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Revealing Students' Behaviors in a Game-based Learning Environment: A Sequential Analysis Approach

Calvin C. Y. LIAO*, Zhi-Hong CHEN, Hercy N. H. CHENG, Tak-Wai CHAN
Graduate Institute of Network Learning Technology, National Central University, Taiwan
*Calvin@cl.ncu.edu.tw

Abstract: Previous study developed a game-based learning environment, entitled My-Pet-My-Quest (MPMQ), for arithmetic practices. The purpose of this study is to understand the learning process of game-based learning in long-term real world. The study considered to define how the behavioral patterns be implemented and which coding scheme be used in the behavior analysis approach. For understanding students' behaviors in the environment, two processes were carried out. This study attempted to implement long-term intervention in an elementary after-school club as well as students' home, and then to analyze the learning process. Furthermore, this study adopted a sequential analysis approach, based on a designing framework, to help us examine and understand the each aspect of behaviors on students' learning and playing. These results can provide suggestions and references for the design of efficient learning environments in the future.

Keywords: game-based learning, sequential analysis, behavior

1. Introduction

Our research team developed a game-based learning environment, entitled My-Pet-My-Quest (MPMQ) (Chen, Liao, & Chan, 2010), for arithmetic practices. This study attempted to implement long-term intervention in an elementary after-school club as well as students' home, and then to analyze the learning process to understanding the students' behaviors. The system provides pet-keeping tasks and learning tasks. More specifically, in the environment, students can play the role of pet-keepers who can interact with virtual pets and solve a series of small quests that sustains students' motivation and engagement. Furthermore, this study adopted a behavior analysis approach, based on a designing framework proposed by Dickey (2007) and Amory (2007), to help us examine and understand the each aspect of behaviors on students' learning and playing. Process lag sequential analysis (Bakeman & Gottman, 1997) was used to analyze the process pattern of students' learning. Hence, the purpose of this study is to understand the learning process of game-based learning in long-term real world. The study considered to define how the behavioral patterns be implemented and which coding scheme be used in the behavior analysis approach. Different learning behaviors will be defined in order to code the students' actions and allow further sequence analysis. The design of game-based learning environment and the coding scheme are described below.

1.1 The Design of Game-based Learning Environment

In MPMQ, the students adopted a virtual character role and played the game as the character. The MPMQ design contains three main elements: *the virtual character design*, *the narrative environment*, and *the small quests (including learning contents)* (Dickey, 2007; Amory, 2007). All supported students' motivation in various ways.

1.1.1 Virtual Character Design

In MPMQ environment, the design of virtual character (VC) focuses on three virtual characters—*avatar*, *virtual pet*, and *virtual creature*—that are used frequently in game-based learning environment. Each student played a player-character of "avatar" role, named pet-keeper. The pet-keeper nurtures a virtual pet. The computer control a non-player-character of "virtual pet", named My-Pet. The game goal is to take good care of the My-Pet. The computer controls the non-player-characters of "virtual creature", named informer or entruster. The informer will inform the pet-keeper of where quests need to solve. The entruster will entrust the pet-keeper with quests. My-Pet has some numerical attribute to show its status, such as, energy, mood, and effort. The "energy" and "mood" attributes mean the interaction between My-Pet and the pet-keeper. The two attributes could be improved through feeding and playing with My-Pet, respectively. When the pet-keeper feeds the My-Pet, the "energy" attribute would be increased. Similarly, when the pet-keeper plays with the My-Pet, the "mood" attribute would be increased. To take good care of My-Pet, the pet-keeper needs to buy food and goods by EduCoins. The EduCoins could be earned from quests. In other words, the student is guided to conduct the quests for his/her pet.

