


Article

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. Although teachers offer the information foundation and relationship among knowledge points, there are still few methods to encourage students to explore the structure of knowledge by themselves outside of classes. This paper explores 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 in the university. The results show that this method works well in promoting learning enjoyment and that splitting demonstrates 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 university education.

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

1. Introduction

An essential goal of a university education is helping students understand and master knowledge [1]. Teachers impart knowledge to students in many ways. Regarding the aspect of hardware, we have changed from the traditional blackboard to a twenty-first century multimedia classroom [2]. Regarding the teaching approach, schools have traditional classes, massive open online courses (MOOCs), and flipped classrooms [3,4]. Additionally, smart technologies are applied in the education environment, such as slides, virtual reality (VR), and augmented reality (AR) [5]. All these attempts are aimed to help students get a deeper understanding of what they learn.

The knowledge students obtain generally is structured [6]. Knowledge is not isolated, there are relationships existing in the knowledge web. Knowledge structure shows the relationships within the web of knowledge. Consider the computing course as an example, students are required to master several knowledge points according to the syllabus. A knowledge point is the primary unit in the knowledge structure. Several basic knowledge points put together can make an advanced knowledge point. An advanced knowledge point as parent node can also be deconstructed into several knowledge points. Knowledge points and the relationships among them composed the knowledge structure. The knowledge of a “Digital Certificate” and a “Digital Signature”, can evolve into the concept of “Communications Security”. We call a “Digital Certificate” and a “Digital Signature” basic knowledge points, and “Communications Security” is an advanced knowledge point (Figure 1). The relationship

among them is “include”. Having the awareness of the relationships among knowledge points is the process of “structured knowledge learning”. Many studies of 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 needed on how educators can offer students a better experience during the learning process of knowledge structure, such as encouraging students to explore structures and relationships.

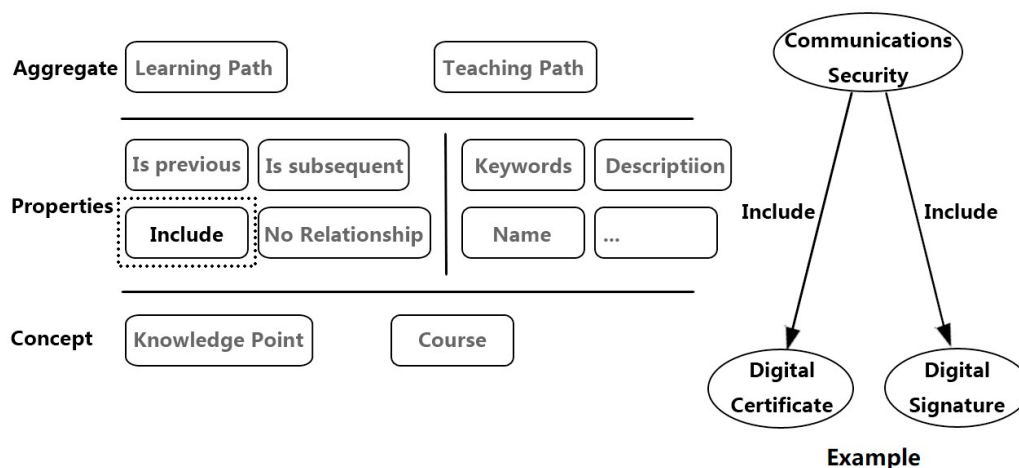


Figure 1. Ontology model of semantic knowledge base and the example of SC method on platform.

