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Splitting and Combining as a Gamification Method in Engaging Structured Knowledge Learning

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Abstract: The understanding of the structure of knowledge is an essential step of education. However, although teachers offer the knowledge structure and relationship among knowledge points, there are still few methods to encourage students to explore the structure of knowledge by themselves outside of classes. In this paper, we explore the gamification method and the knowledge structure of computer science. We assess the gamification method of "splitting and combining" (SC) to encourage students to finish the process of learning structured knowledge. The results show that this method worked well in promoting learning enjoyment and that splitting demonstrated better performance than combining. We can consider the SC method when recommending a gamification method to engage students in structural learning assistance in future smart education.

Keywords: Gamification; splitting and combining; mechanics; structured knowledge learning

1. Introduction

An essential goal of university education is helping students understand and master knowledge [1]. In class, teachers impart knowledge to students in many ways. From the aspect of hardware, we have changed from the traditional blackboard to a twenty-first century multimedia classroom [2]. From the aspect of the teaching approach, we have traditional classes, massive open online courses (MOOCs), and flipped classrooms [3, 4]. In addition, we apply smart technologies in our education environment, such as slides, virtual reality (VR), and augmented reality (AR) [5]. All these attempts are aimed to help students understand knowledge well.

The knowledge students obtain is generally structured [6]. There are composition relationships among the knowledge points. For example, some advanced knowledge points consist of several basic knowledge points. In addition, different combinations of basic knowledge points make up different advanced knowledge points. Many attempts at structured knowledge learning mainly focus on knowledge visualization to show the structure to students, such as the knowledge map of Khan Academy and knowledge graphs in education [7]. However, more research is need on how we can offer students a better experience during the learning process of knowledge structure, such as encouraging students to explore structures and relationships.

In recent years, a handful of universities and online platforms have utilized gamification as an attractive strategy to enhance student engagement in class [8, 9, 10, 11, 12]. Different gamification strategies are used in relevant scenarios. Points that can be accumulated are often used to encourage learning behavior. The stage mode can be used to divide the overall learning goals into smaller targets. Leaderboards are used to arouse a sense of competition [13]. From the aspect of structured knowledge

learning, teachers must encourage students' desire to explore knowledge both from basic to advanced and from advanced to basic. We need to improve the efficiency and effectiveness of structured knowledge learning. However, many general gamification elements, such as points, badges, and leaderboards, are used in structured knowledge learning without sufficient targets. We consider whether there is a gamification method with a similar principle as the structured knowledge that is suitable for learning it. We explore the gamification mechanics and elements to find a method that can fit the features of knowledge structure and provide engagement during the process of exploring the knowledge point relationships. We find that splitting and combining (SC), as a common method used in games and gamification applications, have not been defined in the structured knowledge learning environment.

Splitting and combining often appear in the many scenarios of life. In the industrial age, the general idea of dealing with problems involves splitting and classifying them. As time progresses, more situations require us to consider fusing and integrating. In the field of philosophy, the resolutive–compositive method put forward by Hobbes [14, 15] includes the idea of SC. In Hobbes' theory, he distinguished between two kinds of methods: resolutive and compositive (i.e., analytic and synthetic) [14, 15]. The resolutive or analytical method uses reasoning from effects to causes, whereas the compositive or synthetic method uses reasoning from causes to effects [14].

In addition, in the culture of language, the idea of SC is used in coinage. In Chinese, there is a Chinese character called the associative character [16]. Some original characters work together to compose a new one. In English, prefixes, suffixes, and roots combine to make a new word. Many popular games use SC ideas. The Chinese ring puzzle [17], burr puzzle [18], and mobile game 'the room' (http://www.fireproofgames.com/games/the-room) are all based on the idea of splitting. Legos, the 24-point game, and decorating games are full of combining. There are also many applications using this idea to design; for example, SCRATCH [19] and APP Inventor [20] help users to code using the thought of combining. Mondly (https://www.mondly.com/), a mobile language learning application also teaches learners Japanese by combining simple words into a whole sentence.

