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Spaced Formula Learning

Engin Baysen

[*]Near East University, Atatürk Education Faculty. Near East Blv. Nicosia, North Cyprus, Mersin 10, Turkey
E-mail: engin.baysen @neu.edu.tr

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ABSTRACT Spaced learning was applied to solve a very challenging aspect of the traditional approach in learning scientific formulas. Learning formulas, starting from their memorization to their application and the attitudes toward them, was asserted to be achieved using the spaced learning approach. A sequential, explanatory, mixed methods research design was implemented to see the effects of massed and spaced learning on learning formulas in three intact groups of early childhood teacher candidates. Lessons were designed to resemble the teaching carried out in most traditional physics classrooms and convince physics teachers that there is an approach to solve the problems they encounter in formula learning. Although teacher candidates think positively about repetition, and while massed learning was found to be boring, massed learning is also more efficient in achieving positive attitudes towards formulas and results in greater retention than spaced learning. Discussions concerning the results were subsequently held.

INTRODUCTION

Arguments concerning the dilemmas about whether or not to memorize knowledge frequently take place in educational environments. Science teachers may find themselves in these discussions more than other teachers, as those studying the sciences have to learn a greater number of concepts, facts, rules, principles and formulas.

Those teachers in favor of memorizing formulas, and thus the improvement of formula application skills, may base their reasons on different realities. First of all, they think that the program requires them to do so. Secondly, their students' success in national examinations depends on formula memorization. Without learning and applying formulas in qualification tests, students are not accepted as successful. Tsai (2002), studying with Taiwanese science teachers, found that more than half of the teachers believed that "for successful science learning, students, first, need to memorize relevant scientific formulas". One other teacher group, although not required to teach, but to understand when to apply a formula properly in the right conditions, includes early childhood teachers. For example, they may be obliged to explain why people on the moon "fly in the air" instead of walk, as on earth. Early childhood teachers also need to motivate their students to construct rules dependent on (scientific) reasoning, which in turn forms the preliminary steps in understanding what the formulas are, and their importance.

The application of formulas by students mostly does not take place step-by-step, in an automatic and unconscious manner, and do not achieve meaningful learning. In this sense the process may seem easy for stakeholders. At first, students have trouble with memorizing and applying formulas. This obliges traditional science teachers to spend more class time, and most of their energy, focusing on teaching formulas, working on problem examples concerning formulas, and simply giving students exercise questions to be done with or without the teacher's assistance. Nonetheless, much research (for example, Bar et al. 1994) has shown how unsuccessful students are in the application of scientific rules and laws. Calculations and numbers are factors that negatively affect learning science (for example, Francis and Greer 1999) by impeding people's attitudes towards science. Lipson (1992) on the other hand showed that students emphasize the importance of formula learning so much that they believe laboratory activities are a facilitator for memorizing formulas. Whenever one temporarily memorizes, and has the skill to apply a formula required in the next exam, she/he would be successful in that exam.

Time management in education was analyzed by the researchers to find the best time for learning tasks. A one-time management strategy is distributing teaching time. In distributing learning tasks over time, spaced learning was found to improve learning more than massed learning, known as the spacing effect (Tsao 1948 a,b; Kornell and Bjork 2008). Spaced repetition enhances retention (Karpicke and Bauernschmidt 2011). Grimaldi and Karpicke stated even that unsuccessful retrieval attempts could enhance learning (Grimaldi and Karpicke 2012). The benefits of spaced learning opposed to massed learning were stated in most of the studies concerning learning and memory (Meixia 2016; Smolen 2016; Swehla et al. 2016). Participants from a wide range of schooling, including preschool (Toppino 1991), early elementary (Gluckman et al. 2014), elementary school (Toppino and DiGeorge 1984), middle school (Carpenter et al. 2009) and college (Rohrer and Taylor 2006; 2007) benefited from spaced learning. A great deal of spaced learning research was conducted in laboratory conditions (Vlach et al. 2008) (memory and category induction by 3-year-old children). Laboratory studies were mostly aimed at the learning of words or simple facts and pictures (Bahrick et al. 1993; Childers and Tomasello 2002; Rea and Modigliani 1987; Toppino 1993).

