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Exploring Elementary-School Students' Engagement Patterns in a Game-Based Learning Environment

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ABSTRACT

Unlike most research, which has primarily examined the players' interest in or attitude toward game-based learning through questionnaires, the purpose of this empirical study is to explore students' engagement patterns by qualitative observation and sequential analysis to visualize and better understand their game-based learning process. We studied the sequential behaviors of 34 students (17 male and 17 female) and considered issues of gender differences and sequential pattern similarities. The results show that the behavioral coding schema provided by the authors and the innovative method of sequential analysis can provide researchers with a certain level of understanding of students' engagement patterns in game-based learning environments. In terms of the overall sequence results, this study identified higher and lower engagement patterns to represent students' learning processes in game-based learning. Moreover, the sequential patterns represent qualitative differences and similarities in engagement patterns grouped by gender. A good engagement cycle, in which male and female students started the game to attempt to think and solve problems, was noticeable. However, male students were observed to demonstrate more engaged behaviors, with continuous self-conversations when confused. The frequency of self-conversation from female students was obviously lower than that of male students and revealed more verbal and nonverbal behaviors. The deep examination of students' verbal and nonverbal engagement behaviors may make beneficial contributions to the educational technology field with the adoption of sequential analysis.

Keywords

Engagement pattern, Sequential behavioral pattern, Gender difference, Game-based learning

Introduction

In recent years, game-based learning has become a critical issue in education (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012) because games may help students engage with learning by offering fantasy and academic content (Chen, 2014; Chang, Wu, Weng, & Sung, 2012). According to previous studies, students' involvement and participation in learning activities should be constructed based on positive interactions between students and their learning environment (O'Brien & Toms, 2008). To fulfill this requirement, a game must embed fantasy content to motivate students to active participate in the task (Gunter et al., 2008). Moreover, a game should provide sufficient challenges, immediate and clear feedback, and playable experiences to increase students' engagement in the learning process (Inal & Cagiltay, 2007; Hou & Li, 2014; Kiili, 2005).

The game design mechanism includes the game goals and the learning goals (Gunter, Kenny, & Vick, 2008; Ke & Abras, 2012). The game goals must be designed to attract students' attention and to encourage their engagement in game-based learning activities (Alessi & Trollip, 2001). Therefore, we can optimistically speculate that students acquire knowledge through the game play process to achieve learning goals. Based on Chen (2014), the mini-game approach benefits the development of GBL in two ways. First, the mini-game approach maintains the structure of the materials, which makes it suitable for well-structured subject domains, where the learning materials can be decomposed into smaller lessons or units to be drilled upon. Second, the mini-game approach offers more flexibility for application in domain-independent subjects. That is, the mini-game is allowed to utilize a signal principle to set knowledge or skills that students are required to learn (Maertens, Vandewaetere, Cornillie, & Desmet, 2014). However, the influences of mini-game-based learning on students' engagement behaviors are still unclear.

To confirm whether game-based learning effectively facilitates students' learning, some available methods, such as interviews, observations, surveys, and usability tests, have been used (Reeves & Hedberg, 2003). For example, based on the technological acceptance model, researchers suggest that students' experience of both usefulness and ease of use of game design features are related to their attitude toward game-based learning (Hou & Li, 2014). In addition, researchers have emphasized the relationships among game interfaces, users' learning-skill development, and achievement (Pinelle, Wong, & Stach, 2008).

Generally, while learning in a game-based environment, individuals must engage in activities such as problem identification, hypothesis making, and reflective thinking (Maertens et al., 2014). The degree of engagement is positively related to the individual learning outcomes (Admiraal, Huizenga, Akkerman, & Dam, 2011). Typically, researchers have proposed a three-part typology, emphasizing affective, behavioral, and cognitive dimensions of engagement (Fredericks et al., 2004). Behavioral engagement refers to the observable behaviors reflected in attendance or active participation, such as asking questions or participating in discussions. Cognitive engagement refers to an individual's goal setting, self-regulation of performance, or application of learning strategies. Affective engagement refers to attitude — a sense of intention, interest, or motivation to engage in a task.

Most research has examined students' engagement behaviors in game-based learning through questionnaires. For example, most researchers have used flow assessments to measure engagement (Admiraal et al., 2011; Hsieh, Lin, & Hou, 2013; Hou & Li, 2014; Inal & Cagiltay, 2007; Kiili, 2005). However, standard questionnaires may not be easily incorporated into various game-based learning environments. Moreover, important information that arises during the task execution process may be lost. For example, the elements of the game may produce physical reactions (Barsalou, 2003); at the same time, every action is associated with an instant reward or feedback from the game (Ke & Abras, 2012). Thus, unlike most research, which has examined only the students' attitude or final performance of game-based learning through questionnaires, qualitative observations of students' behavioral engagement with game-based learning are fundamental for the educational technology field.

Interaction with the digital application may also increase users' cognitive and affective experience (Weibel, Wissmath, Habegger, Steiner, & Groner, 2008), and some of these experiences will be embodied by physical behaviors (Smith, Cottrell, Gosselin, & Schyns, 2005). For example, a previous study found that students showed verbal behaviors, such as murmuring, expressing strongly positive/negative comments, asking questions to themselves, or stating their confusion or frustration while navigating the digital application (Tullis & Albert, 2008). The private speech may play a critical role in individual's thinking and action. Private speech is critical for the development of self- regulation and helps individuals decide whether they acted the way that they had planned. Thus, observing verbal information may help educators understand students' inward reflection on what they are doing and how these behaviors guide their own actions purposefully.