Recently, a handful of universities and online platforms have utilized gamification as an attractive strategy to enhance student engagement in class [8–12]. 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. A leaderboard is used to arouse a sense of competition by displaying ranks of users’ performance comparison [13]. Regarding structured knowledge learning, teachers must encourage students’ desire to explore the relationships among knowledge points both from basic to advanced and from advanced to basic. During this type of learning, students are required to explore the relationships among knowledge points. An advanced knowledge point is a parent node which is aggregated by several basic knowledge points. The process of students learning how basic knowledge points make up an advanced knowledge point is called “explore knowledge from basic to advanced”. In this process, they would learn the advanced knowledge point as well as understand what basic knowledge points it includes. 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 the structure of knowledge. We explore 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 many scenarios in life. During the industrial age, the general idea of dealing with problems involves splitting and classifying them. Since time progresses, more situations require people to consider fusing and integrating. Philosophy states that the resolute–compositive method put forward by Hobbes [14,15] includes the idea of SC. Hobbes’ theory distinguishes between two kinds of methods: Resolute and compositive (i.e., analytic and synthetic) [14,15]. The resolute or analytical method uses reasoning from effects to causes, whereas the compositive or synthetic method uses reasoning from causes to effects [14].

Additionally, in the culture of language, the idea of SC is used in the creation of characters. There is a kind of Chinese characters called the associative character [16]. Some original characters work together to compose a new one. Prefixes, suffixes, and roots combine to make a new word in English. 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 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 concept 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 research. 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. It can be considered like the ideas of SC. How the gamification SC method influences each part in the learning process still needs to be studied.

This study first summarizes 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 structured knowledge learning in different learning stages according to the different skill requirements in an undergraduate computer course. The 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?

This 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 in the university.

2. State of the Art

2.1. Splitting and Combining in Humanities

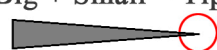
Splitting and combining is the general way a person perceives the world. It takes apart the overall structure into several parts for the students to understand them easily. Additionally, it can bring several pieces together to make a new thing. This method was made famous in philosophy by Hobbes [14,15] who put forward the resolute–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. 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. To demonstrate, “game” and “fy” make “gamify”, and adding “cation” makes the word “gamification” (Figure 2).

How Chinese character forms

大 + 小 = 尖
Big + Small = Tip



How English character

Game + fy → Gamify + cation → Gamification

Figure 2. Splitting and combining (SC) method in character forming.

2.2. Split and Combination in Games and Gamification

There is also a method that can be described as SC in games. Regarding splitting, the Chinese ring puzzle [17], burr puzzle [18], and game “the room” ask players to open a box using their intelligence. Players are challenged to collect items using hints to open several strange puzzle boxes in the game “the room”. Legos, the 24-point game, and decorating game “nikkiup2u2” (<http://nikkiup2u2.com/p/index.html>), among others, use combining. The players assemble and connect the Lego pieces in many ways to construct objects. The 24-point game, combines four integers with allowed operations (addition, subtraction, multiplication, division, and parentheses) to make the result of 24. Game nikkiup2u2 asks players to dress the avatar in different ways to get high scores. Many educational games are also designed to teach the formation of words or Chinese characters using the SC method. People are rarely bored with the use of SC in games. The educational game “Refraction” also uses the idea of SC to teach fractions [22]. The player must use a combination of laser benders and splitters to reduce the whole laser into two or three parts and direct the reduced laser to the target fraction shown in a spaceship.

Gamification mechanics and elements create patterns of repeated behavior and feedback loops intended to produce enjoyable gameplay. These are the building blocks that can be applied and combined to gamify any non-game context [23]. 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. Following analysis, it is 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 might 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

Recently, numerous universities and online platforms have utilized gamification as an attractive strategy to enhance student engagement in class [9–12]. These have focused on different periods of courses. PeerWise [24] 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 where only one of the answers is correct. Badges have been used since 2013 to improve student engagement in this system. PeerWise is used in both preview and review periods. Gamification elements are applied during and after class at the University of Cape Town. They give the course a Steampunk theme [25]. 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 divide 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 [26]. Achievers are players who focus on points, prizes or material possessions. Explorers want to learn new things and discover new secrets. Socializers prefer the social aspect of the game, rather than the game itself. Killers live to win, love competitions and want to see other people lose. 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 might 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; they might act by exploring hidden places or creating new ways of accomplishing missions. Explorers might be pleased when they find a hidden Easter egg or discover new knowledge. Achievers might focus on collecting all kinds of relationships in a knowledge network. Thus, in a gamified environment, we consider that Explorers and Achievers would likely 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, "Introduction to Computer Science", for non-computer-major students ($n = 56$) in a university in China in 2016. Students in class came from the schools of mathematics, physics, chemistry and life science. The course lasted for eight weeks and had one class each week. This five-week experiment was conducted from the third week to the seventh week of classes.