In contrast to most research, some findings do not show spacing effects. A different experimental context varies the findings of spaced versus massed research. For example, Toppino and DiGeorge (1984) found that preschool students benefited from both spaced and massed repetitions. Toppino et al. (2009) found that rapid presentation rates for difficult items resulted in worse memory for spaced and better memory for massed nomenclature, as a negative spacing effect by Metcalfe and Kornell (2003). The spacing gap, the duration between two learning sessions, was also researched to reveal its effect on learning. Research results showed in favor of long spacing gaps (Kahana and Howard 2005; Bahrick and Phelps 1987). But not all research is in favor of using long spacing gaps (Cepeda et al. 2009; Verkoeijen et al. 2008). Attitudes towards spaced and massed learning were also researched. Learner preferences in spaced versus massed learning are also found to depend on the context. While Son (2004) revealed that students prefer spaced learning for easy items, the reverse is true in another study by Benjamin and Bird (2006).

Ground for Research

A real and complicated educational problem is hoped to be solved in the present study. First of all, the condition of learning a more difficult and complex subject is chosen, that is, to learn and retrieve a formula, and to create a positive attitude towards the formula. Secondly, instead of doing an experiment in laboratory conditions, real school conditions, as far as possible, were held. It is noted here that these conditions are not new to the literature. Some studies have already been conducted in the context of a real school environment (Sobel et al. 2011: retention of definitions of uncommon English words by 5th graders; Carpenter et al. 2009: retention of historical facts in eight grade students; Seabrook et al. 2005: reading skills of 1st graders). More difficult and complex learning objectives were also investigated (Rohrer and Taylor 2006: retention of mathematics knowledge by college students; Reynolds and Glaser 1964: retention of academic biology material by junior high school students; Vlach and Sandhofer 2012: simple and complex generalization of science concepts by 5-7-year-old children).

A great number of researchers have aimed to reveal people's attitudes toward science. They asked about numbers and calculations as well, but included numbers and calculations only as one aspect of science learning, and found that utilizing numbers in teaching impedes students' science learning. However, research focusing on the formulas alone has not been designed to the researchers' knowledge. In addition, no research has focused on the enhancement in learning formulas and attitudes towards formulas. It does not seem possible to exclude formulas from the program for now, or to quickly change teachers' habits. So, can a teaching approach be recommended, which does not expect teachers to greatly change their way of teaching, and concluding with an improvement in learning a formula and an improvement in positive attitudes towards a formula? Thus, a teaching approach in the present study, explained in the 'lessons' section of the present manuscript, is maintained and followed accordingly. The highlighted feature of the lessons is that the presentation rate is rapid, as it is in traditional, (real) school conditions for the context of formula learning.

Such research, showing accomplishment in spaced learning utilization mentioned above, motivated the researchers of the present study to use the spaced learning approach in formula learning. Thus, one way to memorize and utilize formulas properly may be to deliberately repeat related formulas occasionally and apply it. This approach can be easily practiced in most science lessons when teaching formulas.

Objectives of the Study

The present research study aimed to test the success of massed and spaced learning approaches in promoting teacher candidates' attitudes towards the formula and learning, and the retrieval of formulas. Thus, the present study is a study of human culture encompassing learning of knowledge and beliefs. It is asserted that spaced learning will improve student learning, the retrieval of formulas and attitudes towards formulas. For this purpose, four research questions are to be answered.

1. What effect does massed and spaced learning have on teacher candidates' attitudes to formulas?
2. What effect does massed and spaced learning have on teacher candidates' learning of formulas?
3. What effect does massed and spaced learning have on teacher candidates' retrieval of formulas?
4. What do the teacher candidates think about the efficacy of repetition in learning formulas?

METHODOLOGY

At first, quantitative methods were proposed for the present study, however, a sequential, explanatory, mixed methods research design (Creswell 2008) was eventually chosen for the present study. The second and third intervention lessons held for the third group also led the researchers of the present study to use qualitative research methods. This was because, unexpectedly, contradicting the research assertion, teacher candidates were found not to be interested in the intervention lessons, showing similar behavioral attitudes with those found in traditional classes. During intervention lessons, teacher candidates talk to each other, they daydream, and checked messages on their mobile phones. A mixed methods procedure enables a greater understanding, obtains more detailed and specific information, and confirms findings from different data sources, like triangulation (Creswell 2008). Thus, multiple forms of data, both text and numeric, were gathered and analyzed. Data was gathered in two phases (quantitative followed by qualit-ative). The data gathered was mixed in the data analysis and interpretation section. A greater priority was given to the quantitative approach. Qualitative data (themes) gathered via observations and interviews was used to assist in explaining and interpreting the data gathered from the quantitative procedures.