In an interactive context, observation of reactive behavior was a more reliable indicator than children's responses to questions (Hanna, Risden, & Alexander, 1997). Some nonverbal behaviors were observed, including facial expressions and body language directed toward the digital application task (Tullis & Albert, 2008). Sometimes, students with multiple learning disabilities are often unable to talk to teachers. Such important nonverbal behaviors may provide preliminary clues to help researchers understand students' learning experience and evaluate the appropriateness of the design of game mechanism. however rarely studies explore the effects of these potential behaviors. To know more about what type of verbal and nonverbal behaviors occur in a game-based learning process may inform us regarding the relationships between students and the design of the game. Therefore, to understand the effectiveness of game-based learning, we believe that the scope of the methodology should be extended to better understand users' reaction.

Gender differences in game-based learning have recently received increasing attention from researchers. Although gender difference is not a new issue, gender sensitivity toward educational games is strongly needed (Robertson, 2012). However, a large body of empirical research has noted the absence of gender differences in learning performance and motivation (Ke & Grabowski, 2012; Papastergiou, 2009). For example, to investigate whether there are gender differences in the game-making skills displayed by students, Robertson (2012) found that female students chose to spend more time writing dialogue than did boys, and female students scored higher in games than did male students. Hou and Li (2014) evaluated multiple aspects of problem-solving-based educational games and found that male students reported more positive results than did female students for the flow antecedents of challenge, goals, feedback, and playability. However, several studies found no significant gender differences in learning and motivation in game-based learning (Ke & Grabowski, 2012; Papastergiou, 2009). Accordingly, the impact of gender on game-based learning may reveal different results based on different game mechanisms. Additionally, because qualitative empirical research on gender issues in game-based learning remains limited (Papastergiou, 2009), it is necessary to explore gender differences in learning patterns with game-based learning.

In sum, this study suggests that a game design mechanism that matches the features of the game's goal may produce corresponding behavior patterns. To a certain extent, these behavior patterns may represent students' learning states, such as engagement behaviors, which are essential in achieving learning goals. Observation may be a highly appropriate method to collect data about students' dynamic behaviors in game-based learning environments. Understanding students' behavior patterns may help us to examine the relationship between the learning and gaming processes. Careful collection of students' verbal and nonverbal behaviors may be helpful in discovering the way that individual behaviors contribute to these processes in a game-based learning environment. Recently, sequential analysis has been integrated into behavioral analysis methods to examine the overall learning process (Hou, 2012a). Sequential analysis allows researchers to identify the sequential relationships of behaviors (Bakeman & Gottman, 1997). Through the visualized results of sequential analyses, we can see how learning occurs for students from inside out. Additionally, research has utilized sequential analysis method to analyze the behavioral patterns in massively multiple online role-playing games (Hou, 2012b).

Therefore, this study moves away from normative evaluations of students' achievement and focuses on the game-based learning process. This empirical study focuses on students' game-based learning process using a sequential analysis. The main purpose of this study is to explore students' engagement patterns in the game-based learning environment through integrating observation, content analysis, and sequential analysis. The questions to be addressed in this study are as follows:

- In a game-based learning environment, what is the distribution of the engagement behaviors demonstrated by students?
- What are the overall sequential engagement patterns displayed by students?
- What are the differences and similarities in behavior patterns between genders?

Method

Participants

The participants included 34 fourth- to sixth-grade elementary students (17 males and 17 females). Using a purposive sampling method, these students were selected from a cram school in Taiwan. All of these students attended the cram school for additional instruction in English, Chinese, and mathematics. All of them had experience in online games; their average time spent playing computer games was five to ten hours per week.

Game introduction

In Taiwan, students from elementary school to college are asked to perform resource classification. Resource classification is made based on their material and recyclable value. According to the current promotion of the government, resource classification is a public movement in train stations, airports, movie theaters, and streets. The resource classification ability has become necessary for all people in Taiwan.

Accordingly, a resource classification matching game called "Happy Black-faced Spoonbill" (Lin, Hsieh, Hou, Yen, Chou, & Chen, 2011) served as the platform for game-based learning in this study. The game was designed and developed using the mini-game approach to teach resource classification concepts to elementary school students. The mini-game is short and designed based on a signal principle. Based on the theory of experiential learning (Kolb, 1984), knowledge is gained through both personal and environmental experience during game play process. Experiential learning focuses on developing concrete experience and reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Thus, through its rules, the game allows students to engage in direct experience and reflect on their learning. As students go through the experience of playing this game over and over, they learn to develop their own ideas, try them out, and generate concrete concepts based on their experiences. While navigating within the game environment, each student has the opportunity to think about the resource classification concepts and to test their understanding of these concepts (Lin et al., 2011).

