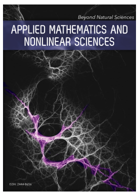
sciendo
Applied Mathematics and Nonlinear Sciences 5(2) (2020) 425–434



Applied Mathematics and Nonlinear Sciences

https://www.sciendo.com

Experimental simulation of mathematical learning process based on 'chunk-objective'

Yukong Zhang[1]†, Hongwei Li[2], John D. Clark[3]

[1]School of Teacher Education,Weifang University, Weifang, China

[2]Weifang High-Tech Phoenix School, Weifang, China, E-mail: lihongwei0536@163.com

[3]Laboratory of Neuroscience and Cognition, University of Maryland, Maryland, USA,
E-mail: Johnclark@umd.edu.cn

Submission Info

Communicated by Juan Luis García Guirao
Received June 3rd 2020
Accepted August 14th 2020
Available online December 21st 2020

Abstract

Traditional mathematics learning always paid excessive attention to the memorisation and repeated practice of theoretical knowledge and ignored guidance on learning method, resulting in bad learning outcome and insufficient problem-solving ability. Based on the theory of 'chunks' and 'objective', this paper analyses the mathematics learning process from the perspective of experimental simulation, designs a mathematics learning process based on 'chunk-objective', and simulates it. The data show that the learning mode is scientific and effective, which can help students learn better according to cognitive rules, thus forming their knowledge structure and improving their ability to solve problems.

Keywords: experimental simulation, chunk-objective, mathematical learning process
AMS 2010 codes: F17449

1 Introduction

Mathematics is a fundamental course to train the ability of thinking, and the learning of mathematics is crucial to the development of students thinking ability, intelligence and problem-solving ability. Moreover, the contents of middle school mathematics are enormous, complex and intersectional, it is very difficult for students to study. So, mathematical teaching should adopt scientific methods to guide student to master learning contents step by step, build knowledge framework through continuous practice and reflection and finally form mathematical ability. However, currently, mathematical teaching of middle school over-emphasizes the memorization of concept, formula and theorem as well as excessive repeated exercises, which often decrease learning interest and the missing of learning initiative. Therefore, using scientific learning method to motivate students' learning incentive is very important for mathematical learning.

†Corresponding author.
Email address: jyjs217@163.com

sciendo
ISSN 2444-8656 doi:10.2478/AMNS.2020.2.00061 sciendo

Objective teaching method is a kind of classroom teaching method with teaching objective as its core, and its teaching process and activities always revolve around teaching objective, which could effectively stimulate students' learning interest and enthusiasm. The chunk theory, a type of cognitive theory, considers that 'chunk' is a storage form of knowledge in human brain and is the recoding of knowledge by brain [1]. This theory 'truly' reflects the course of processing knowledge in brain.

This study will regard the mathematics chunks as the target of learning, analyse the formation process of mathematics chunk, design the mathematics learning process and simulate the learning process. On this basis, the learning effect will be verified and the corresponding learning strategies will be proposed.

2 State of the Art

Recently, the application of chunk theory in mathematical learning mainly focuses on three categories: teaching practice, experimental research and theoretical research. Among them, there are more researches on teaching practice and experimental research at home and abroad respectively, and theoretical research has been studied both at home and abroad.

At the level of teaching practice, Yuefu Shen put forward 'chunk teaching' model based on the characteristics of review lessons of middle school mathematics. By exploring the deep-seated knowledge points of mathematical exercises, the model aims to enable students to associate vertical and horizontal knowledge points, and be able to solve multiple similar questions by knowing one knowledge points, so as to achieve the goal of 'combing knowledge points through questions' and 'discussing solution through questions', and make the knowledge and experience to develop synchronously with ability and thoughts. But this research was only for review and ignored the accumulation of knowledge learning at ordinary times, so the actual effects of this learning method should be verified comprehensively. SongRu Zheng carried out a chunk theory based teaching strategy research integrating with Geometry learning, which provides guidance to effective mathematical learning. But this research expounded merely with geometrical problem, lacking of theoretical analysis and the effects of 'migration' from special category to general one.

To analyze the level of experiment, Beishuizen made two independent sample learning experiments, and concluded that there were significant differences between the performance of experiment group and control group [2]; Nicola Spotorno made a psychological experiment and concluded that chunk learning could stimulate students' learning motivation [3]. They have verified through experimental data that the chunk theory is effective to learning and teaching.