Measures were taken to increase the credibility of the findings (Creswell 2008). An attempt was made to eliminate the diffusion effect. The instructor (the researcher of the present study) told the teacher candidates not to discuss or share the relevant lessons carried out in their classes with those in different classes, but this is still a weakness of the study. The study was arranged to simultaneously finish at the end of the semester, allowing the researcher to become acquainted with potential participants. Thus, the researcher has known the teacher candidates for three months. A colleague of the researcher, who has experience in science teaching, contributed to the research as an observer and interviewer. The colleague was introduced to the class and she occasionally participated in the lessons for other reasons. On those occasions she sat silently in front of the class with her notebook listening to the lesson. She participated in the research related lessons in the same way. It is thought that her presence in the class did not affect the behavior of the teacher candidates much, and hence showing the teacher candidates' natural behavior. Three different sets of data from three different information sources of tests, observations and interviews were incorporated for data analysis. Member checking was realized by probing questions, repeating and summarizing the notes taken during the interviews for each student and the group.

Participants

Early childhood teacher candidates (N=101) in their third year took part in the research. Groups were intact, available for the researcher. The researcher explained that the test results would not affect their grades and only those who offered to volunteer would take part in the research. Although all teacher candidates volunteered to participate in the research, there were absentees. Absentees not attending the full requirements were excluded, but this did not affect the sample size needed for inferential statistics. There were three groups of teacher candidates attending the research. Group I included twenty-five teacher candidates. Group II and Group III included thirty-nine and thirty-seven teacher candidates, respectively. Each group of teacher candidates was taking the Early Childhood Science Education lesson during the research, and the research was carried out during these class times. Group I was assigned as the control group, while Group II and Group III were assigned as experimental groups.

Measurement

The behavior of the teacher candidates concerning the present study was measured utilizing different methods and approaches, both quantitative and qualitative, to build a coherent justification for the themes. Three different types of data sources were included, that is, survey instruments, observation and interview. Survey instruments included data obtained from applying the Formula Attitude Scale (FAS) and Newton's Second Law Test (NSLT). The teacher candidates did not write their names on either the FAS or the NSLT.

FAS

The FAS was developed and implemented by the researcher for the present study. First, twenty early childhood teacher candidates in their third year took part in the scale construction process. The teacher candidates (who later attended the experimental study) were asked a single open-ended question, *"What do you think about the formulas you encountered during the science lessons?"* The answers gathered were analyzed to generate attitude test items. The continuous scale, including sixteen Likert-type items (strongly agree to strongly disagree), were prepared and pilot-tested. Items included cognitive, affective and behavioral aspects. Three experts in science education verified content validity. The scale was filled by 278 teacher candidates not attending the present experimental study, chosen from the same department, Early Childhood Teaching, in their first, second and fourth class. Principal component analysis and Varimax rotation were used to reveal a factor analysis. Applying item-test analysis, the researcher decided to remove two items. The analysis indicated that the items accumulated under four factors. These factors were named afterwards. The first factor is the need for formulas in the lessons (7 items, $\alpha = 0.62$). The second, third and fourth were, understanding problem-formula interconnection (3 items, $\alpha = 0.68$), understanding formula symbols and proportions (2 items, $\alpha = 0.54$), and formula indispensability for life (2 items, $\alpha = 0.57$), respectively. On the other hand, overall, the Cronbach's alpha coefficient was found to be 0.75, accepted as sufficient reliability for the attitude test.

NSLT

The teacher candidates were presented with a test including a set of four question types that required knowledge of Newton's second law. In three questions, the teacher candidates were required to use one of the expressions ($F=m \times a$; $m=F/a$; $a=F/m$) derived from Newton's second law. The fourth question in a set, that requires summing the two forces acting in different directions before solving it. SI units were used in the test and in lessons. Examples given in the lessons were essentially those asked at the pre-test (0^{th} week), post-test (4^{th} week) and delayed post-test (16^{th} week), but difference was created by changing the numbers assigned for the variables.

Observation

Both researcher and colleague took the role of participant observation. While the researcher was an active participant observer, the colleague took the role of a passive observer by sitting in front of the class. The observation aimed to find how do teacher candidates feel about the lessons, their likes and dislikes, what they did, how did they listen, how did they behave in different phases of the lessons, and what do they feel and do while answering the attitude and Newton tests. The observation notes included both what the researchers heard and saw, including body language signals and reflection information based on their experiences.

