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Effects and Motivation/Engagement of an Interactive Digital Game for Special Education Students in Elementary School: A Case Study Analysis

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Abstracts

Objective: The rapid changes in and development of information technology have made life convenient. Tablets are used in classrooms, allowing students to learn through digital games. This study aimed to explore the learning effects and learning interests of special education students, to whom a lively interactive digital game along with an appropriate course design were applied.

Materials and Methods: This study applied the case study method to eight students with **autism spectrum disorder** (ASD) and cerebral palsy from a special education class in an elementary school. The effects of an interactive digital game on learning outcomes and learning interest (motivation/engagement) were analyzed through observation and documentation by the researchers.

Results: The findings revealed that the composition of the special education students was highly heterogeneous, and the learning effect varied among individuals. The learning effect and time-series analyses on participants' learning interest indicated more or fewer effects and outcomes in the eight participants. In addition to discovering the learning traits of each case, behavioral patterns and characters that differed from those in traditional teaching were observed for each participant, and involved some facets the researchers had never observed in other courses. In addition, the students with attention deficit hyperactivity disorder were observed to sit well on their seats to operate the game; they watched with concentration, and their eyes moved following the protagonist in the game. In addition to operating the tablets in their hands, they occasionally looked at other classmates to see the parts they were playing, and they were attentive to others.

Conclusion: All of them could accomplish the mission by following game instructions, and their motivation and engagement significantly improved during the game.

Keywords: Interactive digital games, ASD, intellectual disability, cerebral palsy

Introduction

The composition of special education students in elementary schools is mostly mixed-age and covers diverse disability types. In teaching, teachers must consider each student's learning style and speed as well as physical and mental traits. Special education teachers are responsible for helping students learn effectively. Computer assistive technology is applied to special education, ranging from communication training, learning lessons, everyday life, and entertainment activities to pre-employment training. Technology products such as tablets and smart phones are characterized by individualized learning, providing repeated exercises and real-time feedback; sound and light effects encourage children in special education to focus their attention, facilitate their hand eye coordination, and develop patience and emotional stability in them [1].

From computer-assisted learning and e-learning to digital game-based learning, through the simulation of real settings and high interactivity, learners were allowed to control objects in a game at will, leading to them feeling completely immersed [2]. This attracts their interest and concentration, allowing them to engage in the game and in learning [3,4].

1. Learning Traits of Children with Autism Spectrum Disorder (ASD)

Due to autism spectrum disorder (ASD), children with ASD lack communication skills in social and interpersonal interaction; added their innate interest and behavior, and self-stimulation, leading to great difficulty in learning and adaptation to life [5]. The dominant cognitive functions of people with ASD include visual space perception, visual perception, and visual motor integration; they exhibit rather strong performance in graphic composition and block design [6,7]. Teaching approaches adopted for autistic people include multi-sensory, structured, and random teaching; the Picture Exchange Communication Systems (PECS); social stories; game therapy; behavior therapy; art therapy; hug therapy; and animal therapy [8-11].

2. Learning Traits of Children with Intellectual Disability

Children with intellectual disability have difficulty in focusing

their attention, which has a short span. With gross and fine motor delays, these children's physical coordination and perceptual-motor performance are affected. In terms of teaching strategies, structuring of the learning situation is required and the principles adopted consist of starting from easy and moving to difficult, from simple to complex, and from concrete to abstract, as well as assimilating past experience into new experience. Learning content is divided into small steps through task analysis, thus improving the preservation and transfer of learning results; furthermore, multisensory learning activities are adopted to facilitating the formation of concepts and acquisition of knowledge. Learning outcomes and self-worth can be improved by providing suitable teaching materials and assignments, as well as successful learning experience, and giving appropriate feedback [12-14].

3. Learning Traits of Children with Cerebral Palsy

Regarding cerebral palsy, abnormal neuromotor control in aspects such as reflex, muscle tone, and coordination ability affect the person's mode of action, stability, balance, and coordination ability among others, leading to sensory integration disorder. This is followed by perceptual impairments regarding body image, left–right discrimination, spatial awareness, and sight, along with issues of cognition, communication, epilepsy, and persistent musculoskeletal disorders [15]. Students' individual needs, such as mobility aids, limb positioning, and communication should be understood to be able to design appropriate physical fitness activities according to their abilities, and to provide barrier-free facilities and environments as well as proper assistive technology devices [16].

4. Interactive Digital Games

Digital games consist of hardware information platforms providing audio-visual entertainment; game-integrated technology products include TV, PC, arcade, handheld, and mobile games [17] have been developed. Baecker and Buxton [18] as well as Ghasemifard et al. [19] proposed human computer interaction, which covers human–computer interaction and relationships of usability test methods. Rollings and Adams [20] held that interactivity is how the player watches, listens, and acts in the world of a game. In another study applying interactive video games, the complexity of human–computer interaction, expression of learning subjects, user interface, and game content were submitted for review and modification in consideration of game practicality, improving the applicability of interactive video [21].