Game cards were the avatars of knowledge points along with relevant learning materials in this experiment. A student clicked and chose one card to 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 accomplished the mission, they completed the learning operation. The major feature of this platform was that it provided SC in learning. Orange cards were advanced knowledge cards, and blue ones were basic knowledge points. The splitting process was 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 [27]. There were two concepts in the semantic knowledge base: Course and knowledge points. There were several kinds of relationships among the knowledge point concepts, such as “is previous”, “is subsequent”, “include” and “no relationship” (Figure 1). One of these relationships was chosen to be the relationship among the knowledge point entities. We used the “include” relationship part to design our experiment (Figure 1). The gamification learning platform for SC is shown in Figures 3 and 4. Students picked a card and answered the questions on it.

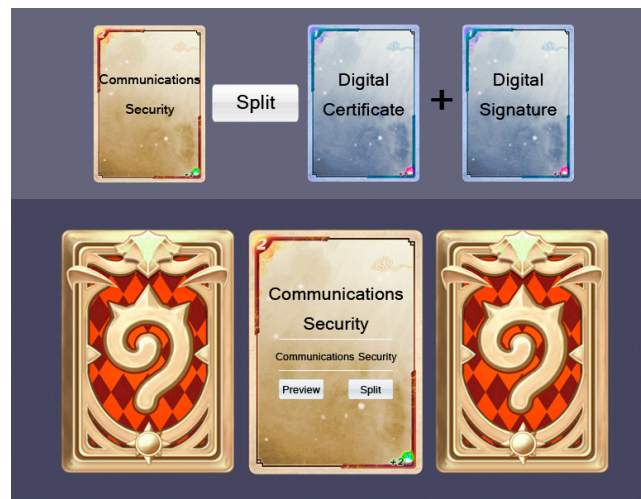


Figure 3. Splitting process in learning. Split one orange card into several blue cards.

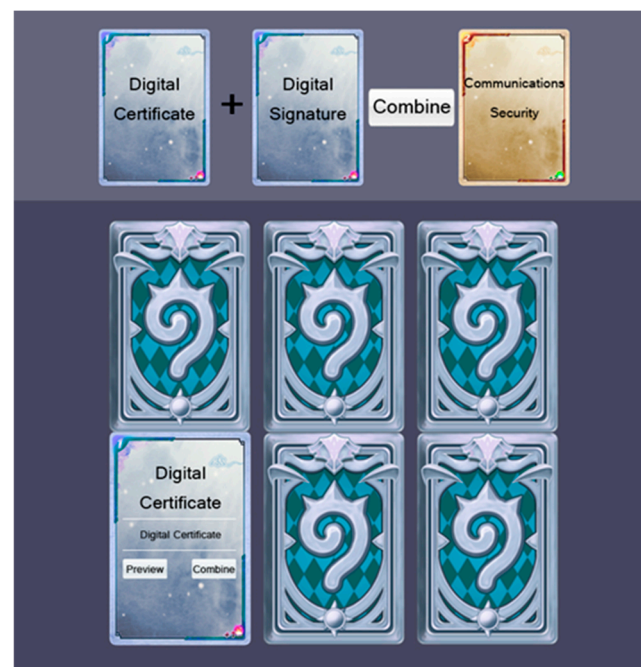


Figure 4. Combining process in learning. Combine several blue cards into one orange card.