XiaoXing conducted a theoretical research for which he set forth from cognitive psychology, used the chunk theory in the learning of primary school mathematics, made an analysis on the similar chunk learning, problem solving, pattern recognition and other mathematical problems, and described the principle of mathematical learning in essence, which can better enlighten teachers and students in their teaching and learning. But he only analysed mathematical learning from knowledge management, rather than from the perspective of learning and teaching, so this research cannot comprehensively guide the teaching practice. Kamran Sedig et al. used the knowledge of cognitive psychology, visually described the knowledge framework of mathematical chunks [4], and provided an intuitive and vivid explanation for mathematical learning. Nevertheless, as its visual angle is only limited to psychology, its description is still more subjective without the help of brain science and bioscience and other physical sciences.

The above application research of chunk in mathematical learning still did not involve two aspects: first, they have not combined students' cognition to deeply analyse the formation process of chunk, so that the teachers couldn't have a deep understanding of students' learning, thus indirectly affecting the effective implementation of learning activities. Second, they haven't put forward specific and workable procedure for the implementation of chunk learning. This paper exactly explores on basis of this.

3 Methodology

3.1 Principle and characteristics of the chunk

(1) Principle of chunk

Chunk is a concept in cognitive psychology, which means a combination of multiple components that are closely interconnected with each other [5]. The concept of chunk was initially proposed by George A.Mile, a well-known American psychologist, aiming to explain how information is encoded in short-term memory. In 1973, Chase and Simon raised the Chunk-learning Theory[6]: when a learner is studying, he/she encodes and extracts new knowledge with 'chunk' as unit. Chunk, as an effective strategy of information processing, integrates complex fragmentary knowledge as a whole, makes hard things simple, highlights the significance and effectively expands the space of memory.

The cognitive scientific research also indicates that knowledge is not dispersedly stored in human brain, but stored in form of 'group' or 'block' [7]. The surrounding information firstly enters the instantaneous memory through perception, and then, partial information enters the working memory via selective attention. The working memory is an information processing zone, which compares, infers and classifies the new information with the existing knowledge, so as to encode information and form meaningful chunk. After the chunk is stored in long-term memory, it can be transferred from long-term memory to the working memory at any time under the stimulus of related information, which is an extraction exercise.

According to the view of neuroscientists, learning is a process in which neurons transfer signals to each other through electric discharge in essence [8]. When two neurons transfer information, they are transferring neuronal discharge, where the signals are transferred from axon to the dendrite of receiving neuron, and these two neurons complete the transfer of signal by delivering neurotransmitter. The process is simulated in Fig. 1. When Neuron A receives a stimulus, it causes Neuron to action; if Neuron A discharges multiple times by repeat or exercise, a connection will be built between Neuron A and B; similarly, the discharge of Neuron B can also activate Neurons C, D and E. In case these activities repeatedly occur, these five neurons will form a network; through multiple repeated activities, the interconnected numerous neurons in different brain zones will form a chunk with specific relationship. Therefore, the formation of chunk depends on analysis, comparison and other thinking activities, and its nature is the process that multiple neurons transfer signals to establish a connection. The research shows that the connection between knowledge chunks is essentially a synthesis of protein[9]. At the same time, the formation of chunk is a process needing multiple and repeated consolidation. In this process, the memory gradually tends to stable from a unstable state, accompanied with the synthesis of new protein[10]. After the chunk is formed, when the neuronal activities caused by external stimulus is related or similar to the characteristics of neuronal activities in chunk, the chunk will be activated, causing the activities of neurons in related brain zones.