5. Relationship of Digital Games with Learning Effect and Learning Interest

Dalgarno and Lee [3] indicated that virtual multimedia game environments helped improve motivation and engagement, as well as more effective collaborative learning, and were a base for improving learning outcomes and efficiency. Wu [22] suggested applying a handheld device, namely tablet computers, to teaching lessons, which were integrated into the environment to improve the learning effect. Research by Girard et al. [4], Sitzmann [23], and Wouters, et al. [24] has indicated that digital games yield effective and positive learning outcomes. Giannakos [25] revealed that a joyful feeling and attitude with intention to use during participation in digital games increased the learning effect.

O'Neil et al. [26] and Hays [27] as well as Southgate [28] indicated a lack of sufficient proof indicating enhanced learning outcomes from game-based digital learning compared with traditional classroom learning. Gunter et al. [29] indicated that the effect of game-based digital learning stresses learning motivation, interest, and attitude, or social interaction, rather than the effect of knowledge or achievement tests. Lorant-Royer et al. [30] indicated that young people, teenagers, and children were strongly motivated for digital games, and useful digital games could be developed into effective educational tools.

6. Computer Technology Used in Special Education

Su [31] found that the teaching strategy of using multimedia computer games in an applied language curriculum for elementary students with intellectual disabilities exhibited a significant, immediate learning effect. Annetta et al. [32] indicated that digital games helped to enhance the learning participation and motivation of children with learning difficulties or attention deficit disorder. Berman [33] held that tablet touch screens requiring only touches and clicks were convenient to operate for patients with stroke or cerebral palsy whose movements were limited following brain injury; they also stimulated multiple senses such as sight, hearing, and touch simultaneously. Tsao and Yang [34] researched the ability of computer-assisted education programs based on games to improve the attention of primary school children with high-functioning **ASD**.

This study aimed to explore the learning effects and learning interests of special education students, to whom a lively interactive digital game along with an appropriate course design were applied. Furthermore, it aimed to provide opportunities for children with physical and mental disabilities to interact with their peers.

Research Design and Implementation

The factors influencing learning effects and learning interests regarding a digital game were explored profoundly. The case study method was adopted; data collection and case analysis were performed by means of the researchers' observation journals and documentation analysis, assisted by some quantitative data, including a learning effect test and a learning interest questionnaire to support the research results.

1. Participants

Eight special education students of an elementary school were the research participants, comprising two female and six male students. Because of the vast differences among individual students, their behavioral patterns, learning interests, or learning effects could not be analogized. Prior to the study, all the students had experience of using a Nintendo Wii, tablet, smartphone, or computer games. Table 1 presents the basic information of the eight cases researched.

Name code	Sex	Disability type	Description of characteristics	Experience of digital game operation
B	Male	Moderate **ASD** along with attention deficit hyperactivity disorder	Rather distracted attention; abundant reminders and some physical assistance are required to utter common things in everyday life by observing objects and images; has occasional need to leave the seat for a walk. Sight is the dominant learning channel; touch is still required for learning.	Often uses a tablet computer to watch videos at home.

Table 1. to be cont...

K	Male	Severe **ASD**	Quietly sits on a chair in class most of the time. Has verbal ability; capable of imitating terms; identifies things mostly through images; some physical assistance required to operate things.	Occasionally uses a tablet computer to watch videos at home.
M	Female	Severe **ASD** along with attention deficit hyperactivity disorder	Occasionally makes sounds, or shouts when resisting things; has verbal ability; capable of imitating short phrases; some physical assistance required to operate things.	Often uses a tablet computer to watch videos at home; takes photos with a cellphone.
T	Male	Moderate **ASD** along with attention deficit hyperactivity disorder	Distracted attention; considerable physical activities required; capable of uttering common things in everyday life by observing actual objects and images; a literacy level in Mandarin equal to that of second graders in primary schools. Sight is the dominant learning channel.	Has played games on a smartphone; has a preference for listening to stories using a story player (simply turning on/off, and clicking on the previous/next page) most of the time.
A	Male	Moderate **ASD**	Interacts with the teacher and answers questions; concentrates in class; capable of uttering common things in everyday life by observing objects and images; sight and touch are the dominant learning channels.	Has experience of using a Wii, tablet computer, and smartphone; less frequently allowed by parents to operate them.
G	Female	Moderate (with intellectual disability)	Has a preference for operating things; less capable of obedience, and reiterating rules is required; weak voice; capable of saying short phrases.	Often uses a tablet computer to watch videos at home.
J	Male	Moderate cerebral palsy along with intellectual disability	Serious in class; no verbal ability; capable of selecting the answer from two to three options; has a preference for interacting with people; positive and works hard; with weak grasp, grip, and pinch forces; close assistance is required.	Has used a Wii; occasionally uses a desktop computer to watch videos or play games at home.
W	Male	Severe cerebral palsy	Rather distracted attention; hearing is the dominant learning channel; has verbal ability; capable of expressing ideas following encouragement; has weak grasp, grip, and pinch forces; considerable close assistance is required.	Has experience of using a Wii; often uses a desktop computer to play games at home.