Interview

The colleague of the researcher carried out face-to-face group interviews with the teacher candidates. The teacher candidates were chosen by the researcher from among those who volunteered to attend the interviews and those who attended class discussions frequently. A total of twenty-eight teacher candidates attended the interviews in different sessions (Table 1). The teacher candidates were told why they were

Table 1: Interview schedule

Session	*Group I*				*Group II*				*Group III*			
	Girl	*Boy*	*Total*	*Total time (min.)*	*Girl*	*Boy*	*Total*	*Total time (min.)*	*Girl*	*Boy*	*Total*	*Total time (min.)*
1	3	1	4	**12**	2	1	3	**10**	2	1	3	**10**
2	4	2	6	**17**	3	-	3	**10**	3	1	4	**12**
3	-	-	-	-	3	2	5	**13**	-	-	-	-
Total	7	3	10	**29**	8	3	11	**33**	5	2	7	**22**

chosen and the aim of the interviews. A specified set of questions, planned beforehand, were asked (what differences, if there were any, did you notice about this/these lessons compared to the lessons you attended before concerning physics lessons, what did you feel during the lesson/s, how was/were the lesson/s (good-bad, meaningful-nonsense, useful-useless). Only a few clarifying questions were needed. No audio or videotaping was used but, so as not to interrupt the interviews, the researcher took very short notes as keywords and expanded these notes after each interview.

Procedure

According to the early childhood teaching program held in the university, the research was carried out on successive weekdays, that is, Group I on Monday, Group II on Tuesdays, and Group III on Wednesdays. Early Childhood Science Education lessons normally last three hours. The lessons concerning the present study started with theoretical discussions and teaching applications according to the aims of the Early Childhood Science Education lesson for half an hour. Then, the time allocated for the present research, depending on the group number, began after a five-minute break. The lessons continued normally just after the application of the research sessions. The timings followed for measurement and intervention are summarized in Table 2.

Test Applications

FAS was administered twice to the groups as pre-test and post-test. NSLT on the other hand, was administered three times to the groups as pre-test, post-test and delayed post-test. Teacher candidates were given as much time to answer, but they finished in 3-8 minutes and 10-20 minutes for the FAS and NSLT, respectively. During these periods, the researcher stayed in the class to respond to any questions asked.

Lessons

Lessons began with an explanatory speech for each group, only once for each group in their first lesson. The explanatory speech informed the teacher candidates about the research study, lesson content and the way the lessons would continue. For the validity of the study the teacher candidates were not informed at all about spaced or massed learning. The content and the objectives of the lessons were decided not before, but only after the first lesson. The researcher roughly decided the objectives of the lessons beforehand, but found it reasonable to finalize the objective's decisions just after analysis of

Table 2: Measurement and intervention timing

Week	*Group I (Control)*	*Group II (Experiment)*	*Group III (Experiment)*
0		Newton's Second Law Test & Attitude Test (pre-test)	
1.			Intervention
2.		Intervention	Intervention
3.			Intervention
4.	Intervention	Intervention	Intervention
		Five minutes to study before test application	
		Newton's Second Law Test & Attitude Test (post-test)	
16.		Newton's Second Law Test (delayed post-test)	

the first intervention lesson, which was an audio video recording targeting the researcher.

The lessons included two general episodes. In the first episode a short introduction to Newton's laws in general, then the second law was stated and identified by its formula in its different expressions (F=ma; m=F/a; a=F/m), and how these expressions are related. The first episode continued to analyze the formula, its symbolization, how to assign the values to the right symbols given in the question asked, how to understand what is asked, how to choose the particular expression needed in that particular question's solution, how to place the right numbers at the formula, how to make the calculation, and how to assign the unit at the end of the calculation. The researcher wrote the required formulas on one side of the white board and did not clean the board until the end of the lessons. The second episode included solutions to questions concerning the second law. The questions themselves were not written on the board. The researcher read each question slowly while stating and writing what was given in that particular question. The researcher asked the teacher candidates to choose one of the formulas best suited for a particular question from among those already written on the board. Additional questions such as, "what shall we do now?" and "what is the answer?" were also used, but students were not given enough time or the opportunity to voice their answers, as in a traditional class (Rowe 1986), where there is a rapid presentation rate, and which is congruent with the research aim. The time spent and the number of examples solved in total for the three groups were equal at forty minutes and sixteen examples, respectively. The time allocated was adjusted by rehearsing the lesson to an empty class several times. The researcher decided to allocate ten minutes for the first episode and the solution of four questions. The researcher and his colleague agreed that this arrangement could be considered as a *rapid* presentation rate but totally traditional, which is again congruent with the research aim. The lessons were thus designed to resemble lessons carried out in a traditional physics class. The researcher and colleague did not find this difficult to do, as both have taught science and physics for more than ten years. To ensure the timing, one student from another class was present in the class and acted as a prompter, signaling to the researcher the time remaining, half of the time allocated for each presentation starting from the allocated time. For example in the massed group, the prompter signaled the time remaining as 20-10-5-2 minutes. The researcher successfully allocated the time and content for each lesson.