Although people use SC in many scenarios, few research studies have focused on it as a gamification method, especially its application in structured knowledge learning. According to its characteristics, we suspect that using SC in the process of learning can encourage students to engage in more learning behaviors and raise awareness of knowledge structure. How it works as a gamification method in the learning process still requires more study. During the learning process, we can generally divide the class session into two parts; students do previews before class and engage in review after class. These two periods are two different steps of acquiring knowledge. We consider that the before-class period requires more diverging, and the after-class period requires more converging. In a way, it is similar to the ideas of SC. How the gamification SC method influences each part in the learning process still needs to be studied.

In this study, we first summarize the history and mechanics of the SC method as a gamification technique to explain why we consider the SC method to have similar characteristics as structured knowledge learning. Then, we explore how this method influences the structured knowledge learning in different learning stages according to the different skill requirements in an undergraduate computer course. Our research questions are as follows:

RQ1: Does SC as a gamification method make sense during structured knowledge learning?

RQ2: During the before-class period, is splitting an idea more effective (e.g., more answers and less answer time) for students? During the after-class period, is combining ideas more effective for students?

RQ3: What are the relations (if any) between students' player types and their performance in an SC learning environment?

Our work contributes the use of the SC gamification method in the process of learning knowledge structure and examines in detail how it influences structure learning. We explore the deep mechanism of SC and use SC in a fun way to improve efficiency and quality in knowledge acquisition and structure cognition. Our results show that the SC method works well during the learning process and can be mapped to two learning periods (i.e., preview and review periods). We did not observe

differences in students` performance using SC among different types of players. We hope to provide a possible method that educators can use to improve student learning efficiency and joy in structured knowledge learning.

2. State of the Art

2.1. Splitting and Combining in Humanities

Splitting and combining is the general way we perceive the world. It takes apart the overall structure into several parts for us to understand them easily. In addition, it can bring several pieces together to make a new thing. In philosophy, this method was made famous by Hobbes [14, 15]. He put forward the resolutive–compositive method and explained the differences between these two methods (i.e., analytic and synthetic) in De Corpore [21].

The SC method persists in our present culture. The ideas of SC also occur in language, and SC is one of the most important methods in word formation. In Chinese, the associative character is one kind of Chinese character. Some original characters work together to compose a new one [16]. For example, 'big' and 'small' together make a new character that means 'tip'. The English language also has prefixes, suffixes, and roots. For example, 'game' and 'fy' make 'gamify', and adding 'cation' makes the word 'gamification' (Figure 1).

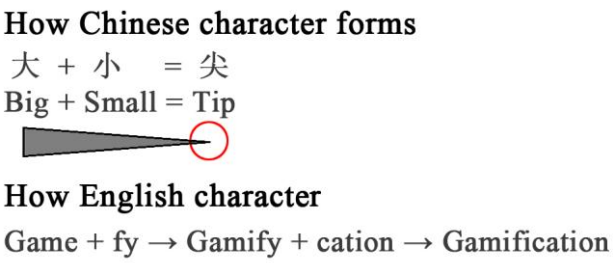


Figure 1. SC method in character forming.

2.2. Split and Combination in Games and Gamification

In games, there is also a method that can be described as SC. Regarding splitting, the Chinese ring puzzle [17], burr puzzle [18], and the game 'the room' ask players to open a box using knowledge. Legos, the 24-point game, and decorating game 'nikkiup2u2' (http://nikkiup2u2.com/p/index.html), among others, use combining. Many educational games are also designed to teach the formation of words or Chinese characters using the SC method. People are never bored with the use of SC in games. The educational game 'Refraction' also uses the idea of SC to teach fractions [22].

Several games and applications that apply SC in their design have been collected. We analyzed the gamification mechanics or elements in their SC designs, as shown in Table 1. After analyzing, we found that the SC method usually includes the following gamification mechanics and elements: accomplishment, discovery, degrees of freedom, time pressure, puzzle, hints, and feedback. Accomplishment and discovery may be the core of the SC method. In our opinion, the accomplishment mechanic may focus more heavily on the satisfaction of achievement or accomplishment.

Table 1. Mechanics or elements in some SC applications.

