considered appropriate approaches.

When the instructional system industry began to recover in the mid-seventies, it did so by taking a more humanistic and personal task. Programming techniques have further expanded to meet the needs of instructional software (courseware) of microcomputers.

The emphasis of research on programmed instruction has been changing as shown in Table 1. Much of the research has been concerned with secondary variables: response mode, and presentation mode (Holland, 1965). I shall not discuss it in detail. The difference between LS and MS will be, however, illustrated below.

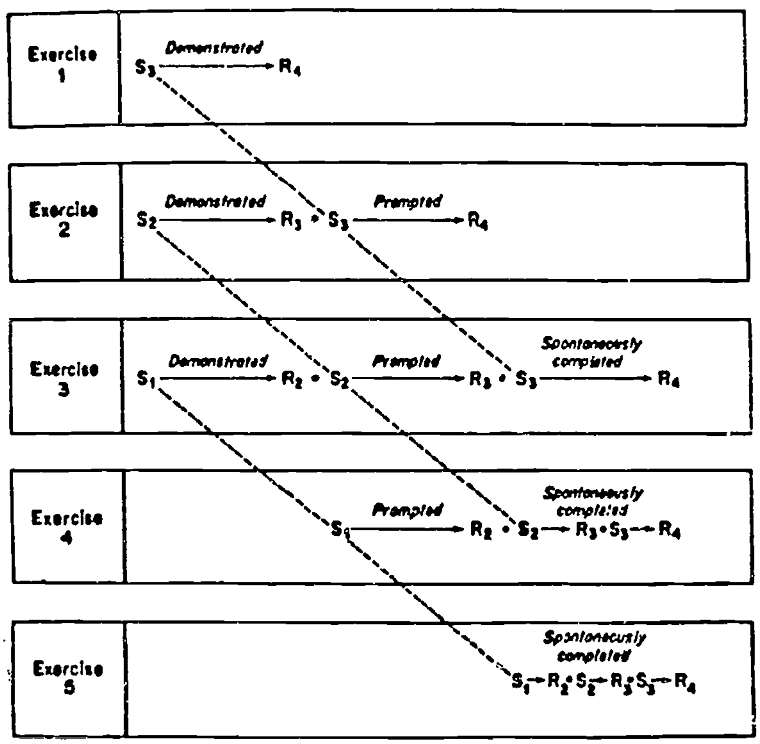
(1) Model of the Logical Sequence (LS)



S - stimulus R - response O - objective G - goal

(2) Model of the Mathetical Sequence (MS)

BEHAVIOUR CHAIN TO BE LEARNED: $S_1 \longrightarrow R_2 \cdot S_2 \longrightarrow R_3 \cdot S_3 \longrightarrow R_4$



Skeleton of mathetical lesson plan. Beginning with terminal operant, each operant is (1) introduced with full demonstration, (2) prompted in the next exercise, (3) performed spontaneously thereafter. (Gilbert, 1962)

Figure 1. Comparison between the LS and MS.

The mathetical approach originated by Gilbert is characterized, largely by (1) the use of the largest response units possible as the starting point of instruction, and (2) the criteria of mastery. Mathetical programming assumes that all necessary responses are already in the repertoire of the student, and that it is only necessary to those responses to be manipulated in terms of the circumstances and the order in which they occur. Therefore, every response is first "demonstrated" to the student by means of text and illustrations, then "prompted" by having the student perform the response with assistance, and then "released" so that the student performs the response without assistance In order to help the learner in making the transition between instruction and performance, several specific techniques are employed. For instance, discriminations among potentially confusing stimuli are all taught simultaneously; mnemonics are used literally as mediators, and motivation is enhanced by having the completion of the task – with its normally occurring results – conclude each step in the program. What is more, the style and characteristics of the program are not decided until the very last, after the aims, sequence, and features of instruction already have been determined.

Mathetics is somewhat eclectic in nature, but is unque in application, if not in principle. McGalley (1967) indicated that mathetical programming is ideally suited to the training needs of vocational schools and industry where transfer of skills to the actual job situation is critical. Although mathetical lessons are inherently more expensive to produce than are those of other programmming techniques, savings resulting from the "spin-off" effect and from increased training efficiency may offset the extra cost.

PROBLEM

Does mathetical presentation sequence improve achievement of language teaching?