During the preview period, students were asked to preview upcoming class information. The platform displayed all the knowledge point cards regarding the upcoming class and allowed the students to complete the preview operation. The start of previewing was one day before the class

began. Students could screen at any time during this previewing period. During the review period, students were asked to re-examine the previously presented knowledge. The reviewing period lasted from the end of one 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 simultaneously. How the two groups of students attended the experiments of SC is shown in Table 2. To demonstrate, one group did the splitting review in the first week, and the other group did the combining review during the same week. The gamification was applied in the first, second, and fifth weeks. During the third and fourth weeks, non-gamification environments were used. Students also needed 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. We hope students to answer more questions and spend less time in answering questions using gamification method SC. The answer time means the time from the beginning of preview/review to the time when students answered per question. The shorter time, the students responded more quickly to the questions. The students might be engaged by the SC method because they would like to answer the questions earlier instead of until the deadline.

Table 2. Experiment schedule.

Group	Week 1		Week 2		Week 5	
	Preview	Review	Preview	Review	Preview	Review
Group 1		Splitting		Splitting	Splitting	Combining
Group 2		Combining		Combining	Combining	Splitting

Experimental Procedure

All the participants received a questionnaire to assess the types of players and game experience before the course began. There were several games categorized by their genres. After a brief introduction of each game, students were asked to choose 10 games they had played or they wanted to play [28]. How the students were familiar with the games and their preference of games were also considered. The points of each player type accumulated from their choices of games allowed the classification of students in four types: achievers, explorers, socializers, and killers.

We began our experiment during the third week of the course. First, we did a self-controlled study to observe the effect of gamification on one student during the whole study process [29]. The five weeks of the experiment were divided into three parts. During the first and second week, students did SC in review. Throughout the third and fourth week, students did no gamification in preview and review. During 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. Then, we did a comparison to the same course in 2015 taught by the same teacher and all students came from the same schools as 2016.

Following completion of the experiment, all the students completed the questionnaire of the course using a 5-point Likert scales ranging between “strongly disagree” and “strongly agree”. The questionnaire addresses their feelings about the course and the learning outcomes they perceived. These questions include: The help of preview period for the students, the acceptability of the SC method in learning environment, the students’ right to choose in doing homework, the usefulness of SC method to the students for learning knowledge structure, and the engagement of the learning platform for doing homework.

4. Result

Initially, a preliminary statistic between the gamification environment (SC method) and non-gamification environment was conducted to verify RQ1: “Does SC as a gamification method make sense during structured knowledge learning?”. To analyze the experiment of the five-week course, we

presented the students' learning situation in Table 3 (review) and Table 4 (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. The answer rate meant how many questions had been answered according to the total number of questions and students that week. Tables 3 and 4 demonstrated that the gamification environment showed a higher answer rate than the non-gamification environment. Students who were engaged by SC answered more questions. The standard deviation in Tables 3 and 4 reflected the fluctuation of answers each week. The standard deviations of the second and fifth weeks were slightly lower in the gamification environment. However, the lowest standard deviation came from the third week in the non-gamification environment, and the highest one came from the first week. We then performed the Wilcoxon rank-sum test (two-sided) to examine the differences of the answer results between the non-gamification and gamification environments. Gamified weeks and non-gamified weeks were compared in Tables 5 and 6. We hypothesized that the SC weeks would have a higher performance than non-SC weeks in the number of answers and the average answering time. The "average answer time (student)" was the mean value of "answer time" of each student in that week. Regarding Table 5, we compared the answer rate in non-gamification weeks to gamification weeks. The mean value of the answer rate in the third week (mean value = 0.3363) is less than that in the first, second and fifth week (mean value: 1st = 0.5982; 2nd = 0.5655; 5th = 0.6548). We chose a significance level of 0.05, and p -values between the third week and gamification weeks (1st, 2nd, and 5th) were 0.001342, 0.01877, and 0.001766 with the students answering more questions in gamification weeks. We found the answer rate in the fourth week is less than gamification weeks (1st, 2nd, and 5th), but this was not as significant (p -value = 0.8225, 0.5904, and 0.8136). Regarding Table 6, we compared the average answer time for students in non-gamification weeks to gamification weeks. The average answer time in the third week is longer than that in the gamification weeks (1st, 2nd, and 5th). Students used less time to answer questions in gamification weeks. However, there was a significant difference on the answer time between the fourth week and the first week. Only one comparison showed the fourth week had longer answer time than the fifth week ($p = 0.0001165 < 0.05$).