Massed Learning-Traditional Lesson-Control Group (Group I)

The massed learning group was taught the first episode, repeated four times consecutively. Next, they were given a set of question types, repeated four times, as follows, 1st type question, 2nd type question, 3rd type question and 4th type question, 1st type question, 2nd type question, and so on. During the interviews, Group I students clearly stated and approved that the lesson was "traditional" and teacher centered.

Spaced Learning-Intervention Lessons-Experiment Groups (Group II and Group III)

The time used in the intervention lessons for Groups II and III differed from the traditional lesson only by allocating forty minutes of traditional lesson content into two (2x20 minutes) and four (4x10 minutes), respectively. Spaced learning Group II was taught the first episode two times consecutively, and the set of question types was repeated two times in each lesson. Spaced learning Group III was taught the first episode once and a set of questions (four questions) in each lesson. During the interviews, the spaced group students clearly stated and approved that the lesson was "traditional" and teacher centered. The only difference was that the same lesson was repeated two or four times.

Data Analysis

Quantitative Data Analysis

Quantitative data analyses, both descriptive and inferential, were carried out using scores calculated for both FAS and NSLT. For comparisons, mean scores, paired sample t-test and ANOVA were utilized. The scoring for FAS depended on each item, a total of 14 items. Items in favor of formulas were scored 5 for strongly agree responses, 1 for strongly disagree, and the inverse scoring for those not in favor of the formulas. Thus, a student scored between 14 and

70. A paired, sample t-test analysis was carried out to reveal if there was a difference in the group in-between scores concerning pre-test and post-test. ANOVA was utilized to reveal if there was a difference among the three group scores.

Scoring for NSLT was based upon the lessons' objectives. As each step mentioned above is seen as important, the researcher and his colleague decided to give a value for each step. The researcher chose ten papers randomly and scored separately, to calculate the inter-rater reliability coefficient. The inter-rater reliability coefficient was seventy percent, and after discussions, the scoring technique was finalized and the second researcher continued the scoring alone. A blank scoring table for each participant was prepared, filled accordingly, and the total score was calculated for each student. Teacher candidates scored between 0 and 18. Paired sample t-test analysis was carried out to reveal if there was a difference in the group between scores concerning pre-test, post-test and delayed post-tests.

Qualitative Data Analysis

Qualitative data analysis was based on observations and group interviews. Data from each source was independently analyzed to obtain meanings, and the data interpreted from these sources was analyzed together to finalize the analysis.

Observations

Observation notes from what the researcher and his colleague saw and heard during the lessons were taken separately by them, and were analyzed by the researcher and his colleague together. In the procedure of the lessons, the agreed phases were timing of each lesson (beginning, course of time and last period), repetition, reification, questioning and answering, and silent periods. Then, codes were assigned or the behaviors were interpreted for each phase and tabulated to enhance comprehensive analysis for group comparison (Table 3).

Group Interviews

Expanded notes taken soon after the interviews were tabulated and then analyzed. This process was carried out by the researcher and his colleague studying together. A typical example is presented in Table 4, including statement, coding, categorization and interpretation strategies, and decisions for a boy attending session 2 in Group I (Massed Learning), and a girl attending session 1 in Group III, (Spaced Learning). To see the effect of the intervention, themes

Table 3: Observational data analyses example

Observation Method	*Phase*	*Behaviour/ Signal*	*Interpreted as*						
			Motivated	*Bored*	*Convince*	*Lack Interest*	*Anxiety*	*Happy*	*Relax*
See	Repeating the formulas	Check others			√				
	First solution process	Listen carefully	√		√				
	Reification	Nodding	√		√				
	Silent period	Talk to others				√			
	In the course of time	Sulk		√		√			
	Lasting the course	Smile						√	
	First encounter with the formulas	Talk to others					√		
Hear	Researcher explained that same solution approaches will be held	Say: "haa...							√
	what will we do next?″	Answer the questions″	√						
	Questioning: which formula do we need for this question?″	Answer the questions	√		√				