Names of Apps/ Games	Description	Main Mechanics/ Elements
Mondly	Language learning	Puzzle, Time pressure, Rewards
SCRATCH	Programming software	Accomplishment, Discovery
APP Inventor	Programming software	Accomplishment, Discovery

LEGO	Game	Accomplishment, Creation, Freedom
24-point Game	Number game	Discovery, Competition, Time Pressure
The Room	Game	Discovery, Puzzle
Chinese Ring Puzzle/ Burr Puzzle	Structure Game	Discovery
Wordament	Word Game	Discovery, Competition, Time pressure
2048 Game	Number game	Points, Leaderboard
Refraction	Educational game	Puzzle, Discovery, Accomplishment

2.3. Gamification in Learning Periods

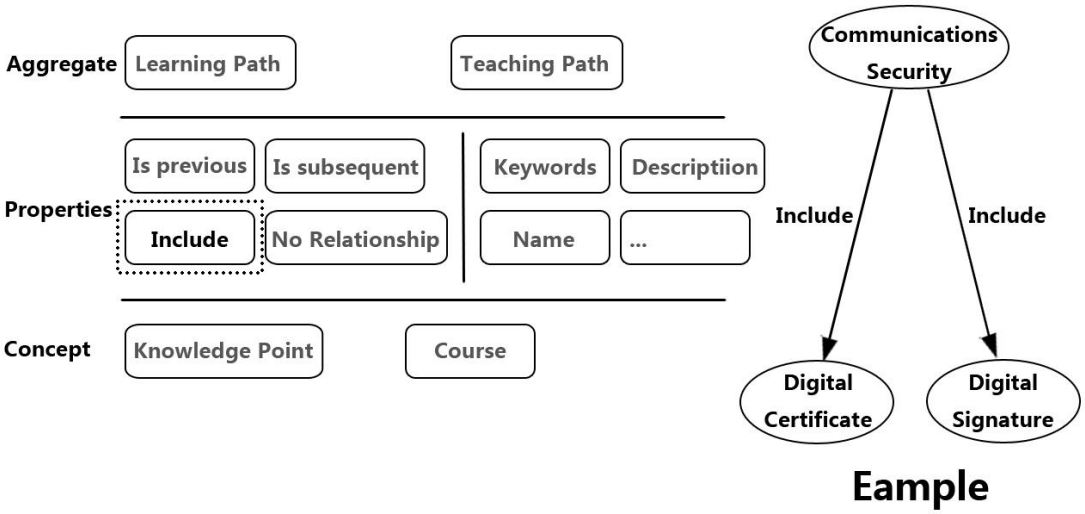
In recent years, numerous universities and online platforms have utilized gamification as an attractive strategy to enhance student engagement in class [9, 10, 11, 12]. These have focused on different periods of courses. PeerWise [23] is an online repository of student-generated multiple-choice questions. Multiple choice questions consist of one question that is attached to a class along with a set of answers. Only one of the answers is correct. In this system, badges have been used since 2013 to improve student engagement. PeerWise is used in both preview and review periods. At the University of Cape Town, gamification elements are applied during and after class. They give the course a Steampunk theme [24]. Using a storyline, puzzles, points, badges, and a leaderboard, this university works to improve lecture attendance, content understanding, problem solving skills, and general engagement. Khan Academy provides short lectures in the form of YouTube videos and educates students outside of class. Khan Academy has implemented several specific gamified elements within its online environment, such as knowledge maps, badges, and progress indicators [7]. An education game called Refraction [22] uses the idea of splitting to teach children learning fractions in leisure time. Players in Refraction use splitters to split the laser equally into two or three parts then redirect the laser to target a spaceship.

2.4. Player Types

Different players may be influenced by the SC method in different ways. Richard Bartle`s character theory consists of four player types: Achievers, Explorers, Socializers, and Killers [25]. According to the core mechanics of the SC method (i.e. Accomplishment, Discovery), we consider that the game preferences of students are complex so that students may constitute a variety of player types. We can initially think that the SC method would appeal to the Explorers. Explorers are players who prefer discovering and creating. In games, they may act by exploring hidden places or creating new ways of accomplishing missions. They may be pleased when they find a hidden Easter egg or discover new knowledge. Achievers may focus on collecting all kinds of relationships in a knowledge network. Thus, in a gamified environment, we consider that Explorers and Achievers would like to be motivated by the SC method that is full of accomplishment and discovery.