As shown in Figure 1, the game includes a cover story, clear rules and missions, a main screen, and the ending story, in that order. In the game, students must correctly find at least three types of resources to complete the game's mission. Students must execute the game task individually within a restricted timeframe (three minutes per run) and with ten health points. The time pressure and limited health points are regarded as one of the challenges of the game (Lin et al., 2011). A marker is shown under each recycle bin for students to evaluate their progress. Feedback is provided on the bottom right corner of the screen, with an angry black-faced spoonbill face if the player classifies a resource in an incorrect recycle bin. When students collect more than three resource objects for each classification, they are given a badge as a reward in the upper right side of the screen. When the game is over, score statistics are provided for the performance of the entire play session. Finally, the ending story is shown to promote the important concept of resource classification.

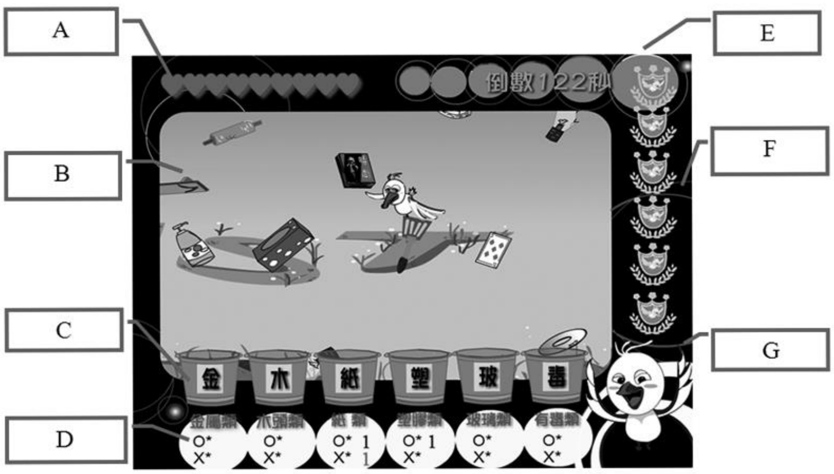

Figure 1. Interface of the "happy black-faced spoonbill" (A refers to the health points; B to the main screen for playing; C to recycle bins; D to score statistics; E to the countdown timer; F to badges as rewards; G to the angry face as feedback for wrong answers)

Procedure

This study was conducted in a cram school, an after-hours tutoring program. First, to control the effect of students' prior knowledge about resource classification, each student received individual, informal instruction for less than five minutes about basic concepts of resource classification. Then, the students were invited to play the game individually. Except for the cover story, introduction to the rules, and ending story, each run of the game play takes three minutes to execute. Each student was allowed to play the game repeatedly. After completing the game play, the students were given a brief review to increase their familiarity with the classification conceptions or to clarify their misconceptions.

Data collection

A synchronous video-capturing system and web camera were used to collect students' engagement behaviors. For example, the video-capturing system automatically recorded the computer screen and game background. Simultaneously, the web camera collected students' voices, facial expressions, and posture to understand how students reacted to the game mechanism. Verbal behavior refers to what students actually say, and the nonverbal behavior refers to students' facial expressions and body language. In this study, we chose the first barricade for further analysis and discussion. In all, the students contributed 1,899 behaviors during the game-playing process, and each behavior was categorized by content analysis.

Data analysis

Two stages of analysis were executed on the data analysis in this study: (1) content analysis of individual students' video data and (2) sequential analysis to assess students' engagement patterns.

Content analysis

Process videotapes were reviewed and coded. Using content analysis, we analyzed students' video-recording data for behavior distribution. We adopted a coding schema from Tullis and Albert (2008) and Hanna et al. (1997) as the reference to assess students' reactive behaviors to the digital application. The schema reflected the extent of students' general active engagement in a learning activity. Through the open coding and constant comparison of data, researchers generated the core categories (shown in Table 1). Episodes of student behavior related to students' verbal and nonverbal behavior were transcribed.

Each student had three minutes of video recording data. Based on muscular evaluation, previous research has indicated strong facial reactions 500 to 1000 milliseconds after the stimulus presentation (Moody, McIntosh, Mann, & Weisser, 2007). However, because this study attempted to artificially observe verbal and nonverbal behaviors in video data, five seconds was considered an acceptable coding block. If a block showed two or more different behaviors, coding was performed based on the order of appearance. Based on the coding framework, if the block did not show obvious behaviors related to the categories of the table, "OT" was coded. After observing every behavior from all students, two senior researchers coded each behavior based on the schema. The coders categorized all of the behaviors and discussed them to reach consensus. The inter-rater Kappa for these analyses was greater than 0.82 ($p < 0.001$).

Table 1. Coding schema of verbal and nonverbal behaviors

Categories	Code	Description of students' behaviors
Verbal behavior		
Verbal — Self-question	VS	Student asks himself/herself questions
Verbal — Frustration	VF	Student expresses frustration
Verbal — Murmur	VM	Student murmurs to himself/herself
Nonverbal behavior		
Smile	SM	Smiling and a noticeable up-twist of student's lips
Focus	FO	Focusing on the screen and seldom moving the head and body
Close	CL	Moving closer to the screen
Leave	LE	Moving body away from the screen
Scratch	SC	Scratching face, hair, or body
Arrow path	AR	Student's eyes and head move following the arrow path
Other behaviors		
Others	OT	Behaviors not included in the above, consisting mostly of unapparent behaviors, such as sitting motionless. These behaviors are difficult to categorize, and it is difficult to identify whether students have dropped out of the game or are attempting to find the solution.