Table 4: Coding and categorisation procedure examples for group interviews

		Massed learning (Group I; Session 2; a boy)		
Statements	*Theme*	*Code*	*Category*	*Interpreted as*
Comparing with the high school		learned	Learning Outcome	Successful
the course was good. The course was				
classic, we were passive, as in				
the high school, only more	The present course	classic	Learning Process	Traditional
questions are solved. I learn if				
plenty of examples are solved and		repeated	Learning Process	Useful
explained. But I felt bored in time,		questions		
as there were a lot of questions and		bored	Learning Outcome	Boring
they look very alike. The subject				
should be changed during one lesson.	High school physics	classic	Learning Process	Traditional
	courses	not learn	Learning Outcome	Unsuccessful
		Spaced Learning (Group IIII; Session 1; a girl)		
Statements	*Theme*	*Code*	*Category*	*Interpreted as*
The subject was easy. But I have		easy	Learning Outcome	Successful
friends still not successful in solving		teacher		
the problems, although the same subject		centred	Learning Process	Traditional
was repeated for four weeks. I think	The present course			
the lessons should be student centred not	repeated			
teacher centred as in the present study		questions	Learning Process	Useful
and in high school. I think the lesson	High school physics	changed belief		
was successful. Before this lesson I	physics courses	/attitude	Learning Outcome	Successful
had prejudice about physics but I can		teacher	Learning Process	Traditional
manage solving the problems now.		centred		
		not manage	Learning Outcome	Unsuccessful

were chosen for both the present courses and high school physics courses, to define the teacher candidates' experiences before the present course. Codes were revealed from the students' statements, categorized, and interpreted accordingly. The last process was to compare the interpretations obtained from the three approaches.

Following the quantitative and qualitative analysis, the data was separated and grouped as belonging to knowledge (learning and retrieval) and attitude. Thus, the results regarding attitudes to formulas were organized and interpreted using the Formula Attitude Test and interview data. Observations and interview data were used for attitude to repetition. Finally, for knowledge, data was obtained from NSLT, observations and interviews.

RESULTS

Attitude to Formula

The results showed that there was a change in the mean of each group. An increase in Group I (41.4 to 48.2), a slight decrease in Group II (46.4 to 45.0), and an increase in Group III (46.6 to 51.0) concerning the differences between post-tests and pre-tests. Statistical analysis showed that while attitudes toward Newton's formula for Group II and Group III did not change significantly ($p > 0.05$ for each group), there was a significant change within Group I ($p = 0.042$) in favor of post-test. On the other hand, the ANOVA results showed that no one group showed a statistically significant improvement over the other two groups concerning attitudes towards the formula, which was one of the main topics of the research. The students showed anxiety at the beginning of the present study whenever they were told that the subject would be formulas. Thus, it is interpreted that learning formulas at the beginning of the present study is perceived to be difficult for the participants. In particular, in the interviews, some of the teacher candidates in Group III confessed that they had prejudices concerning the formulas and physics lessons before the present study. However, afterwards, they had changed their minds and began to think that lessons in physics were not as difficult as they had previously thought.

Attitude to Repetition

Observations showed that the approach of repeating the same formulas and solutions to each question made the teacher candidates feel relaxed and reassured. The teacher candidates were focused on the lesson when the researcher said, “We are going to repeat the same [emphasized in the lessons as well] solution approaches in further questions, there will be no more new information to come, and we are going to use only these formulas the same way each time”. This explanation even made some of the teacher candidates look around, checking others’ behaviors, feeling convinced that they knew the rest of the solution, and that there was no need to watch the researcher for the rest of the solution. The data gathered by observation showed that there was no significant difference among the three groups concerning attitudes to repetition. The teacher candidates did not believe in traditional teaching methods. All of the teacher candidates attending the interviews criticized traditional teaching methods, but they praised the use of repeated exercises. Some of them even stated that “repeating the subject is the key to learning, although utilizing the traditional teaching methods the addition of repetition would cause success”. Only one difference was revealed between the groups stated by six of the teacher candidates in Group I. They praised the use of repeated exercises, and stated that the lesson was successful. However, while they learned the subject at first, they eventually became bored and stopped focusing on the course. This kind of answer did not arise from the Group II and Group III teacher candidates. From this result it can be interpreted that teacher candidates in spaced learning conditions are not bored, which shows one very important and advantageous feature of the spaced learning approach. On the contrary, it can be interpreted that massing causes boredom.