3. Experimental Design Overview

To explore the application features and validity of knowledge learning of SC as a gamification method, we separated the strategy into the two periods of learning: preview and review. We put our gamified design to the test in large-scale basic computer courses for non-computer-major students (N = 56) in a university in China. The course lasted for eight weeks and had one class each week. Our five-week experiment was conducted from the third week to the seventh week.



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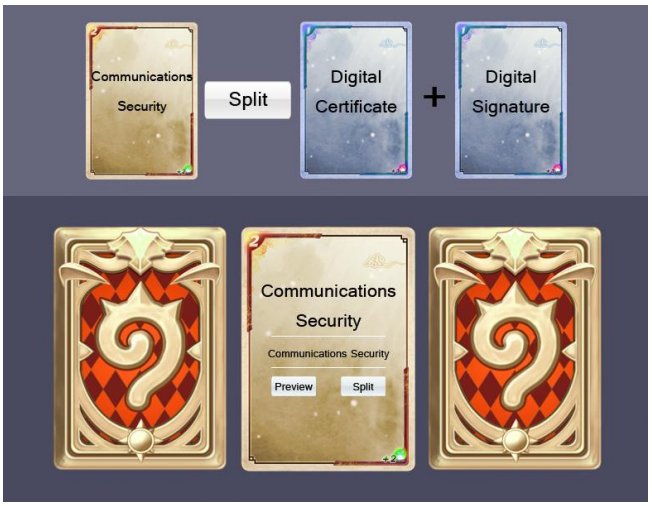
166 **Figure 2.** Ontology model of semantic knowledge base and the example of SC method on platform.



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168 **Figure 3.** Splitting process in learning. Split one orange card into several blue cards.

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Figure 4. Combining process in learning. Combine several blue cards into one orange card.

In our experiment, game cards were the avatars of knowledge points along with relevant learning materials. A student clicks and choses one card and will receive the mission, such as a question based on the knowledge point, reading a paragraph of information, and uploading a small text about the knowledge point. When the student accomplishes the mission, they complete the learning operation. The major feature of this platform was that it provided SC in learning. Orange cards were secondary knowledge cards, and blue ones were basic knowledge points. The splitting process could be described as splitting the orange cards into several blue cards, and then students completed the blue cards' learning operation. The combining process was the opposite; the blue cards were selected to form a new orange card and then students completed the orange cards' learning operation. The relationship, hierarchy, and questions (i.e., the structure of knowledge) were developed by experts (i.e., the tutors of the course) to ensure their appropriateness and reasonability. The semantic knowledge base model was defined in the previous research [26]. We used the "include" relationship part to design our experiment (Figure 2) .The gamification learning platform for SC is shown in Figures 3 and 4. Students picked a card and answered the questions on it.

During the preview period, students were asked to preview upcoming class knowledge. The platform displayed all the knowledge point cards of the upcoming class and allowed the students to complete the preview operation. The start of previewing was one day before the class started. Students could preview at any time during this previewing period. During the review period, students were asked to review the previously presented knowledge. The reviewing period lasted from the end of the class until the beginning of the next class preview.

During the study, 56 students were randomly assigned to two groups to receive different SC methods during the experiment at the same time. How the two groups of students attended the experiments of SC is shown in Table 2. For example, one group did the splitting review in the first week, and the other group did the combining review in the same week. The gamification was applied in the first, second, and fifth weeks. In the third and fourth weeks, non-gamification environments were used. Students also need to choose cards of knowledge points but there was no SC operation. The first two weeks only had a review period, and the other three weeks had both a preview and a review period.

Table 2. Experiment schedule.