Sequential analysis

To investigate a possible connection between students' verbal and nonverbal behaviors, we used a sequential analysis proposed by Bakeman and Gottman (1997) to discern the behavioral patterns in this study. The sequential analysis was used to visualize sequential correlations between chronologically ordered behaviors (Bakeman & Gottman, 1997; Hou, 2012a). To meet the requirements of the sequential analysis, students' behaviors were coded in the chronological order of their occurrence. For example, after focusing on the main task (FO), a student expressed his/her frustration (VF), followed by a smile (SM), and he/she may have been close to the screen (CL). This coding was described as FO→VF, VF→SM, SM→CL. Then, we calculated the frequency transfer matrix, the condition probability matrix, and the expected-value matrix. The calculated Z-scores from the above three matrixes were used to examine the significance of each sequence. Finally, we consolidated significant sequences into a sequential graphic summary to understand the sequential correlations among each behavior.

Result and discussion

Descriptive findings of the content analysis

As shown in Table 2, nonverbal behaviors were found to be the major distribution (94%). Within the total set of nonverbal behaviors, FO (focus on the screen and seldom moving the head and body) was identified at a relatively high frequency (44%). Moreover, the students were frequently found close to the screen (CL) (moving the body forward and close to the screen). A number of behaviors were identified, such as AR (eyes following the arrow path) (7%), SM (smiling) (4%), SC (scratching head or body) (2%), and LE (leaving the screen) (2%). The descriptive results are in line with the suggestion that games should involve students in an activity (Killi, 2005) and that long-term focus should be part of the learning task (Alessi & Trollip, 2001; O'Brien & Toms, 2008). For example, we found that students frequently moved their body to get closer to the screen and seldom took their eyes away from the screen. Moreover, after interacting with the game mechanism, students scratched their heads or smiled. These behaviors demonstrated that the game in this study stimulates students' curiosity and allowed students to experience pleasure (Alessi & Trollip, 2001; O'Brien & Toms, 2008).

In contrast to nonverbal behaviors, verbal behaviors (6%) were observed less frequently, such as VM (murmuring) (3%), VS (self-questioning) (1%), and VF (expressing frustration) (2%). For example, behaviors such as saying, "Oh my God, how does this work?" "How come? What happened?" or "Oops, wrong again" were observed. The verbal behaviors in this study provide evidence of an engaging experience that was aroused by the challenge of the game. Researchers indicated that the challenge experience may prompt students to reflect on their thinking and to revise what they have done (Woszczynski, Roth, & Segars, 2002). We suggest that verbal behaviors may have an implicit influence and can be regulated during students' gameplay process.

Additionally, gender differences have been found in verbal and nonverbal behaviors. Male students expressed more VS (self-questioning), VF (expressing frustration), and VM (murmuring). In addition, male students tended to demonstrate SM (smiling), CL (moving closer to the screen), LE (moving body away from the screen), and AR (eyes following the arrow path). In contrast, female students behaved with more FO (focusing on the screen and seldom moving the head and body) and SC (scratching face, hair, or body) behaviors. The distribution of the behaviors (OT) that were not related to the category schema was 5%. However, the verbal, nonverbal, and OT behaviors do not exist independently. Because the engagement assertion is not substantiated by the separate results, we present the results of the sequential analysis.

Table 2. Frequency distribution of students' engagement behavior

	Verbal behavior			Nonverbal behavior					Other	Total
	VS	VF	VM	SM	FO	CL	LE	SC	AR	OT	
Male (*n* = 17)	15	25	39	46	359	343	26	14	109	63	1039 (55%)
Female (*n* = 17)	4	13	18	30	471	237	12	24	24	27	856 (45%)
All (*n* = 34)	19 (1%)	38 (2%)	57 (3%)	76 (4%)	830 (44%)	580 (31%)	38 (2%)	38 (2%)	133 (7%)	90 (5%)	1899

Results of the sequential analysis

The sequential analysis helped us to identify the significant sequence of behavior transference during the game play process. The results are shown in the tables and figures. In all tables, the rows indicate the starting behaviors, and the columns indicate the follow-up behaviors. The Z-scores of the table were greater than 1.96, indicating that behavioral continuity from a certain row to a certain column reached statistical significance ($p < 0.05$). According to the significant sequence, we further inferred a sequential engagement pattern diagram, as illustrated in the figures. In the figures, the arrows indicate the direction of the significant behavior sequence, and the thickness of the arrowhead line indicates the level of significance. The circle represents students' nonverbal information (facial expressions and changes in body language), verbal information, and OT behaviors.