1.1.2 Narrative Environment

In MPMQ environment, the design of narrative environments focuses on places—*to undertake tasks*, *to buy something*, and *to interact with peers*—that are installed in game-based learning environment. The places were divided into three types: pet-keepers would undertake tasks (e. g., pet-forest, bright city, and devil tower); pet-keepers could buy something for My-Pets (e. g., shopping street); pet-keepers interact with peers (e. g., pet-arena). The narrative storyline that pet-keepers could inspect the status of pet-keep and the My-Pet. My-Pet inhabits in a backyard, which is one of locations in the "island" game world. The pet-keepers could go to the shopping street to buy pets' food and goods, as well as to conduct accepted quests in the forests. In addition, the pet-keepers also could control own My-Pet to interact with peers in pet-arena.

1.1.3 Small Quests

In MPMQ environment, the designs of small quests develop appropriate activities that include *a task description*, *specific task goals*, *learning contents*, and *rewards*. When the pet-keeper conducts the quest in the forests, the pet-keeper will meet the entrusters who appear with different requests for help. The entruster then tells the pet-keeper information about how to complete the quest and what the rewards are. That is, the pet-keeper needs to accomplish the quest for earning the rewards, such as EduCoins. The entruster tells the pet-keeper that there are a series of quests about mathematical festival. The pet-keeper can conduct these quests. For example, the entruster offer the first quest is about mathematical basic computation. The quest goal is to do multiplication exceeding the given threshold.

1.2 Coding Scheme

In order to understand the learning and playing of students' behaviors patterns in the game-based learning environment, the designing framework proposed by Dickey (2007) and Amory (2007) was modified for this study. The study adopted the behavior analysis approach that coding scheme is divided into five categories (as shown in Table 1), and each category represents a type of learning or playing of students' behaviors patterns.

Table 1. Coding scheme for students' learning and playing behavioral patterns.

Game Designing Framework	Categories (Codes)	#Event	Description
Virtual Character Design	Nurturing (N)	#101	To examine the status of pet-keeper
		#102	To examine the status of My-Pet
		#103	To examine the items
		#104	To examine the equipments
Narrative Environment	Game World (GW)	#107	To move the island game world
		#108	To move the shopping street
		#109	To move the pet-forest
		#110	To move the bright city
		#111	To move the devil tower
	Interaction (I)	#112	To interact with peers
Small Quests	Scripting (S)	#106	To inform the pet-keeper about quests
		#128	To entrust the pet-keeper with quests
	Learning (L)	#129	To start with the task
		#105	To examine the history of tasks

2. Research Design

The participants were 29 nine-year-old third-grade students from elementary school in Taiwan. Each participant had a computing device with wireless capability as "small notebook". Each participant used a notebook to practice the math problems about basic computation in game-based learning environment. The experiments using MPMQ environment were conducted in a classroom of elementary school in Taiwan. The experiments were divided into two phases: *summer school* phase and *after-school club or students' home* phase. Firstly, in order to be familiar with the using small notebook and the manipulating game-based learning application for the participants, the instruction session was conducted each day forty-minutes. During the 5-day period of summer school, students could access the MPMQ environment and browse a list of all functions. Secondly, authors implemented to utilize a ''game-based learning'' activity in an elementary after-school club. During the 120-day period of after-school club in 2009, students could nurture the virtual pet and practice the math problems about basic computation in MPMQ environment. In each day, the students used the small notebook for approximately thirty or forty-minute sessions for four months.