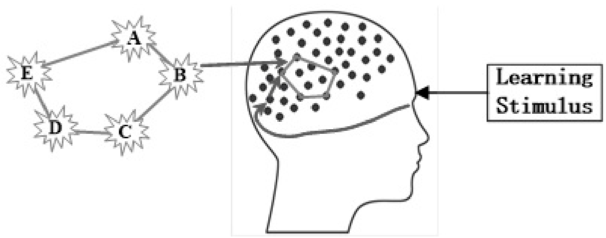


Fig. 1 The process of chunk formation and calling

(2) Characteristics of chunk

First, chunks have the characteristics of reconstruction. Andre Giordan, a doctor of science in biology and education of university of Geneva, Switzerland, has proposed that learning is as complex as alchemy, which is an allotectonic process characterised by reconstruction. The reconstruction of chunk is initially manifested in its formation process. It not only requires that the sub-contents be digested and absorbed to clarify the internal principle and operation process of the chunk, but also requires learners to step out of the sub-contents and examine its whole functions, conditions and conclusions from the holistic perspective. It is this kind of transformation that combines its sub-content and connects them from different directions, forming the function chunk with specific relations, and producing the effect of '1+1>2'. In addition, its reconstruction also has the characteristic of construction. The formation of chunk, including the reflection on internal sub-contents and external reflection, will be affected by the knowledge, experience and cognitive structure of the learning subject. With the same unit knowledge, some learners may construct it into chunk, while others cannot. Some people may build the chunk tight, solid, with high quality, while some people may build it loose and unstable. Therefore, chunk is the embodiment of learners' existing knowledge and unique mind.

Secondly, chunks have the property of encapsulation. Encapsulation refers to treating a chunk as a separate unit, hiding its internal details as much as possible, and using it only by calling its methods and properties. When the unit knowledge is formed into a chunk, they are encapsulated into a 'box' with specific functions which shows relative stability and the specific procedural knowledge in it. The box has some 'interface' methods and properties, such as what it can do, when to use it, and how it relates to other chunks. When analysing the problems by chunk, it is not necessary to pay too much attention to its internal knowledge, but only to its interface.

Blending is also an important feature of chunk. Primary and secondary school mathematics textbooks are arranged according to the order of content from simple to complex and from easy to difficult. Therefore, the chunks before and after show a strong hierarchical or inclusive relationship, such as the relationship between monomial multiplication and the power of the same base number, the power of product and the power of power, the relationship between polynomial multiplication and monomial multiplication. On the other hand, different chunks have transverse cross relations. Such as function, equation and inequality. The characteristic makes the mathematical chunks present a network relation of interrelation, and each one is connected and closely related, which provides several paths for solving mathematical problems. Studies have shown that the differences between experts and novices mainlyexist in their different ways of organising, storing and applying knowledge [11].For example, experts can better extract and apply knowledge by means of chunk strategy [12], and can quickly identify some meaningful patterns and structures based on experience. They also tend to associate specific knowledge with deep principles or schemas, so as to realise knowledge transfer [13]. All of these have to do with the network of knowledge structures and cognitive structures of the experts. The research also shows that because their knowledge structure is reticular, even when a link in the structural chain is broken, it will be automatically repaired.

3.2 Analysis on the chunk-based mathematical learning process

It is known from above analysis of chunk formation process that chunk is a product that the brain re-encodes the information when learning, and is the connection of neurons. As shown in Fig. 2, the operating principle of mathematical chunk includes chunk formation and chunk calling.

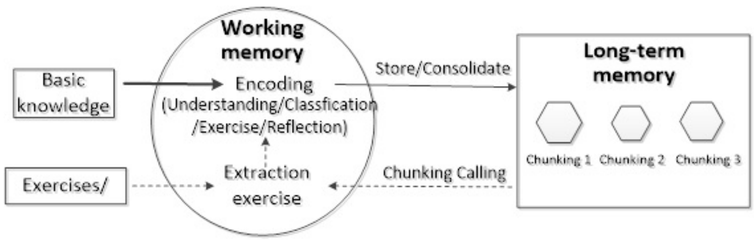


Fig. 2 Formation and extraction of mathematical chunk

(1) Formation of chunk

Combining mathematical knowledge with the above analysis of the formation process of chunks, we can see that the formation of each mathematical block includes two stages of internal understanding and external reflection. If the current knowledge is treated as a whole, internal understanding is an understanding of the internal sub-content, while external reflection is the reflection of the whole and other parts of the same level. When these two stages are completed, the current knowledge can be construed as a mathematical block.

- Internal understanding stage

This stage refers to that basic knowledge should be deeply understood at first. In this process, current knowledge is analysed, compared and classified with existing concepts, formulas, theorems or methods in long-term memory, and it will be assimilated or adapted. This stage proceeds accompanied with the learning of basic knowledge.