PURPOSE

Gilbert (1962) mentioned that mathetics is applicable to all subject matter, and has been used to train delicate manual skills as well as to teach complex verbal repertories. However, only a few experiments were carried out to test the effectiveness of mathetics in real classroom settings. Therefore, the purpose of this research is to compare the backward Gilbertian mathetical sequence with the forward Skinnerrian logical sequence (LS) in their effectiveness for language teaching.

METHOD

Subjects

Ss were 24 Japanese 5th graders in a Japanese weekend school in New York. There were 10 boys and 14 girls. They were divided into two balanced subgroups based on their achievement in the fourth grade.

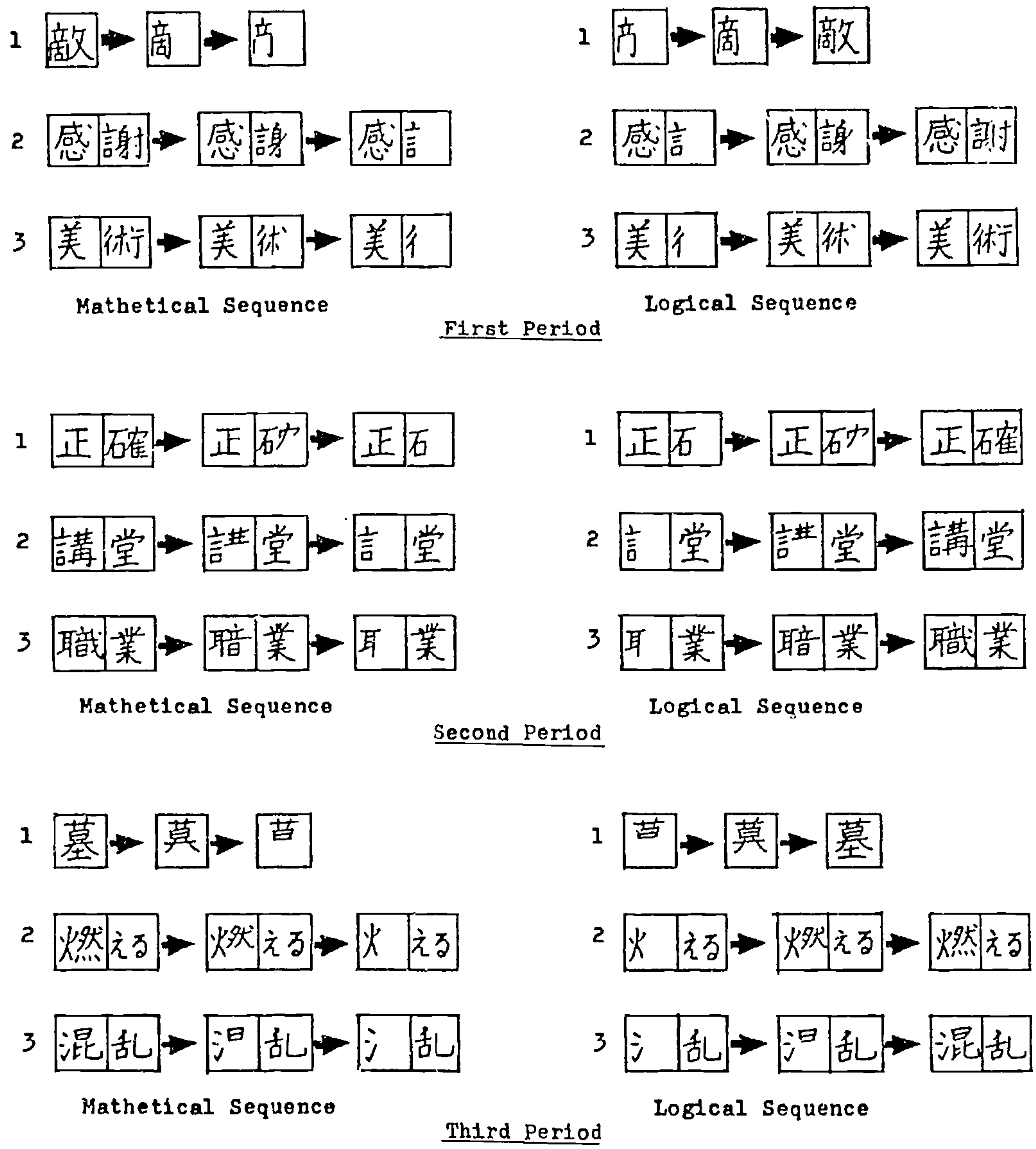


Figure 2. Sequences of character presentation: Mathetical program and Logical program in three experiments.