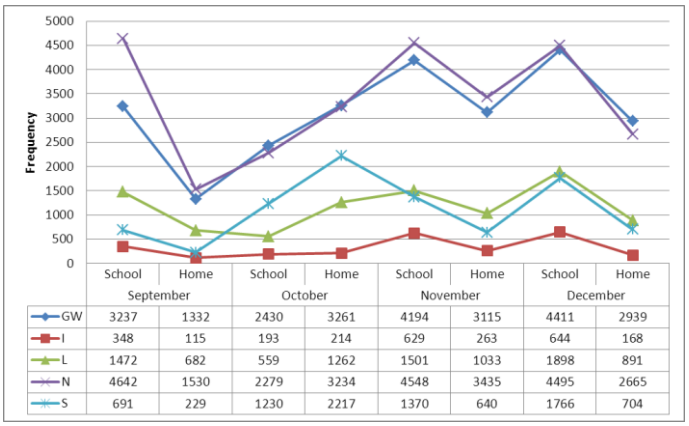
This study employed a mixed approach for data collection and analysis. There were two types of dates collected. Data collection mainly came from students' behaviors recorded in game-based learning environment. In addition to students' behaviors generated from daily solve a variety of learning task and game activities, each student was also observed to keep the observation comments. Regarding data analysis, a descriptive analysis and a lag sequential analysis (LSA) were applied to explore students' online behaviors. The behavior analysis approach was divided into five steps: collecting, defining and classifying, preparing, computing, and interpreting (these steps modify form Jeong, & Davidson-Shivers, 2006). *Step 1:* Collecting a series of actions of students' behavior on GBLE. *Step 2:* Defining the students' behavior—including Nurturing (N), Game World (GW), Interaction (I), Scripting (S), and Learning (L), and classifying these behaviors. *Step 3:* Preparing data for analysis according to variables under investigation. *Step 4:* Computing transitional probabilities, Z scores and transfer diagrams. *Step 5:* Interpreting the transitional probabilities for

interaction behavior patterns and transfer diagrams. We attempted to explore a dynamic process for students' behaviors in game-based learning environment during four months.

3. Findings

3.1 Distribution of Students' Participations in MPMQ Environment

These codes (a total of 72,466 behavior codes) of 29 students were collected from the students' actions during the period of the MPMQ environment. Figure 3 represented the distribution of students' learning and playing behavioral patterns — nurturing (N), game world (GW), interaction (I), scripting (S), and learning (L) — that are each student' actions during four months.



	School	Home	School	Home	School	Home	School	Home
	September		October		November		December	
GW	3237	1332	2430	3261	4194	3115	4411	2939
I	348	115	193	214	629	263	644	168
L	1472	682	559	1262	1501	1033	1898	891
N	4642	1530	2279	3234	4548	3435	4495	2665
S	691	229	1230	2217	1370	640	1766	704

Figure 1. The distribution of students' learning and playing behavioral patterns.

Figure 1 showed that the trend of categories (code) was stable and slowly increasing on most the period (including school and home), except October. Because school has the three cases of N1H1 in October 2009; school shut for a week which lead to the frequency of each categories is decreased at school, but otherwise these is increased at home. We also found that students highly frequency interact with virtual character (N) and narrative environment (GW); students slowly increasing interact with peers (I); and the frequency on students participating the learning tasks (L) is highly than students inspecting the task description (S) in Figure 1. These phenomenons showed that MPQP has potential to sustain the motivation of students for learning. In order to reveal how these behaviors intertwined among students with peers and learning environment, we need further examination with LSA to uncover the behavioral patterns of the students as a MPMQ environment.

3.2 The Dynamics of Students' Behavior Patterns Analysis during Four Months

We adopted the LSA to investigate students' sequential behavioral patterns in game-based learning environment. This initial analysis in figure 1 was very helpful in interpreting the results of LSA in figures 2. In figure 2, the graph shows eight behavioral transfer diagrams of 29 students at school and home during four months. Z-scores that are 1.64 or higher than expected to identify the probabilities and indicate the behavioral sequences has reached significance ($P < 0.05$; Jeong, 2003; 2005). Figure 2 shows the significant sequences on behavioral transfer. The circles represent a series of students' behaviors (N, GW, I, S, and L) while the numerical values in these diagrams represent the probabilities of behavioral transfer; the arrow indicates the direction of transfer for each sequence while the thickness indicates the level of significance.