	Week1		**Week2**		**Week5**	
	Preview	**Review**	**Preview**	**Review**	**Preview**	**Review**
Group1		Splitting		Splitting	Splitting	Combining
Group2		Combining		Combining	Combining	Splitting

3.1. Experimental Procedure

All the participants received a questionnaire to check the types of players and game experience before the course started. Students were classified into four types: achievers, explorers, socializers, and killers. How the students were familiar with the games and their preference of games were also considered.

We started our experiment during the third week of the course. The five weeks of the experiment were divided into three parts. In the first and second week, students did SC in review. In the third and fourth week, students did no gamification in preview and review. In the fifth week, students did SC both in preview and review. Students had the freedom to choose whether they wanted to join and answer questions both in preview and in review.

After finishing the experiment, all the students will complete the questionnaire of the course using a 5 point Likert scales ranging between "strongly disagree" and "strongly agree". The questionnaire addresses their feelings of the course and the learning outcomes they perceived. These questions include: the help of preview period to the students, the acceptability of SC method in learning environment, students` right to choose in doing homework, the help SC of method to the

students in learning knowledge structure, the engagement of the learning platform in doing homework.

4. Result

A preliminary statistic was conducted. To analyze the experiment of the five-week course, we presented the students' learning situation in Table 3 (review) and Table 5 (preview). During the review period, Table 3 showed that students in the SC method weeks (first, second, and fifth weeks) performed better than those in a non-gamification environment (third and fourth weeks). The results showed that the participation rate in SC weeks was higher than in non-SC weeks, although it declined in the last week. We then performed the Wilcoxon rank-sum test to examine the differences of the answering results between the non-gamification and gamification environments. Gamified weeks and non-gamified weeks are compared in Table 4. In this table, we hypothesized that the SC weeks had higher performance than non-SC weeks in answering numbers, and this hypothesis was accepted ($p < .05$). There was a significant difference in the average answer time ($p < .05$), but we could not determine which was better because the average time of gamification weeks was not always less than that in the non-gamification weeks. The standard deviation reflected the fluctuation of answers each week. In the gamification environment, the standard deviations of the second and fifth weeks were slightly low. However, the lowest standard deviation came from the third week in the non-gamification environment, and the highest one came from the first week.

Table 3. Review period. SC: Using SC (gamification) method. No-SC: Without SC (gamification) method.

Week	1 (SC)	2 (SC)	5 (SC)	3 (No-SC)	4 (No-SC)
Participation Rate	92.86%	83.93%	80.36%	37.5%	82.14%
Average Answer Number	64.42%	67.38%	81.48%	89.68%	68.26%
Answer Rate	59.82%	56.55%	65.48%	33.63%	56.07%
Standard Deviation of Answer Number	2.6077	1.5379	1.8090	1.3265	1.8568
Average Answer Time (h)	107.72	107.01	15.62	88.97	59.55

We analyzed the performance of gamification and non-gamification in the preview periods. Overall, gamification played a more significant role than non-gamification during the preview period with respect to answering rate and participation rate.

Table 4. Statistical analysis of answer numbers / answer time in review periods by Wilcoxon Rank-Sum tests. SC: Using SC (gamification) method.

	1st week (SC)	2nd week (SC)	5th week (SC)
3rd Week (No-SC)	0.02883/ 0.01165	0.03236/ 0.002119	1.625e-05/ 1.8e-05
4th Week (No-SC)	6.573e-08/ 0.0003619	6.453e-12/ 2.543e-05	3.575e-13/ 4.725e-08

Table 5. Preview period. SC: Using SC (gamification) method. No-SC: Without SC (gamification) method.

Week	3 (No-SC)	4 (No-SC)	5 (SC)
Average Answer number	98.15%	62.17%	81.62%
Participation Rate	32.14%	82.14%	92.86%
Answer Rate	31.55%	51.07%	75.99%
Standard Deviation of Answer number	0.3233	1.4333	2.2054
Average Answer time (h)	12.64	10.15	11.03

The results of the questionnaire show the attitude of students toward the SC method in learning. Over half of the students (71.15%) chose 1 and 2 (i.e., SC had positive effects on learning) for the item "There were no positive effects on my study when I used this SC learning method." Other students (23.08%) chose the neutral option for this item. For the effect of helping students to learn the structure

of knowledge, 65% of the students agreed with this statement, and 17.30% had no opinion about it. We also observed the students who preferred to give a negative response; most were dissatisfied with the bugs in the platform.