- External reflection stage

In this stage, the learners will look at knowledge from the perspective of a 'third party' rather than the knowledge itself: what problem can it solve? When do we use it? What's the condition to use it? When these questions are figured out, a chunk will initially form in the long-term memory, that's to say, distributed neuron links are formed in the brain. Of course, this chunk is not stable, and needs continuous practice and reflection to consolidate.

(2) Calling of chunk

The calling of chunk is completed by extraction exercise. On one side, chunk is used to solve problem, on the other side, chunk should be consolidated and improved. Just as Dr. Karpicke from the Cognition and Learning Laboratory of Purdue University said that, 'extraction is a key process to understand and promote learning, and extraction exercise can produce meaningful learning' [14].

Some research [7] have demonstrated that the differences in students' problem-solving ability mainly depend on the distinction of chunks and the application of adjustment strategy.

3.3 Design of chunk-objective-based mathematics learning process

Objective learning method is a learning method commonly used in classroom learning of elementary education since 1990s. It combines classroom learning process with definite objectives, having greatly improved students' learning initiative and learning efficiency. During elementary education, the arrangement of mathematical knowledge has a strong hierarchy and progressive relationship, and every part of knowledge can be considered as a chunk. The learning activities taking mathematics chunks as objectives could help students to rapidly construct their knowledge framework, deeply understand knowledge by horizontal and vertical connections, and improve learning effects.

There are many knowledge points in mathematics. Many students cannot grasp these fragmentary knowledge systematically when they study. At the same time, they are not clear about the relationship between exercise and knowledge points. In this paper, the word 'chunk goal' is put forward, which aims to take mathematical chunks as the learning goal, so as to improve the pertinence of students' learning. 'Chunk-objective-based learning' refers to a teaching mode that regards chunk as a learning goal, which can help students grasp knowledge better and improve their ability to solve problems.

It is discovered through practice of the chunk-objective-based learning that students should understand, apply and reflect on knowledge points in every link and node, so as to construct knowledge chunks and form a systematic knowledge framework (Fig. 3).

(1) Construct chunks in new lesson

Mathematics textbooks shall follow strong logical relationship, and the contents of each section are displayed as module or a form similar to module. The major task of new lessons is to guide students to reconstruct

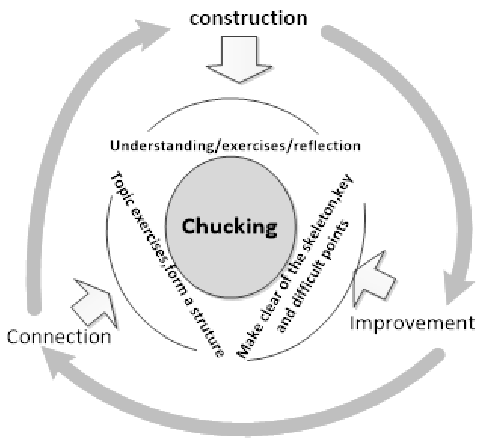


Fig. 3 Design of Mathematics Chunk learning

modularised knowledge into 'chunks' in brain. The formation of chunk is both a deconstruction process and a construction process [16], which includes three sub-processes: component understanding, exercise application and reflective construction. Component understanding focuses on grasping the sub-component knowledge that constitutes the chunk from the angle of structure and procedural knowledge. Exercise application is mainly to carry out extraction exercises of the chunk through tasks, so as to consolidate sub-content knowledge and improve the application automation of chunk. Reflective construction refers to jumping out of chunk itself and thinking the problems like 'what it is' and 'why it do in this way' from outside of chunk, so it is a more essential to understand of chunk knowledge. For example, to give solution to practical problems by using equation set, first, it is required to understand the meaning of the question, find out equivalent relationships, and expresses them with unknown variables, to constitute equation set. Through repetition of exercises, the chunk of 'equation thought' will be formed. That's to say, as long as you set up an equation set according to the meaning of description, making the number of equations included in the equation set to equal to the number of unknown variables, you can complete the task.

This process of constructing chunk is consistent with Bloom's cognitive goals. The 'component understanding' and 'exercise application' correspond to 'understanding' and 'application' of Blooms' respectively, while 'reflective construction' corresponds to higher objectives like 'analysis', 'integration', 'evaluation' and so on.