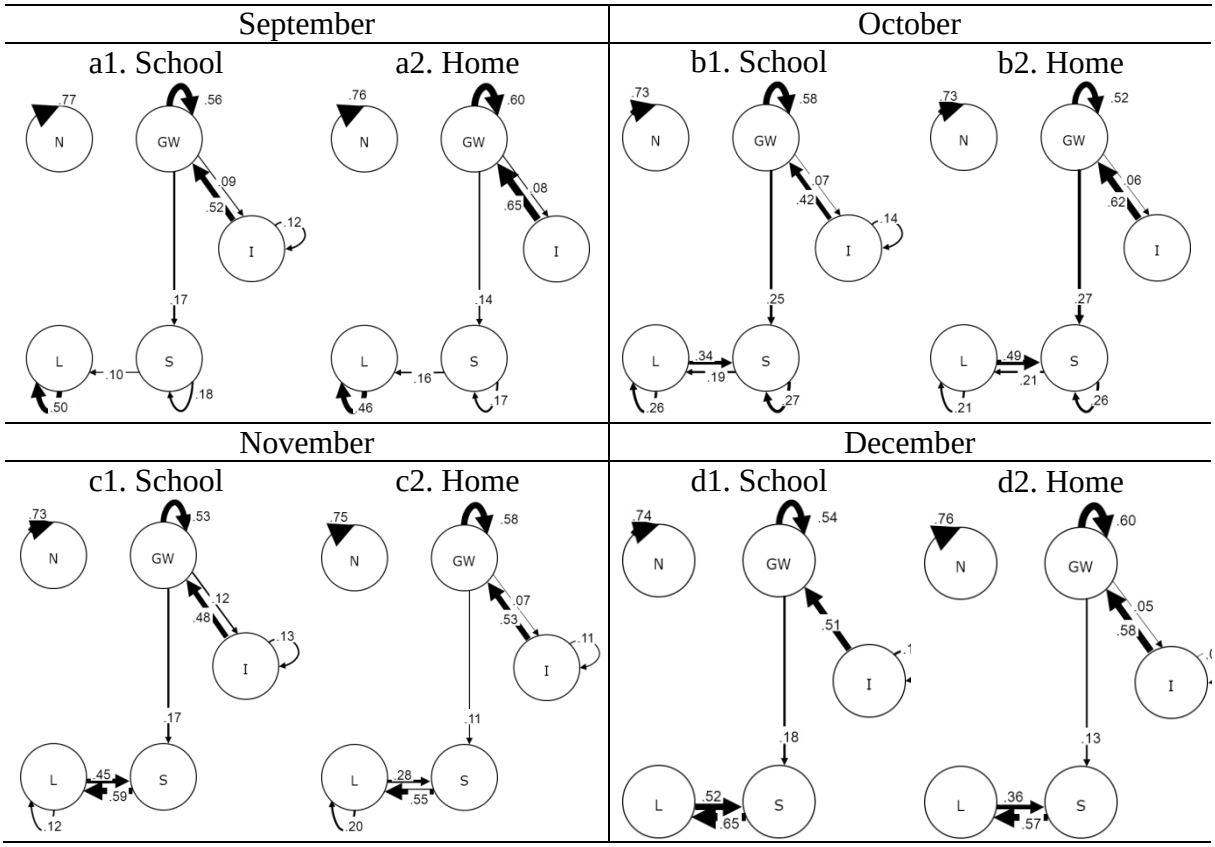


Figure 2. The behavioral transfer diagram of students at school and home during four months.
N: Nurturing; GW: Game World; I: Interaction; S: Scripting; L: Learning

Each behavioral transfer diagram divided into approximately three parties: virtual character (N), narrative environment (GW and I), and small quest (S and L). First, the sequential patterns showed that most students engaged in interacting with different *virtual characters*, such as playing the role of pet-keeper, nurturing their My-Pet, and interacting with informer or entruster (*N→N*). Second, the sequential patterns represented that most students participated frequently in *narrative environment*, such as immersing in game-based learning environment (*GW→GW*), watching the story of learning task (*GW→S*), and interacting with peers (*GW→I, I→I, I→GW*). Final, the sequential patterns indicated that most students participated frequently the *small quests*, such as understanding the specific task goals and accomplishing learning tasks (*S→S, S→L, L→L, L→S*). The interaction of students with the virtual characters, narrative environment, and small quests in this MPMQ environment motivates them to keep learning and to continue to participate in learning activities. These interactive processes may help students sustain motivation.