Table 6 shows the performance of SC in the preview and review periods. During the preview period, students that used splitting took less time ($p = 0.01303 < 0.05$) than those that used combining. During the review period, students that used splitting answered more questions ($p = 0.004164 < 0.05$) than those that used combining.

Table 6. Performance of splitting and combining in the 5th week. H1: Splitting is greater than combining.

	Preview	Review
Numbers	0.6282	0.004164
Time	0.01303	0.6132

5. Discussion

Our results showed that SC as a gamification method encouraged students' performance in learning. This conclusion was driven from students' learning situations every week. Students in SC gamification weeks performed better on numbers of answers and answer rate. However, there were irregularities associated with the standard deviation of answer numbers and answer time. We conclude that the SC method had an obvious effect on the quantity of answers. The reason may be that the SC method works more on the structure of the knowledge, and each knowledge point in the network has its own question. Students will encounter more questions when they engage in the SC process in learning. The results of the questionnaire also show evidence for this. Over half of the students (65%) thought that SC helped them to learn the structure of the knowledge:

"I was confused at the first time. However, when I got the key of this learning game, I think it is fun for me to explore which two cards can make a new card" (P10).

We further analyzed and interviewed this student. He is classified as an achiever, and his favorite game is The Sims (https://www.thesims.com/), a life simulation video game series. This student is just one example in which achievers may gain the key idea of the SC method and immerse themselves in gamification applications. He was interested in combining exploration with these learning processes.

In the fifth week, we found that the students behaved stably overall. There was no significant difference between the preview and review periods ($p = 0.93$). Although there was only one week for students to do preview because of the course arrangement, students still performed similarly. To explain this situation, we consider the possibility of habits. The first two weeks of SC learning and the next two weeks of traditional learning allowed the students to better understand how to learn with the method of SC. Students were used to the gamification learning method, so that they produced stable performance. The SC method is different from gamification elements such as leaderboards or points, which are usually external motivation and have less relationship with the content. In contrast, the SC method is a kind of cognitive tool and provides loose coupling between the gamification method and course content. When students get the key point of this method, they will enjoy learning in this way rather than according to other extrinsic motivations.

When we choose to use the SC method to engage our students, we should consider that this method consists of two processes. Are there any differences between the two processes of splitting and combining? In the fifth week, we analyzed the students' answer behaviors and found that students using splitting performed better than those using combining; they took less time but answered more questions. This may be caused by the nature of splitting. We consider that, although combining induces curiosity to the students and helps them to become more familiar with the knowledge structure, splitting introduces more basic knowledge points with less difficulty, and these questions are more suitable for exams in China. However, in the interview part, students expressed that they preferred the combining process. A possible explanation is that the combining process can

arouse participants' curiosity. The exploration process brings more joy when it yields answers to questions of knowledge.

Initially, we attempted to analyze the relations between student player types and their preferences and performance in the SC learning environment. However, over 89.29% of students were achievers, killers, or both. We realized that achievers and killers are increasingly growing in number among student players. One possible reason is that many mobile games in China increasingly aim at persuading players to spend money and then provide splendid game items to players [27]. These kinds of games amplify the joy of achievers and killers, and more players have been growing accustomed to this. When we analyze the two major groups (i.e., achievers and killers), there were also no significant differences between these two types of players. Therefore, although we had hypothesized that explorers or achievers may be motivated much more than the others, there was no evidence to support this claim.

6. Conclusion and Future Work

This work has explored SC as a gamification method from its history to its application in structured knowledge learning. We discovered that SC as a gamification method worked well in motivating students in structured knowledge learning and facilitating enjoyment. Splitting in the learning procedure had better performance than combining. However, there is no significant difference among player types. We can consider the SC method when engaging in structured learning assistance design. Further research with a more detailed laboratory experiment is necessary. We also need to consider more factors, such as the player types of students, eye tracking when performing SC, and the formation process of thinking.

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