Table 3 and Figure 2 present students' overall engagement patterns while learning in the game-based learning environment. Reciprocal relationships among verbal, nonverbal, and OT behaviors were found. For example, we observed that students expressed smiling or scratching behaviors after expressing frustration (VF→SM, VF→SC), self-questioning (VS→SM), and murmuring (VM→SM). Often, after smiling behavior, students returned to self-questioning (SM→VS), expressed frustration (SM→VF), or murmured (SM→VM). For example, some students murmured with a smile, "Oops, what happened to me?" or "Well, perhaps the battery belongs to this." Moreover, the subsequent scratching behavior may indicate students' confusion (SM→SC, SC→VS, SC→VF). Blank moments prior to other actions or actions progressing to blank moments were also observed. For example, we observed that students went into a blank moment approximately 5 to 15 seconds after asking themselves questions or murmuring (VS→0, VM→0), followed by self-questioning and murmuring (ehavior and continuous attention to the game task. For example, while executing the task, students focused on the screen thoroughly and then moved their bodies closer to the screen (FO→CL; CL→FO). Sometimes students' bodies were close to the screen to reduce their distance from the avatar in the game, with their eyes following the arrow path to focus on the game elements (CL→AR, AR→FO). This pattern was repeated, and students were observed contemplating during the silent period. The reciprocal transference from the nonverbal to nonverbal behaviors seemed to be related to researchers' suggestions that games should evoke students' concentration, capture students' attention, and propel students toward engagement, leading to subsequent learning behaviors (Alessi & Trollip, 2001). Accordingly, lower engagement patterns may help in assessing whether a game is accessible and attainable.

Table 3. Adjusted residuals table of overall students (Z-score)

Z	SM	FO	CL	SC	AR	LE	OT	VS	VF	VM
SM	**6.34***	−2.29	−2.36	**2.83***	−1.58	0.11	**2.41***	−0.71	**4.02***	**2.1***
FO	−5.45	−0.69	**12.14***	−2.49	−0.01	−3.82	−8.86	−1.54	−3.96	−6.17
CL	−0.88	**5.42***	−6.22	−0.22	**4.66***	1.45	−3.58	0.25	−0.78	−1.05
SC	0.82	−2.4	−0.18	−0.3	−1.05	1.64	**2.64***	**5.42***	**1.96***	−0.63
AR	1.1	**6.48***	−5.57	−0.92	−3.19	0.02	−1.5	0.96	−1.3	**2.72***
LE	0.13	−2.12	−0.13	**2.01***	−0.72	**8.53***	0.45	−0.49	1.13	−0.88
OT	1.73	−8.42	−2.35	1.84	−1.99	0.38	**20.35***	−0.94	**3.56***	**2.21***
VS	**3.1***	−0.81	−1.92	−0.35	−1.23	−0.56	**4.02***	**4.55***	−0.5	−0.73
VF	**3.97***	−2.21	−1.75	**2.31***	−1.32	−0.61	1.7	−0.44	**3.28***	**4.48***
VM	**2.89***	−4.05	−2.39	1.3	−0.81	0.28	**2.89***	−0.65	**3.16***	**10.63***

$^*p < 0.05$.

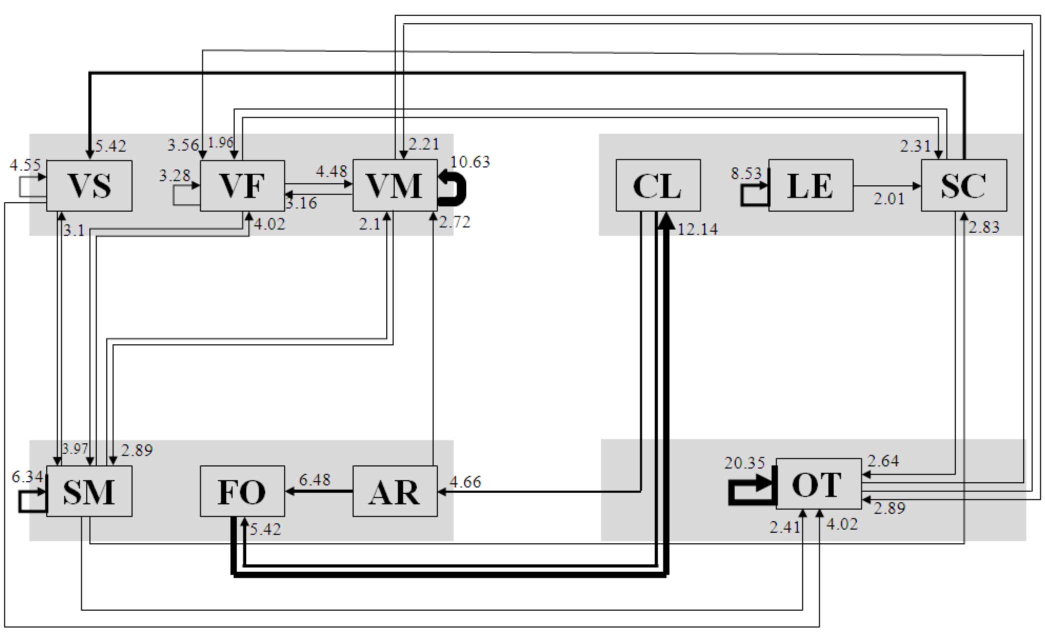

Figure 2. Overall students' engagement pattern

In sum, behavior can be divided into two broad, independent sections based on the sequential relationships between behaviors. One type describes students' higher engagement pattern (reciprocal relations of verbal, nonverbal, and OT behaviors), and the other describes students' lower engagement pattern (reciprocal relations between nonverbal and nonverbal behaviors). Note that the two categories may overlap; however, we are more concerned with illustrating the differences in the degree of engagement in learning tasks rather than defining the categories.