Materials

Equipment consisted of 12 white 8½ "× 11" flash cards on which a complete or incomplete Japanese Kanji character was described on one side. The total of nine characters used in this study were to learn at the end of the year. Those characters were always presented in the context of a phrase based on each instructional sequence.

Procedures

A total of three experiments was carried out over three consecutive Saturday mornings. The independent variable was presentation sequence, which had two values: (1) the mathetical presentation sequence, and (2) the logical presentation sequence (Figure 2).

On each of the three consecutive Saturdays, one subgroup ("the mathetical sequence group") was given instruction following the mathetical sequence, while the other subgroup ("the logical sequence group") was given instruction following the logical sequence. Each day, the groups learned three Japanese Kanji characters. Before the instruction, Ss were asked to indicate whether or not they could already write each character.

After presenting the flash card, a piece of paper was distributed to the subjects. "Ss in the mathetical sequence group" were asked to write a complete character after the second presentation, making up for an incomplete character by means of their memory of the first presentation of the character. "Ss in the logical sequence group" were asked to copy each character presented in the sequence of the writing order. Their wr'ing was quickly collected, and the next presentation was followed. The experimental instruction of each test took 30 minutes. At the end of the class work each day, a reproduction test was assigned and the subjects were asked to write three complete characters which they had learned during the first period of the day.

ANALYSIS AND FINDINGS

The p : centage of correct writing of each Japanese Kanji character in the instruction, and the reproduction test of each experiment is shown in Table 2. In order to calculate the growth rate of learning each character, the measurement of the "G ratio" originated by McGuigan & Peters (1963) was employed. Thus:

$$\text{G Ratio} = \frac{\text{Actual Gain}}{\text{Maximum Possible Gain}}$$

$$= \frac{\text{Mean SL}^1\text{ Score (\%)} - \text{Mean FL}^2\text{ Score (\%)}}{100 - \text{Mean FL Score (\%)}}$$

1. Second Learning, i. e., the post-test score.
2. First Learning, i. e., the pre-test score.

The G ratio of the reproduction test was calculated by dividing the difference between the mean score (%) of the reproduction test and that of FL by maximum possible gain. The G ratio, its mean and SD of the correct writing of each character in the instruction and reproduction test of each experiment are shown in Table 3.

Table 2

Percentage of Correct Writing of Each Character Before and After Instruction and Reproduction Test of Each Experiment.

	Instruction						Reproduction Test		
	敵		謝		術		敵	謝	術
	FL*	SL**	FL	SL	FL	SL			
Mathetical Sequence	0	58	8.3	83	8.3	100	67	75	83
Logical Sequence	8.3	91	8.3	83	0	100	75	83	67

First Period

	Instruction						Reproduction Test		
	確		講		職		確	講	職
	FL.	SL	FL	SL	FL	SL			
Mathetical Sequence	8.3	100	0	83	0	100	92	83	83
Logical Sequence	8.3	72	8.3	91	0	72	75	50	67

Second Period

8

	Instruction						Reproduction Test		
	墓		燃		泥		墓	燃	泥
	FL	SL	FL	SL	FL	SL			
Mathetical Sequence	42	100	8.3	100	0	100	83	66	75
Logical Sequence	42	92	33	100	0	92	75	75	50

Third Period

* "FL", refers to the percentage of subjects who could correctly write each character before instruction.

* * "SL", refers to the percentage of all subjects who could write each character correctly after instruction. (SL includes FL).

Table 3

G ratio, and mean ratio, of correct writing of each character in instruction and reproduction test of each experiment.