3.2.1 Virtual Character Design

We first discuss the design of virtual character. We found that these behavior of interacting with different virtual characters were extremely stable by the numerical values in these diagrams (e.g. *N→N*, September: 0.77, 0.76; October: 0.73, 0.73; November: 0.73, 0.75; and December: 0.74, 0.76). Additionally, the authors observed that most students gradually formed an emotional attachment to their My-Pets after being engaged in nurturing and being attentive to them; they also would discuss that the informer and entruster told with them about new small quests. These data indicated that students could build close relationships by interacting with their My-Pet or other NPC. Students paid close attention to their My-Pets,

took good care of them, bought medicine for them, nurtured them and played with them at school or home.

3.2.2 Narrative Environment

Next, we discuss the design of narrative environment. Regarding game world, we found that most students continued participated in game world (e. g., *GW→GW*, September: 0.56, 0.60; October: 0.58, 0.52; November: 0.53, 0.58; and December: 0.54, 0.60) and sometimes participated and watched the story of learning task (e. g., *GW→S*, September: 0.17, 0.14; October: 0.25, 0.27; November: 0.17, 0.11; and December: 0.18, 0.13). This means that MPMQ could provide the sticky information and facilitate the learning intention of students by joyful, immersing, and engaging environment.

Regarding interaction with peers, we found that most students can interact with peers (e. g., *I→I*, September: 0.12, 0; October: 0.14, 0; November: 0.13, 0.11; and December: 0.17, 0.07). In MPMQ environment, most interactions among students in pet-arena happened on at school, not at home on September and October. Subsequently, the probability of students interact with peers at school was stable while these interactions at home were happened on November and December. Besides, the authors also observed that some students can negotiate an appropriate time with peers to join the interactive competition together. These data showed that the probability of interactions was increased and have positive developed. Additionally, we also found that most interactions happened once a day. Students have high probability to go back the game world, and then they could not interact with peers (e.g., *GW→I*, September: 0.09, 0.08; October: 0.07, 0.06; November: 0.12, 0.07; and December: 0, 0.05; and *I→GW*, September: 0.52, 0.65; October: 0.42, 0.62; November: 0.48, 0.53; and December: 0.51, 0.58). This means that the MPMQ should be encouraged to develop interactive elements that will play a leading role in the future and to provide a wider range of interactive forms in game-based learning for students.

3.2.3 Small Quests

Final, we discuss the design of small quest for the influence of students' behavior. Regarding scripting, we found that a few students just watching many descriptions of story, not practicing learning tasks on September and October, and then they not do these gradually on November and December (e. g., *S→S*, September: 0.18, 0.17; October: 0.27, 0.26; November: 0, 0; and December: 0, 0). Regarding learning tasks, we found that a few students continuous practice the learning task of the day on September, and then they decreased the numbers of learning task (e. g., *L→L*, September: 0.50, 0.46; October: 0.26, 0.21; November: 0.12, 0.20; and December: 0, 0). This data means that students not practice excessive tasks; they balanced the attraction of both parties: learning activity and gaming activity.

Regarding scripting and learning tasks, we found that most students through the scripting of our design lead to learning gradually (e. g., *S→L*, September: 0.10, 0.16; October: 0.19, 0.21; November: 0.59, 0.55; and December: 0.65, 0.57; *L→S*, September: 0, 0; October: 0.34, 0.49; November: 0.45, 0.28; and December: 0.52, 0.36). Besides, after the mostly learning activity, the authors observed that the students would continue to discuss the descriptions of story or would compare their answering status with each other. Classmates would also sometimes consult with and teach each other how to perform difficult tasks. The authors also discovered that a little student spent a lot of time to solve her quest in MPMQ every day.

This means that the strategy of quest-driven learning creates a positive cycle. The desire for accomplishing small quest may facilitate and sustain learning motivation. The strategy is to enhance and transform the learning process by skillfully interweaving learning and gaming to create a new environment. In other words, a MPMQ environment provides an interchange between learning activities and game activities. In this easily accessible and active environment, students' willingness to learn may be enhanced.