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

Content	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%
Mean Value of Number of Answers	64.42%	67.38%	81.48%	89.68%	68.26%
Mean Value of Answer Rate	59.82%	56.55%	65.48%	33.63%	56.07%
Standard Deviation of Number of Answers	2.6077	1.5379	1.8090	1.3265	1.8568
Average Answer Time (h) (Question)	107.72	107.01	15.62	88.97	59.55
Average Answer Time (h) (Student)	107.80	117.10	47.74	137.20	92.97

Table 4. Preview period. SC: Using SC (gamification) method. No-SC: Without SC (gamification) method.

Content	Week		
	3 (No-SC)	4 (No-SC)	5 (SC)
Participation Rate	32.14%	82.14%	92.86%
Mean Value of Number of Answers	98.15%	62.17%	81.62%
Mean Value of Answer Rate	31.55%	51.07%	75.99%
Standard Deviation of Number of Answers	0.3233	1.4333	2.2054
Average Answer time (h) (Question)	12.64	10.15	11.03
Average Answer Time (h) (Student)	28.28	14.69	12.86

Table 5. *p*-Value of answer rate in review periods by Wilcoxon Rank-Sum tests (two-sided). SC: Using SC (gamification) method.

Week	1st Week (SC) (Mean Value: 0.5892)	2nd Week (SC) (Mean Value: 0.5655)	5th Week (SC) (Mean Value: 0.6548)
3rd Week (No-SC) (Mean value: 0.3363)	0.001342 *	0.01877 *	0.001766 *
4th Week (No-SC) (Mean value: 0.5607)	0.8225	0.5904	0.8136

Note: * Indicates cells which non-gamification weeks answer fewer questions than gamification weeks and $p < 0.05$.

Table 6. *p*-Value of average answer time (h) in review periods by Wilcoxon Rank-Sum tests (two-sided). SC: Using SC (gamification) method.

Week	1st Week (SC) (Mean Value: 107.80)	2nd Week (SC) (Mean Value: 117.10)	5th Week (SC) (Mean Value: 47.74)
3rd Week (No-SC) (Mean value: 137.20)	8.484×10^{-5} *	0.005591 *	2.987×10^{-9} *
4th Week (No-SC) (Mean value: 92.97)	0.05242	0.00199	0.0001165 *

Note: * indicates cells which non-gamification weeks use more time than gamification weeks and $p < 0.05$.

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.

The results of the questionnaire showed the attitude of students toward the use of SC method in learning. Over half of the students (71.15%) chose 1 and 2 (essentially 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. Regarding 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 that most of the students who preferred to give a negative response were dissatisfied with the bugs in the platform.

We also compared the student grades for the course without gamification, which taught by the same teacher and the students came from the same 4 schools in 2015, to 2016 with gamification, and used Wilcoxon rank-sum test (two-sided) analysis. There were significant differences in grades between 2015 and 2016, with gamification encouraging students to get higher grades ($p = 0.002464 < 0.05$. 2015: mean = 81.59615; Std. Deviation = 13.26688. 2016: mean = 87.64286; Std. Deviation = 4.522383).

During part two, we analyzed the performance of splitting and combining to verify 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?”. Table 7 showed the performance of SC in the preview and review periods. During the preview period, we compared the number of answers using splitting, which had a mean of 7.444, to combining, which had a mean of 7.28. In addition, we compared answer time using splitting, which had a mean of 9.831, to combining, which had a mean of 12.420. Students that used splitting took less time ($p = 0.02607 < 0.05$) than those that used combining. During the review period, students that used splitting answered more questions than those that used combining (Splitting: mean = 7.846; Combining: mean = 6.632 $p = 0.008329 < 0.05$). However, there was no significant between splitting and combining in answer time (Splitting: mean = 9.831; Combining: mean = 12.420 $p = 0.6132 > 0.05$).