(2) Perfect chunks in exercise lesson

Exercise lesson refers to the class type of systematic practice of the learned knowledge after a stage of learning. Its purpose is to guide students to recognise the knowledge structure and promote digestion ability. From the perspective of chunk, it is also a process of applying and improving the knowledge chunk. On one hand, through the extraction practice of exercises, the students could consolidate the component knowledge inside the chunk, find out key points, further clarify the 'muscles' and 'veins' of the chunk, and reach to automatic level; on the other hand, it is essential to discover bias through errors in the learning process, sort out the difficulty and fallible points of chunk application, further repair chunk by reflection and induction. The knowledge chunk polished by exercises is an angular and clear-cut mathematical model, which is the basis of constructing new knowledge and solving model in the future.

(3) Link chunks in topic lesson

The mathematical comprehensive abilities not only requires a deep grasping of learning content, but also needs to develop connections among various parts. In other words, this requires a horizontal and vertical association of chunk on the basis of deeply grasping the knowledge chunk. In the process of linking chunks by topic lessons, it is first to help students to sort out the knowledge structure of current part with chunk as unit,

Table 1 Comparison of knowledge chunk abilities and scores before experiment

	Chunk_consciousness	Error_correction ability	Knowledge_structure	Scores
t	0.384	-0.409	1.192	0.565
p	0.702	0.684	0.237	0.574

then guide students to understand the relationships between chunks via topic practices, and comprehensively use each chunk to solve problem. Similarly, confused and contrary knowledge chunk can be deeply analysed through connection, so as to make clear of the function and application of chunk from peripheral interface and thus to form a systematic knowledge network structure. This helps students to expand their divergent thinking ability. For example, after the unit 'one-variable quadratic inequality' is taught, the teachers could connect it with 'one-variable quadratic equation' and 'one-variable quadratic function' chunks, helping students to understand one-variable quadratic inequality with the help of 'one-variable quadratic equation' and 'one-variable quadratic function', form an one-variable quadratic function centred knowledge network, and generate a profound understanding of the thought 'combination of numbers and figures'. Through extensive knowledge practices, the students will be able to deeply understand the parallel, progressive or inclusive relationships between knowledge chunks, form lucid logic knowledge structure and obtain basis to solve problem.

4 Result Analysis and Discussion

4.1 Application practice

To investigate the effects of chunk-objective learning method, two teaching classes of junior middle school freshman in F school in W city were taken as samples to make a comparative teaching experiment in three-consecutive-units teaching: the control class adopted regular teaching, and the experimental class were taught according to above design which highlighted chunk objective, chunk orientation and knowledge structure. Based on the principle and process design of chunk-learning and through expert assessment, the students' knowledge structure, knowledge chunk awareness and reflective error-correction ability were determined as three indexes to influence knowledge chunk ability, and we designed an experiment, collected data and made corresponding analysis with the three indexes. These three indexes reflect students' mastery of 'chunk-objective-based learning' from three aspects of cognition, emotion and behaviour. The first one is the result of systematisation of mathematical chunk knowledge, which reflects students' learning situation of chunks. The second one reflects students' understanding of chunk learning methods, and the third one shows the students' ability to use chunks.

(1) Comparison of knowledge chunk abilities and scores before experiment

Before the experiment, the above three indexes of experimental class and control class were measured, and the last unit test score was taken as pre-test score. Then two (both) classes received independent sample T test. It can be seen from the results in Table 1 that there was no significant difference among the four variables ($p>0.05$), indicating that both classes are parallel class and suitable for experiments.

(2) Comparison of knowledge chunk abilities and scores after experiment

After experiment, correlated sample t-test was conducted on three indexes and unit test scores of both classes, and the results are shown in Table 2. It can be seen from the table that, each index of control class shows no significant difference ($p>0.05$), while each index of experimental class shows more significant difference ($p<0.01$). This indicates that the experiment exactly facilitate the promotion of all indexes and scores.

(3) Correlation analysis of knowledge chunk abilities and scores in experimental class

The sum of three indexes scores of experimental class is considered as the level of students' knowledge chunk abilities, and a correlation analysis is made between the abilities and unit test scores. The results show that the correlation coefficient between them is 0.807 ($p<0.01$), so they are significantly correlated. This indicates that the experiment facilitates the raise of scores by promoting students' knowledge chunk abilities.