	Instruction			Reproduction Test		
	敵	謝	術	敵	謝	術
Mathetical Sequence	0.58	0.81	1.00	0.67	0.73	0.81
Logical Sequence	0.90	0.81	1.00	0.73	0.81	0.67
X̄	0.74	0.81	1.00	0.70	0.77	0.74

First Period

	Instruction			Reproduction Test		
	確	講	職	確	講	職
Mathetical Sequence	1.00	0.83	1.00	0.91	0.83	0.83
Logical Sequence	0.69	0.90	0.72	0.73	0.45	0.67
X̄	0.85	0.87	0.86	0.82	0.64	0.75

Second Period

	Instruction			Reproduction Test		
	墓	燃	泥	墓	燃	泥
Mathetical Sequence	1.00	1.00	1.00	0.71	0.63	0.75
Logical Sequence	0.86	1.00	0.92	0.59	0.63	0.50
X̄	0.93	1.00	0.96	0.65	0.63	0.63

Third Period

The difference of the effectiveness between two presentation sequences was examined by using the test with the mean G ratio of three characters which Ss of each group learned, and its SD^2. It is shown in Table 4.

Table 4

Achievement of Fifth Graders in Ecah Experiment

	Instruction				Reproduction Test		
	M.S.*	L.S.**	Difference		M.S.	L.S.	Difference
N	12	12		N	12	12	
X̄	79.7	90.0	10.3	X̄	73.7	73.7	0
SD^2	73.8	24.6		SD^2	8.7	8.7	
	$t(22)=3.63$	$p<.01$			$t(22)=0$	$p>.05$	

First Period

	Instruction				Reproduction Test		
	M.S.	L.S.	Difference		M.S.	L.S.	Difference
N	12	12		N	12	12	
X̄	94.3	77.0	17.3	X̄	85.7	61.7	24.0
SD^2	16.1	21.5		SD^2	3.7	35.3	
	$t(22)=9.24$	$p<.01$			$t(22)=12.77$	$p<.01$	

Second Period

	Instruction				Reproduction Test		
	M.S.	L.S.	Difference		M.S.	L.S.	Difference
N	12	12		N	12	12	
X̄	100	92.7	7.3	X̄	69.7	57.3	12.4
SD^2	0	8.2		SD^2	6.2	21.0	
	$t(22)=8.49$	$p<.01$			$t(22)=7.90$	$p<.01$	

Third Period

* M.S. = Mathetical Sequence group

* * L.S. = Logical Sequence group

The mean achievement score of each group was calculated by multiplying the mean of the total mean G ratio of three characters presented in each test by 100.

This analysis showed us the following:

(1) there was a greater amount of learning in the logical sequence instruction than in the mathetical sequence instruction in Test-I, $t(22)=3,63$ $p<.01$. However, there was no significant difference between two means of the reproduction test.

(2) there was a greater amount of learning in the mathetical sequence than in the logical sequence both in the instruction and in the reproduction test of Test-II and Test-III at the significance level of $p<.01$.

DISCUSSION

The mathetical sequence produced better learning than the logical one in teaching

Japanese Kanji characters. From this, it may be hypothesized that in language teaching, the achievement will usually increase by presenting in mathetical sequences rather than in logical sequences. Some support for this hypothesis will be gained from Figure 3. The interesting thing in these tests is the fact that the result of Test-I con-

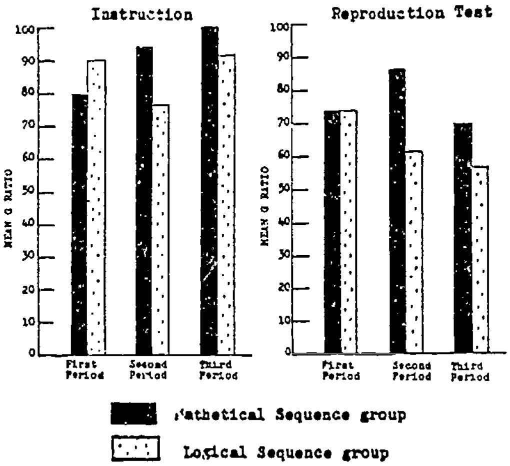


Figure 3. Achievement of Fifth Graders in Mathetical and Logical Sequences.

trasts strongly with those of Test-II and Test-III. In Test-I, the Ss of mathetical sequence group seem to have been confused by the unfamiliar sequential instruction. Because they have been accustomed to the forward logical sequence instruction.