Table 7. Performance of splitting and combining in the 5th week by Wilcoxon Rank-Sum tests (two-sided).

Content	<i>p</i> -Value	
	Preview	Review
Number of answers	0.6282	0.008329 *
Answer Time	0.02607 *	0.6132

Note: * indicates cells with $p < 0.05$.

5. Discussion

Our results showed that SC as a gamification method encouraged students' performance in learning results. This conclusion is driven from students' learning situations every week and the comparison to the last semester. According to the comparison to the course in 2015, it allows us to exclude the null hypothesis and assert that the gamification had a significant positive impact on student grades.

Students in SC gamification weeks (1st, 2nd, and 5th) performed better on answer rate and average answer time than the third week without gamification. However, we found that the answer rates in gamification weeks were higher than the fourth week, but that these were not as significant. We concluded that the SC method could provide a positive effect on the quantity of answers. The reason might 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 would encounter more questions when they were engaged in the SC process in learning. The results of the questionnaire also showed 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 was classified as an achiever, and his favorite game was 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. The student was interested in combining exploration with these learning processes.

The answer time in the third week was significantly longer than those in the gamification weeks (1st, 2nd, and 5th). However, we barely found significant differences between the SC gamification weeks and the fourth week without gamification. Only one comparison showed the fourth week had longer answer time than the fifth week. In addition, it seemed that there could be a statistically significant difference between the mean times within gamification (1st and 2nd: $p = 0.2945$; 1st and 5th: $p = 5.14 \times 10^{-5}$; 2nd and 5th: $p = 2.592 \times 10^{-6}$) and within non-gamification weeks ($p = 1.03 \times 10^{-5}$) in Table 6. This indicated that all the answering times in general were statistically significantly different, regardless of whether we spoke about SC or No-SC weeks. We could not find a significant positive effect on the answer time when using SC. The answer time in gamification weeks had a decreasing trend. There is a possibility that a prolonged gamified period using SC may have an effect on shortening the average time students began to answer the questions. This speculation needs further experiments to be proved.

In the fifth week, we found that the students behaved stably overall and had the best performance during the five-week experiment. In addition, the answer time in the fifth week was significantly shorter than the first two weeks. 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 due to 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 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. Conversely, 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? During the fifth week, we analyze the students' answer behaviors and find that students using splitting perform better than those using combining; they take less time but answer more questions. This might be caused by the nature of splitting. We consider that, although combining encourages curiosity within 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 attempt to analyze the relations between student player types and their preferences and performance in the SC learning environment. However, according to a questionnaire before the experiment, over 89.29% of students were achievers, killers, or both (achiever: 25%, killer: 37.5%, both: 26.79%). We realize 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 [30]. 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 are also no significant differences between these two types of players. Therefore, although we had hypothesized that explorers or achievers might be motivated much more than the others, there is no evidence to support this claim.

6. Conclusions and Future Work

This work explored SC as a gamification method from its history to its application in structured knowledge learning. The results provide indications about the potential improvements in learning more knowledge and have the awareness of knowledge structure using SC method. We discovered that SC as a gamification method had positive effects on improving learning operations such as numbers of answers every week and facilitating enjoyment. Students were interested in the SC method when doing structured knowledge learning. Splitting in the learning procedure has better performance outcomes than combining. However, there is no significant difference among player types. This method could provide enjoyment and desire to explore the relationships among knowledge points but not perform well in answer time in general. 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. In addition, we need to try to design a gamification method recommendation to engage students learning in future smart sustainable university education. We anticipate that this research will continue to guide the application of gamification to encourage students to do structured learning with the SC method.

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