Table 2 Comparison of knowledge chunk abilities and scores after experiment

		Chunk consciousness	Error correction ability	Knowledge structure	Scores
Control class	Correlations	0.78	0.658	0.885	0.892
	t	0.603	0.978	1.517	1.550
	P	0.55	0.334	0.137	0.129
Experimental class	Correlations	0.818	0.826	0.666	0.691
	t	-5.818	-6.549	-7.623	-3.351
	P	0.000**	0.000**	0.000**	0.002**

4.2 Strategies and enlightenment

Through practice, it is discovered that knowledge chunks constitute the organisational structural relationships of different parts in mathematics knowledge system. During the learning of mathematics in middle school, students should be guided to cultivate the consciousness and the strategies of chunk-learning, which follow the principles of 'combination of learning and practicing' and 'equal emphasis on thinking and practicing', instruct students to learn from parts to whole, from whole to network, and deal with the relationships among understanding, practice and reflection scientifically.

(1) Use chunks to help student constructing knowledge network

As an 'object', mathematical chunk is a deep form of mathematical knowledge [16]. It is an understanding about 'what it is' formed after the knowledge is processed through 'psychological activity' and 'operating procedures'. Chunks contribute to forming knowledge network more quickly and effectively, thereby providing foundation for deep thinking activity. There are three points to build a knowledge network by chunks. First, it is required to systematically grasp every chunk, from its internal structure to overall function. At the same time, appropriate exercises can help chunk application to achieve automation. Second, after an entire unit is taught, the knowledge should be sorted and summarised with the form of chunks, so as to grasp the structure of the part. Finally, the relationships between two chunks can be well understood with the help of comprehensive and topic training, and the important nodes of the chunks can be made clear by the reflection to wrong and typical questions. So that, the whole knowledge structure is clear, and the vein is distinct. To get a better effect of chunk learning, it is better to draw the knowledge structure by form of mind map, write it down by form of semantic knowledge, and make correction and improvement by continuous exercises.

(2) Help students to enhance reflection ability in chunk-learning

Deep comprehension of mathematics mainly depends on students' understanding, which can be achieved only by continuous reflection. The abstractness of mathematical objects, the exploration of mathematical activities, the preciseness of mathematical reasoning and the particularity of mathematical language determine that middle school students who are in the stage of thinking development cannot directly grasp the essence of mathematics, and must achieve it through reflection after learning. As American mathematician Polya said, 'the solution of mathematics problem was only a half, and what more important was the retrospect after solution' [17]. Reflection runs through the whole process of mathematics chunk learning. The process of chunk formation should reflect the relationships between current knowledge and previous knowledge and cultivate the connective thinking ability and network thinking ability in mathematics learning.

The process of chunk extraction exercise should reflect the generative condition knowledge and objective knowledge of chunk, and develop students' reasoning ability and logical thinking ability. In the exercises for mistakes and difficulties, we should reflect on the relationships among the relevant mathematics chunks, train divergent thinking and comprehensive thinking ability, reflect on learning attitude and self-belief, and cultivate scientific concept of mathematics.

(3) Establish problem-solving framework with chunks, cultivate students' logical reasoning abilities

Problem solution is a process of exploration from 'a known state' to a target state'. When it comes to problem solving, it's important to frame the solution, not how to do it. Mathematical chunk is a kind of modular knowledge with specific functions and characteristics. When solving a problem, teachers should guide students to quickly reason the problem with chunks on basis of the analysis, build an idea and set up a solution to the problem quickly. Furthermore, the solution set up with knowledge chunks could clearly show the problem-solving process, which is conducive for students to study and analyse the problem-solving idea as well as the relationships among different parts, and to promote their understanding of mathematical thoughts and methods.

(4) Students and teachers should implement deep learning and teaching with the help of chunk theory

Based on the above factors, we realise that chunk theory has an important application in mathematics learning. The mathematical knowledge units can be seen as different chunks, and they are closely related to each other. When learning mathematics, students can understand the knowledge from different dimensions with the help of the chunk theory, such as internal and external, micro and macro, conditions and applications, so as to achieve a deep grasp of mathematical knowledge. Therefore, it is necessary for students to understand the chunk theory while learning mathematical knowledge. More importantly, teachers should fully comprehend the chunk theory. In teaching, teachers should not only teach students how to do exercises, but also teach students how to learn, which requires teachers to motivate students to think from a higher perspective rather than knowledge. The application of chunk theory provides an important method for it.