Moreover, the students were observed murmuring after their eyes followed the arrow path (AR→VM). The students murmured words such as "Oops! Dropped it again" or "I cannot get it." This finding may be due to our design mechanism, in which the students had to drag the garbage to the trash can; the students needed to exert more effort to control the mouse for the correct operation. This operation problem may explain some of the continuous frustration (VF→VF), reflecting two students' comments that "the mouse is so difficult to use."

Gender differences

Male students' behavior patterns are shown in Table 4 and Figure 3. Connections between some verbal and nonverbal behaviors were observed (VF→SM, SM→VF, VM→SC, and SC→VS). Additionally, connections were found between verbal behavior and OT (VS→OT, OT→VF) and between nonverbal and nonverbal (FO→CL, CL→FO, CL→AR, AR→FO) and verbal and verbal (VS→VS, VF→VF, VM→VM, VF→VM) behaviors. However, the reciprocal connection between verbal, nonverbal, and OT behaviors occurred less frequently in male students' behavior patterns.

On the other hand, as shown in Table 5 and Figure 4, we observed more complex connection behaviors in female students. For example, the connections between some verbal and nonverbal behavior were observed (VS→SM, VF→SM, SM→VF, VM→SM, SM→VM, VF→SC, SC→VF, SC→VS). Additionally, the connections between verbal behavior and OT were found (OT→VF, OT→VM, VM→OT). Moreover, the connections of nonverbal to nonverbal (SM→SM, SM→SC, FO→CL, CL→FO, FO→AR, AR→FO, CL→LE, SC→LE) behaviors were revealed. However, verbal to verbal behaviors were only found between VF and VM.

As indicated in Figure 5, both male and female students exhibited the same sequential behaviors while executing the game task. For example, they expressed bidirectional sequences between expressions of frustration and murmuring (VF→VM, VM→VF) and between smiling and expressions of frustration (SM→VF, VF→SM). Additionally, a continuing smile was observed (SM→SM), and students' self-questioning behavior occurred after their scratching behavior (SC→VS).

The bidirectional sequence between focus and moving the body closer to the screen was found in both male and female students (FO→CL, CL→FO). In particular, the behavioral sequence "eyes following the narrow path to focus the element of the game" (AR→FO) was observed in both male and female students.

Different sequential behaviors between male and female students are shown in Table 4, Table 5, Figure 3, and Figure 4. Male students' tendency to repeat verbal behaviors was observed. For example, male students tended to express self-questioning, express frustration, and murmur continually (VS→VS, VF→VF, VM→VM). However, it appeared that female students expressed more bidirectional sequences between verbal and nonverbal behaviors, as in the connections between self-questioning, expressing frustration, murmuring, and smiling (VS→SM, VF→SM, VM→SM) as well as between expressing frustration and scratching (VF→SC) (the connection was observed only between self-questioning and smiling (VF→SM) and murmuring to scratching (VM→SC)). Male students were observed moving their bodies away from the screen repeatedly (LE→LE). The leaving behavior was followed by the scratching behavior (LE→SC). Subsequently, the male students asked themselves questions after scratching their face, head, or body (SC→VF). In contrast, female students were observed moving their bodies away from the screen after scratching their face, head, or body (SC→LE).

Moreover, male students were observed moving their bodies to the screen with their eyes focusing on the arrow (CL→AR). However, this engagement pattern was rarely found in female students, who tended to focus on the elements of the game with their eyes following the arrow to execute trash classification (FO→AR). Female students also showed extreme caution while executing the game task. For example, they focused on one element and grabbed it on the main screen. Then, they carefully dragged it to the garbage bin while carefully watching the arrow, in case they lost the element.

Table 4. Adjusted residuals results of male students (Z-score)

Z	SM	FO	CL	SC	AR	LE	OT	VS	VF	VM
SM	**6.37***	−0.76	−2.3	−0.32	−1.49	0.48	1.65	−0.65	**2.45***	0.69
FO	−3.77	−2.33	**10.08***	−1.32	0.65	−2.87	−5.59	−0.84	−2.76	−4.45
CL	−1.36	**2.06***	−3.14	0.04	**5.4***	−0.07	−3.28	0.07	−0.72	−0.81
SC	−0.36	−0.48	−0.33	−0.12	−0.74	−0.29	1.57	**4.15***	−0.24	−0.42
AR	1.56	**7.68***	−5.38	−0.63	−4.03	−0.15	−1.5	0.55	−1.31	1.86
LE	0.52	−1.9	−0.6	**3.78***	−0.92	**9.06***	−0.17	−0.51	1.42	−0.92
OT	0.91	−5.06	−1.93	−0.45	−2.04	0.77	**15.04***	−0.9	**2.51***	−0.27
VS	0.77	0.28	−1.61	−0.23	−1.44	−0.57	**3.32***	**4.1***	−0.47	−0.82
VF	**2.51***	−1.6	−0.74	−0.21	−1.34	−0.53	1.39	−0.42	**4.26***	**2.03***
VM	0.74	−2.37	−1.91	**2.52***	−1.31	0.23	0.45	−0.73	**2.03***	**9.43***

$^{*}p < 0.05$.