Knowledge

Teacher candidates improved in the Newton test. Three post-test sores were significantly greater than the pre-test scores of each group ($p<0.001$). This was not the case between the three groups, as the ANOVA results showed that no one group showed a statistically significant improvement over the other two ($p>0.05$). All of the teacher candidates attending the interviews consistently stated that they had learned the subject.

Differences between the post-test and delayed post-tests scores of each group showed that the mean for each group decreased in the final test, that is, the delayed post-test. However, the only significant decrease was found in Group III ($p<0.001$), not the other two groups. The mean of Group III was found to be significantly less than the Group I mean ($p<0.05$) concerning the delayed post-test results. Thus, the effect of negative spacing is revealed for memory. No significant difference was found concerning the means between Group II and Group I, and between Group II and Group III.

DISCUSSION

Findings of the present study contradict a huge number of researches (for example, Zulkiply et al. 2012; Zhao 2015; Swehla et al. 2016). On the other hand, this finding, contradicting spacing effect in general, but covering presentation in a real school context with a rapid rate, is consistent with Toppino et al. (2009). The spaced learning group lacked the opportunity to recover the wanting parts of the course as the spacing gap was too long, and they started to learn the subject from a beginner’s level each time. This is consistent with Cepeda et al. (2009). The spaced group students learn the course for the post-test (the exam) only, and not for the delayed post-test (3 months after the last lesson), to which they are accustomed. Massed learning, on the other hand, significantly improved attitudes towards the formulas, and it showed better memory than spaced learning for Group III. Thus, a negative effect of spacing was revealed because the massed group of students had the opportunity to listen to the first episode and each of the question types four times consecutively in a course, decreasing the effect of a rapid rate. Thus, they had the time to relate what they already knew/learned, and the formula’s contents and questions, with each other. Kapler et al. (2015) stated some other distractors of space effect, concerning student behavior and class management issues. However, the researcher of the present study is still cautious regarding the use of massed learning as it annoyed the students, contradicting findings of Zulkiply et al. (2012). Further research of spaced learning in a real school context, with consecutive task repetition to decrease the rapid rate effect and a shorter spacing gap, is recommended.

CONCLUSION

The effect of spacing was not revealed in learning formulas, presented in a real school context with a rapid presentation rate, contradicting the assertion of the present study. During the present study, the traditional group repeated the same task four times consecutively. All three groups showed significant achievement in learning the formula. Spaced learning did not achieve significant differences in attitudes towards formulas, but has the capacity to overcome prejudice concerning formulas. A significant decrease in recall was found concerning spaced learning for Group III only.

REFERENCES

Bahrick HP, Bahrick LE, Bahrick AS, Bahrick PE 1993. Maintenance of foreign language vocabulary and the spacing effect. *Psychological Science*, 4: 316-321.

Bahrick HP, Phelps E 1987. Retention of Spanish vocabulary over eight years. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 13: 344-349.

Bar V, Zinn B, Goldmuntz R, Sneider C 1994. Children's concepts about weight and free fall. *Science Education*, 78(2): 149-169.

Benjamin AS, Bird RD 2006. Metacognitive control of the spacing of study repetitions. *Journal of Memory and Language*, 55: 126-137.

Carpenter SK, Pashler H, Cepeda NJ 2009. Using tests to enhance 8th grade students' retention of US history facts. *Applied Cognitive Psychology*, 23: 760-771.

Cepeda NJ, Coburn N, Rohrer D, Wixted JT, Mozer MC, Pashler H 2009. Optimizing distributed practice. *Experimental Psychology*, 56: 236-246.

Childers JB, Tomasello M 2002. Two-year-olds learn novel nouns, verbs, and conventional actions from massed or distributed exposures. *Developmental Psychology*, 38: 967-978.

Creswell JW 2008. *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research.* 3rd Edition. New Jersey: Pearson International Edition.

Francis LJ, Greer JE 1999. Measuring attitude towards science among secondary school students: The affective domain. *Research in Science and Technological Education*, 17(2): 219-226.

Gluckman M, Vlach HA, Sanhofer CM 2014. Spacing simultaneously promotes multiple forms of learning in children's science curriculum. *Applied Cognitive Psychology*, 28: 266-273.

Grimaldi PJ, Karpicke JD 2012. When and why do retrieval attempts enhance subsequent encoding? *Memory and Cognition*, 40: 505-513.

Kahana MJ, Howard MW 2005. Spacing and lag effects in free recall of pure lists. *Psychonomic Bulletin and Review*, 12: 159-164.