4. Discussions

4.1 Incorporating Sequential Analysis Approach

In recent years, some researcher (Bakeman & Gottman, 1997; Jeong, & Davidson-Shivers, 2006) developed sequential analysis that explored the co-constructive knowledge of interaction in on-line discussion forums or computer-supported collaborative argumentation (Jeong, & Davidson-Shivers, 2006), because the sequential analysis could process interaction data to present different data representations and to unpack different types of interactions. Hence, this study followed the above ideas and adopted sequential analysis to investigate students' learning limitation. Sequential analysis tool is possible for us to understand deeply the interactions and behaviors among students in a game-based learning environment with a real classroom. In the future, the diversification and plenty of game-based learning environments for learning activity possibly emerged from computer-supported collaborative learning (CSCL) fields. Therefore, there are enormous potential opportunities how this approach could be integrated with existing game-based learning or interactive learning systems while this kind of method also could monitor, detect, and enhance dynamic students' behavior in game-based learning environments.

4.2 Enhancing Learning Stickiness

We defined the phenomenon of student continuous engaged in learning activity, called learning stickiness. The authors also believe sustaining motivation is critical point for transforming learning through the use of digital games for educational goals. Successful learning often needs constant efforts and perseverance for a long period of time. Above findings showed that the use of MPMQ would bring many benefits and opportunities for students' learning. Because of this study developed two design strategies under the game-based learning approach: *pet-nurturing strategy* and *quest-driven learning strategy* in order to enhance learning stickiness and sustain motivation. The former, pet-nurturing strategy could promote the students to care for their My-Pets. While students want to complete the game; learning must take place in the form of game-playing. The game world leads to learning activities and keeps the students' motivation. Ultimately, the students could build a long relationship with their My-Pet. The latter, the quest-driven learning strategy aims at blending learning tasks by game quests (Chen, Liao, & Chan, 2010). Through the script, students are guided to know how to help the NPC by completing the given game tasks, such as gathering rare plants, or killing evil monsters. Meanwhile, the students could get something valuable as rewards from the successful completion of the game tasks.

5. Conclusions and Suggestions

This is the first study of a game-based learning environment to adopt sequential analysis approach revealing the students' behavior data. The study focuses on reporting the findings of behavior patterns among students in the MPMQ environment by using a sequential

analysis approach with filed observation. First, the findings indicated that the trend of students' behavior was stable and slowly increasing during most of the period (including in school and at home). This revealed that the MPQP environment could sustain the motivation of students for learning during one semester. Second, most students could build close relationships by interacting with their My-Pet, which implied that the students took care of their My-Pet very much. Third, most students positively participated in the game world and interacted with their peers gradually. This meant that the probability of interactions was increased and had position developed. Final, the strategy of quest-driven learning created a positive cycle, which suggested that the strategy could enhance and transform the learning process by skillfully interweaving learning and gaming to create a new environment.

Additionally, we come up with three suggestions in which revealing the students' behavior research could be implemented. First, we can formulate a regular task. We can incorporate the tool-based sequential analysis approach with game-based learning environment. Subsequently, GBLE systems can monitor and detect dynamic students' actions whether good or bad habits; GBLE systems can also actively diagnose students' limitations and trigger for protect students' actions. Second, we can actively provide the parents and teachers suggestions to guide the students through the learning difficulties and support the students' motivation by positive feedbacks and rich responses. Parents and teachers will understand the students' limitations and provide the appropriate guidance and feedback for students by the tool of sequential analysis. Final, we can integrate into virtual character technology and sequential analysis tool with game-based learning environment. We can extensively develop and exploit that the sophisticate educational agents (e.g., learning companion; Chou, Chan, & Lin, 2003) or intelligent agents (e. g. NPC, non-player-character) encourages or facilitates the students to engage the diverse learning tasks in game world. By implementing the above, we can improve the design of the game-based learning strategy and understand the behavior of students in a learning environment.

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