Table 5. Adjusted residuals results of female students (Z-score)

Z	SM	FO	CL	SC	AR	LE	OT	VS	VF	VM
SM	**2.47***	−2.53	−0.98	**3.62***	−0.72	−0.54	1.77	−0.31	**3.35***	**3.35***
FO	−4.14	−1.25	**7.97***	−2.57	**2.98***	−2.14	−6.98	−0.84	−2.82	−3.49
CL	0.18	**6.48***	−5.99	−0.2	−1.96	**2.59***	−1.73	0.2	−0.39	−1.14
SC	1.19	−3	0.09	−0.32	−0.45	**2.71***	**2.31***	**5.06***	**2.71***	−0.34
AR	−0.75	**3.53***	−2.56	−0.4	−0.57	−0.43	−0.89	−0.25	−0.43	−0.43
LE	−0.53	−0.38	0.55	−0.28	−0.4	−0.3	1.06	−0.17	−0.3	−0.3
OT	1.62	−6.89	−1.44	**2.74***	−0.89	−0.67	**13.58***	−0.38	**2.51***	**5.69***
VS	**5.23***	−1.28	−1.27	−0.2	−0.28	−0.21	1.93	−0.12	−0.21	−0.21
VF	**3.19***	−1.42	−1.91	**3.1***	−0.43	−0.32	0.92	−0.18	−0.32	**6.1***
VM	**5.06***	−2.77	−1.91	−0.3	−0.43	−0.32	**5.69***	−0.18	**2.89***	−0.32

$^{*}p < 0.05$.

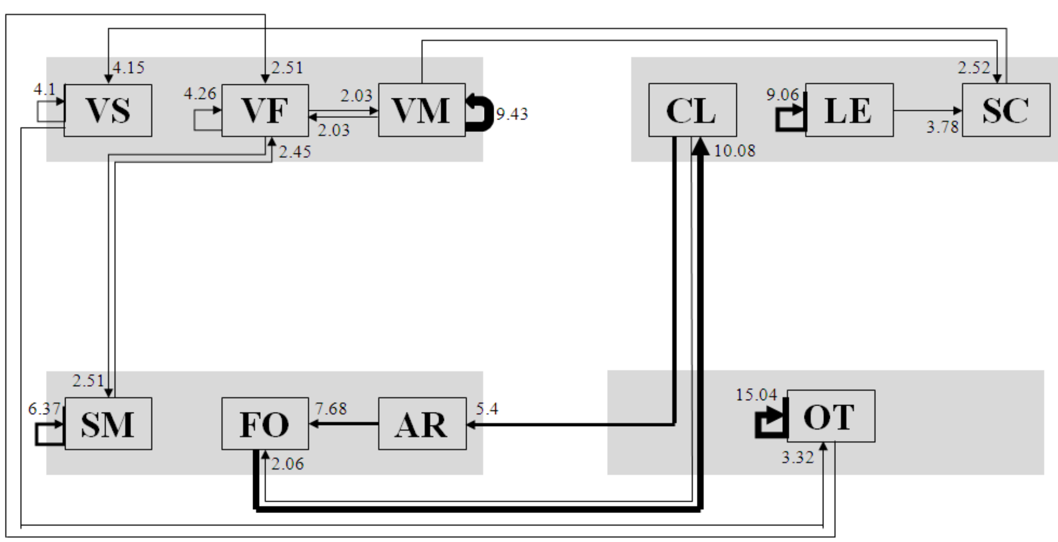

Figure 3. Sequential engagement patterns of male students' behaviors in game-based learning environments

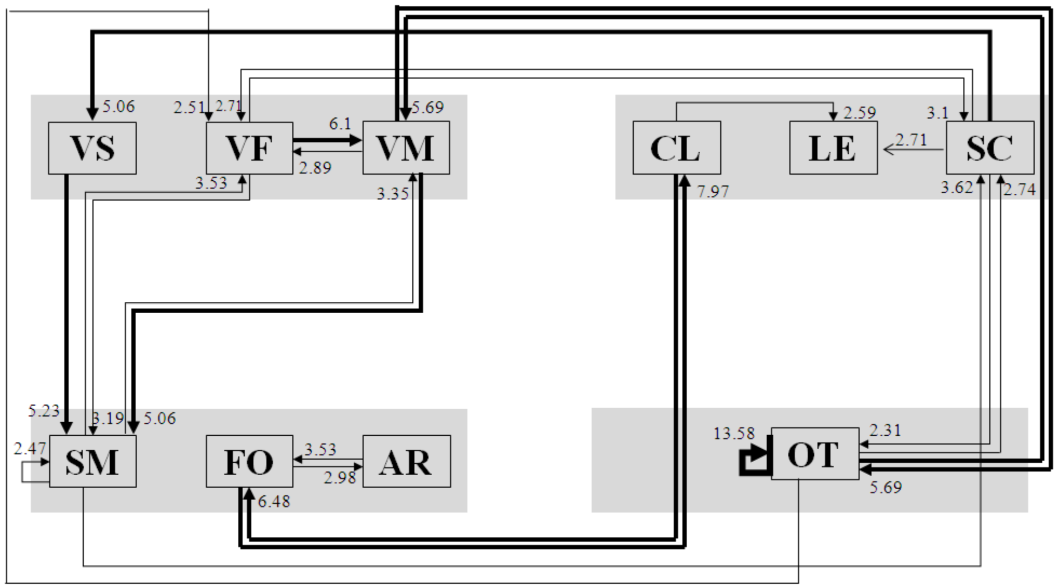

Figure 4. Sequential engagement patterns of female students' behaviors in game-based learning environments