Kapler IV, Weston T, Wisehart M 2015. Spacing in a simulated undergraduate classroom: Long-term benefits for factual and higher-level learning. *Learning and Instruction*, 36: 38-45.

Karpicke JD, Bauernschmidt A 2011. Spaced retrieval: Absolute spacing enhances learning regardless of relative spacing. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 37(5): 1250-1257.

Kornell N, Bjork RA 2008. Learning concepts and categories: Is spacing the "Enemy of induction"? *Psychological Science*, 19(6): 585-592.

Lipson A 1992. The confused student in introductory Science. *College Teaching*, 40(3): 91-95.

Meixia D 2016. Opportunities to learn: Inverse relations in U.S. and Chinese textbooks. *Mathematical Thinking and Learning*, 18(1): 45-68.

Metcalfe J, Kornell N 2003. The dynamics of learning and allocation of study time to a region of proximal learning. *Journal of Experimental Psychology: General*, 132: 530-542.

Rea CP, Modigliani V 1987. The spacing effect in 4 to 9 year-old children. *Memory and Cognition*, 15: 436-443.

Reynolds JH, Glaser R 1964. Effects of repetition and spaced review upon retention of a complex learning task. *Journal of Educational Psychology*, 55: 297-308.

Rohrer D, Taylor K 2006. The effects of overlearning and distributed practice on the retention of mathematics knowledge. *Applied Cognitive Psychology*, 20: 1209-1224.

Rohrer D, Taylor K 2007. The shuffling of mathematics practice problems boosts learning. *Instructional Science*, 35: 481-498.

Rowe MB 1986. Wait-time: Slowing down may be a way of speeding up. *Journal of Teacher Education*, 37: 43-50.

Seabrook R, Brown GD, Solity JE 2005. Distributed and massed practice: From laboratory to classroom. *Applied Cognitive Psychology*, 19: 107-122.

Smolen P, Zhang Y, Byrne JH 2016. The right time to learn: mechanism and optimization of spaced learning. *Nature Reviews Neuroscience*, 17: 77-88.

Sobel HS, Cepeda NJ, Kapler IV 2011. Spacing effects in real-world classroom vocabulary learning. *Applied Cognitive Psychology*, 25: 763-767.

Son LK 2004. Spacing one study: Evidence for a metacognitive control strategy. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 30: 601-604.

Swehla SE, Burns MK, Zaslofsky AF, Hall MS, Varma S, Volpe R 2016. Examining the use of spacing effect to increase the efficiency of incremental rehearsal. *Psychology in the Schools*, 53(4): 404-415.

Toppino TC, DiGeorge W 1984. The spacing effect in free recall emerges with development. *Memory and Cognition*, 12: 118-122.

Toppino TC 1991. The spacing effect in young children's freecall: Support for automatic- process explanations. *Memory and Cognition*, 19(2): 159-167.

Toppino TC 1993. The spacing effect in children's free recall of pictures and words. *Bulletin of the Psychonomic Society*, 31: 27-30.

Tsai CC 2002. Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, 24(8): 771-783.

Tsao JC 1948a. Studies in spaced and massed learning: I time period and amount of practice. *Quarterly Journal of Experimental Psychology*, 1(1): 29-36. DOI: 10.1080/17470214808416740J. C.

Tsao JC 1948b. Studies in spaced and massed learning: II Meaningfulness of material and distribution of practice. *Quarterly Journal of Experimental Psychology*, 1(2): 79-84. DOI: 0.1080/17470214 808416748.

Van der Geer J, Hanraads JAJ, Lupton RA 2000. The art of writing a scientific article. *Journal of Science Communication*, 163: 51–59.

Verkoeijen PPJL, Rikers RMJP, Ozsoy B 2008. Distributed rereading can hurt the spacing effect in text memory. *Applied Cognitive Psychology*, 22: 685-695.

Vlach HA, Sandhofer CM, Kornell N 2008. The spacing effect in children's memory and category induction. *Cognition*, 109: 163-167.

Vlach HA, Sandhofer CM 2012. Distributing learning over time: The spacing effect in children's acquisition and generalization of science concepts. *Child Development*, 83(4): 1137-1144.

Zhao X, Wang C, Liu Q, Xiao X, Jiang T, Chen C, Xue G 2015. Neural mechanism of the spacing effect in episodic memory: A parallel EEG and fMRI study. *Cortex*, 69: 76-92.

Zulkiply N, McLean J, Burt JS, Bath D 2012. Spacing and induction: Application to exemplars presented as auditory and visual text. *Learning and Instruction*, 22: 215-221.