Although the difference between two means of the instruction in Test-I was strongly significant ($p < .01$), there was no difference between two means of the reproduction test. From this it may be said that the effect of the mathetical sequence on the growth of retention in the reproduction has made up the deficit of the instruction. A clear image of the final outcome and the continuous repetition would seem to have produced the better learning in the mathetical instructional group.

So far, programming language teaching has been seen with a skeptical eye. Programmed instruction is especially suitable for giving a student command of the data of an organized body of knowledge such as psychology or arithmetic or physics, and an understanding of this body of knowledge. However, there is considerable doubt that composition in a real sense can be taught any better by this method. Thus, it is a highly complex skill -- perhaps the most complex of all human skills.

The study of language, as a part of language teaching trio of language, literature, and composition, is a body of knowledge. Literature as a subject contributes most strongly to the development of programming technology by the use of records, films, TV shows, microcomputers, and so forth as adjuncts to the study of literature. The computer text editor can help writers overcome typical composing and revising problems, influenced by natural cognitive processes. Thus, it has the possibility to improve many problems of the current teaching of composition.

Programmed instruction is not limited to one medium, as Susan Markle (1965) described, such as the book or its surrogate-- the film page which a machine presents-- nor is it limited to any particular school of programming technology. The small-step linear program is familiar to most teachers at this point and is assumed to be the full measure of programmed instruction.

Traditionally it has been suggested that the teacher should begin instruction with simple material and slowly move to the complex. However, Thomas Gilbert (1962) and David Premack (1959) challenged this traditional concept of the ordering of education.

A great feature of mathetics proposed by Gilbert is "backward" cha...ng. Beginning with the terminal operant the division chain, each operant is introduce with a full demonstration. The se... ...ep establishes the next to the last ... ...t, and the operant before this is established in the third step. The reinforcer is assumed to be given directly by the product of the student's own performance. Each response produces the conditions for behavior that the student knows how to perform, and this continues until the mastery sequence is complete. The reinforcer in a mathetical lesson is truly immediate, being simultaneous with performance itself, and not delayed by answer seeking. Moreover, the student can minimize his reliance on someone else's word that he is correct; he has seen the end-product of mastery, and knows that his performance is leading there again. Therefore, the procedures of mathetics are likely to establish the strong reinforcement which cannot be expected in ordinary linear programs.

Premack's concept deals with response probabilities of frequencies and their sequencing. It may be stated that if behavior B is of higher probability than behavior A, then behavior A can be made more probable by making behavior B contingent upon it. According to the Premack theory, difficult tasks should be arranged before easy tasks.

Many researchers have demonstrated the potency of this principle. We should recognize the merit of Premack's principle in terms of programming technique which provides students with feedback and intrinsic motivation. Evans (1965) claimed that the Premack principle would provide Gilbert with a atronger system by removing the assumptions of motivation. Mathetics and the Premack principle are likely to have great impact on instruction if they are used for computer programming of course ware.

However, a question as to why such a potential technology has not been widely known remains. Gilbert (1978) explains the reason as follows:

Unfortunately, such a technology (I call it mathetics) is unlikely to grow until there are incentives for its growth. At present, textbook publishing -- which could become the principal development industry -- has no incentives for adopting such a technology. Unfortunately, however, school boards do not adopt instruments for behavior change. They buy books. And no one has any expectation that a book should guarantee a behavioral change. (Gilbert, 1978, pp. 248-249)

CONCLUSION

According to the results of the three consecutive experiments for teaching Japanese Kanji characters, it appears that instruction in the mathetical sequence might first lead to confusion because of the unfamiliarity of the sequence. However, as the course of instruction proceeds, mathetical sequence instruction produces better learning than forward logical sequence instruction. The presentation of a clear image of the final outcome as an iconic gestalt at the first stage, as well as continuous repetition in the different condition, results in high learning growth in the mathetical sequence group.

Thus, the findings suggest that mathetical sequencing might be preferable to logical sequencing as a principle for language teaching, specifically for the teaching of characters, or other linguistic signs. For instance, in teaching Japanese or Chinese as a foreign language, students may first be confused by a character presentation in the mathetice sequence. However, in the course of instruction. they seem to learn better when the character presentation is in the mathetical sequence rather than in the forward logical sequence.

Because there were so few subjects in each group, only limited statistical significance could be determined. Therefore, this study should be viewed as a pilot; the results warrant that a larger scale study be completed.

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