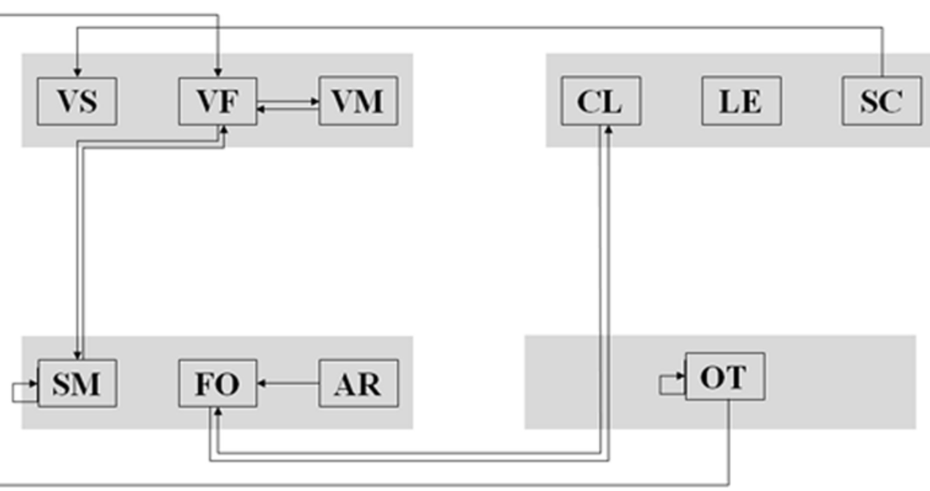

Figure 5. Similarity sequential behaviors between male and female students

Regarding gender issue in game-based learning, a number of commentators believe that gender difference may be diminishing or even disappearing (Ke & Grabowski, 2012; Papastergiou, 2009). However, when considering the learning process, a difference in the learning pattern was evident. For example, male students were observed demonstrating verbal behaviors when they encountered problems, whereas female students exhibited both verbal and nonverbal behaviors when they were confused. Male students demonstrated more engaged behaviors with continuous self-conversations, whereas the frequency of self-conversation by female students was obviously lower than those of male students. The result is in line with previous studies suggesting that males were more involved in the game task and had greater engagement in exploratory behavior than females (Papastergiou, 2009). Moreover, males were found to be more competitive than females and preferred to test themselves in games of skill (Inal & Cagiltay, 2007). In contrast, female students may begin thinking with facial expressions or body language, and these nonverbal behaviors may help to release their tension. This finding may indicate that female students are less confident about using technology to execute learning tasks and need to give themselves space to think. Inherent differences between male and female students' learning was observed in this study.

Conclusion and suggestions

By connecting obvious nonverbal and verbal behaviors, this study visualized the learning process and provided evidence that the game can consistently increase students' engagement in the game-based learning environment, which can provide insights as a good start for qualitative study in game-based learning. Thus, the behavioral coding schema provided by the authors and the innovative method of sequential analysis may help researchers obtain a certain level of understanding of students' engagement patterns and provide an alternative reference for researchers. The results of this study encourage researchers to use this innovative method.

The sequential patterns represented qualitative similarities and differences of engagement patterns by gender. For example, both male and female students exhibited the same sequential behaviors, such as expressing frustration, murmuring continually, or smiling. Differences in engagement patterns were also observed. For example, male students often demonstrated more engaged behaviors with continuous self-conversation, whereas female students did so noticeably less frequently. They tended to present both verbal and nonverbal behaviors when they were confused.

Observing how students respond to conflicting questions during the gameplay process provides an important modeling opportunity for educators to supply appropriate and effective facilitation for students. This may help educators and researchers to develop better game mechanisms to help students engage in meaningful learning. Moreover, these behaviors seem to be subconscious. We believe that follow-up interviews may help to explain the reasons for these behaviors. Interviews may include student-initiated questions and discussions of how they explored difficult concepts during the gameplay process as well as why students decided to terminate their engagement and failed to maintain attention to the game process.

This study proposes suggestions and notes limitations for future researchers who are implementing sequential analysis in game-based learning environments.

- In this study, students only had approximately 15–20 minutes to execute the game. The time participants spent conducting the game task may influence the grounding categories of verbal and nonverbal behaviors. Future studies should give a habituation time to avoid novelty effects. Thus, we suggest that future research should give students a longer time to play to allow researchers to collect data showing long-term changes in behavioral data and to explore the possible relationships between the behaviors. Moreover, the number of participants in this study was rather small. Future studies should increase the number of participants to improve the results.

- Finally, some elementary school students may not be able to control the mouse and may find it difficult to press and hold down the mouse button. Because poor usability is a barrier to engagement (O'Brien & Toms, 2008), this study suggests that future research could use keyboards instead of mice, especially for younger students. Moreover, the elementary school students' learning behaviors may be less constrained by the environment compared with elder students'. Thus, future process studies should recognize the limitations of inference from current field practice. We suggest further studies to explore possible engagement behaviors in elder students.

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