5 Conclusion

This paper analysed the chunk and the chunk-targeted mathematics learning from the two perspectives of theoretical reasoning and simulation calculation, presented based on the learning strategy and concluded as follows:

(1) The chunk theory has a strong theoretical basis. It conforms to the rules of human information processing and can better help students to carry out scientific cognition.

(2) The computational simulation of mathematics learning based on chunk better reproduces students' learning process and more accurately supports the students' learning performance and effect.

(3)The mathematics learning mode based on the block goal can better help students build knowledge structure, improve reflection ability and improve learning effect.

References

[1] Dehaene S, Meyniel F, Wacongne C, Wang L, Pallier C. The Neural Representation of Sequences: From Transition Probabilities to Algebraic Patterns and Linguistic Trees. Neuron. 2015;88(1):2-19. doi:10.1016/j.neuron.2015.09.019.

[2] Beishuizen M, Anghileri J. Counting, Chunking and the Division Algorithm. Mathematics in School.1998;27(1):2-4.

[3] Pang J, Qiu L. Effect of Online Review Chunking on Product Attitude: The Moderating Role of Motivation to Think. International Journal of Electronic Commerce. 2016;20(3):355-383. doi:10.1080/10864415.2016.1121763.

[4] Surya E, Sabandar J, Kusumah YS, Darhim. Improving of Junior High School Visual Thinking Representation Ability in Mathematical Problem Solving by CTL. Indonesian Mathematical Society Journal on Mathematics Education. 2013;4(1):113-126.

[5] Lah N, Saat R, Hassan R. Cognitive Strategy in Learning Chemistry: How Chunking and Learning Get Together. Malaysian Online Journal Of Educational Sciences. January 1, 2014;2(1):9-15.

[6] Fonollosa J, Neftci E, Rabinovich M. Learning of Chunking Sequences in Cognition and Behavior. Plos Computational Biology. November 19, 2015;11(11):1-24.

[7] Chaka JG, Govender I. Students' Perceptions and Readiness towards Mobile Learning in Colleges of Education: A Nigerian Perspective. South African Journal of Education. 2017;37(1).

[8] Ken-ichiro Soma, Ryota Mori, Ryuichi Sato, Noriyuki Furumai, Shigetoshi Nara. Simultaneous Multichannel Signal Transfers via Chaos in a Recurrent Neural Network. Neural Computation. 2015;27(5):1083-1101.

[9] Kraft V. Neuroscience and Education: Blind Spots in a Strange Relationship. Journal Of Philosophy Of Education [serial online]. August 1, 2012;46(3):386-396. Available from: ERIC, Ipswich, MA. Accessed August 25, 2018.

[10] Wan X, Torregrossa M, Sanchez H, Nairn A, Taylor J. Activation of exchange protein activated by cAMP in the rat basolateral amygdala impairs reconsolidation of a memory associated with self-administered cocaine. Plos One. September 26, 2014;9(9):e107359.

[11] Goodwin B, McREL International. Student Learning That Works: How Brain Science Informs a Student Learning Model. McREL International; 2018.
[12] Yian-Shu Chu, Haw-Ching Yang, Shian-Shyong Tseng, & Che-Ching Yang. (2014). Implementation of a Model-Tracing-Based Learning Diagnosis System to Promote Elementary Students' Learning in Mathematics. Journal of Educational Technology & Society, 17(2), 347–357.
[13] Jandhyala S, Phene A. The Role of Intergovernmental Organizations in Cross-border Knowledge Transfer and Innovation*. Administrative Science Quarterly. 2015;60(4):712-743. doi:10.1177/0001839215590153.
[14] D.Zhang,G.Z.Cui,J.H.Wang. Promoting the Retrieval-Based Learning in Primary Mathematics Using the Cognitive Process Analysis [J]. Modern Educational Technology,27(5),pp.74-80,2017.
[15] García-Santillán A, Molchanova VS. Inclusion of Techno-Pedagogical Model in Mathematics Teaching-Learning Process. European Journal of Contemporary Education. 2018;7(3):465-484.
[16] Ernest P. The unit of analysis in mathematics education: bridging the political-technical divide?. Educational Studies In Mathematics. May 2016;92(1):37-58.
[17] Passmore T. Polya's legacy: Fully forgotten or getting a new perspective in theory and practice? Australian Senior Mathematics Journal. 2007;21(2):44-53.