Table 1. Demographic Information of the Cases

2. Research Tools

(1) Researchers

The researchers were homeroom teachers in the special class of the participants; they ordinarily interacted frequently with these students, and knew about their statuses and abilities. With special needs, the participants' insufficient verbal abilities were need to assistive them from stating their thoughts. Thus, to understand the participants' statuses during interactive digital game-based learning, the researchers maintained research and observation journals as well as coding to observe participants' behavior, emotion, facial expression, limb reaction, or verbal articulation during each operation of the game.

(2) The interactive digital game

The Fun Ocean game developed by Professor Hong Jon-Chao was adopted. The game background is in the sea; through experiencing a mysterious world of deep sea creatures, the player makes new friends with Dot, the protagonist (Figure 1), and explores an interesting underwater world.

Figure 1. Fun Ocean interface: Dot, the protagonist, leads everyone on an adventure.

Through the game instructions, the participants were led to learn about diverse deep sea creatures, which emerged randomly. The participant underwent a trial of matching these deep sea creatures with their silhouettes; he or she could proceed to the next stage by clicking the correct silhouette (Figure 2). After making new friends, the participant encountered a terrifying shark. When the game instruction "Send the partner" appeared (Figure 3), the participant was asked to shake the tablet computer or smartphone to send the newly met partner into the fight, and he or she defeated the shark by gliding the partner forward to attack it (Figures 4 and 5). The game allowed an Internet connection to the tablet computer or smartphone, and the participant could invite a friend to help select a deep sea creature to partner with as well as monitor the health of the shark and themselves. The participant could click on "Main menu" in the upper-right corner of the game operation interface, which showed Dot, the game protagonist, leading everyone in viewing illustrations of deep sea creatures and reviewing newly made friends (Figure 6).

Figure 2. Fun Ocean game mission: Matching deep sea creatures' silhouettes.

Figure 3. Fun Ocean game: Listening to the instruction; human–computer interaction.

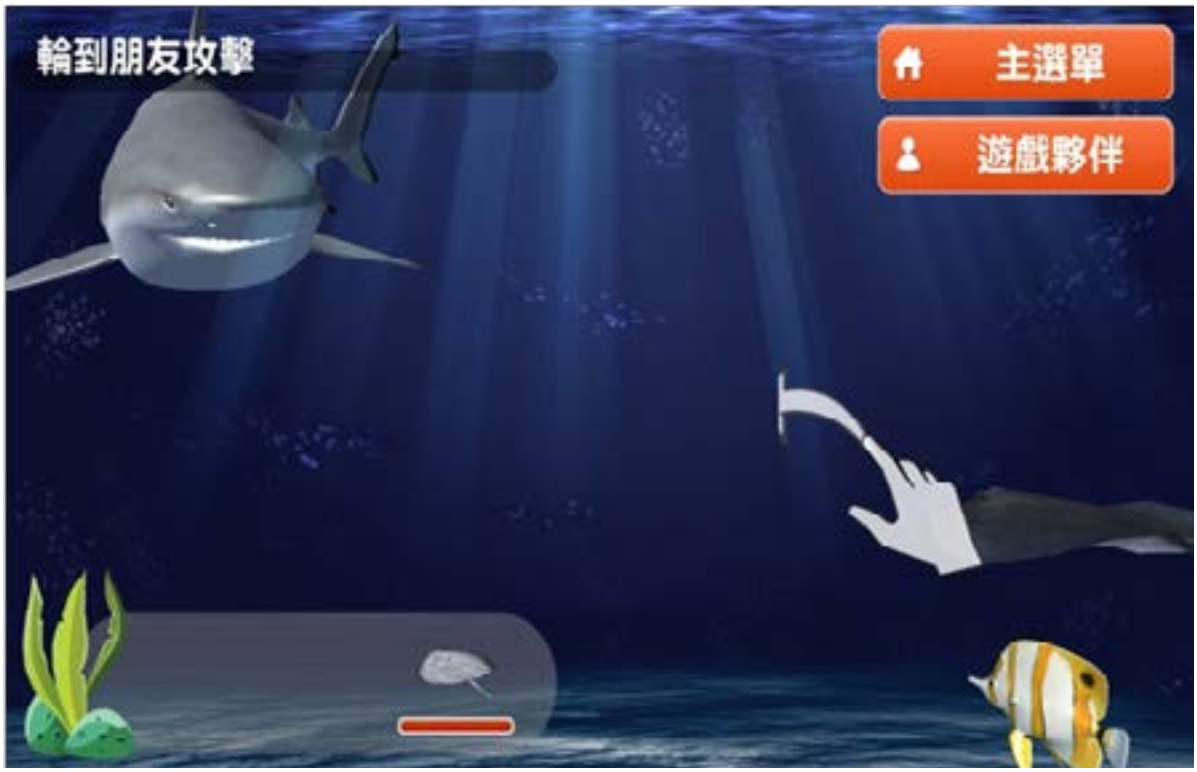

Figure 4. Fun Ocean game: Listening to the instruction; human–computer interaction.

Figure 5. Fun Ocean game: defeating the enemy together with the game partner.

Figure 6. Illustrations of deep sea creatures in the Fun Ocean game.

(3) Learning effect test

To explore the learning effects for the participants through Fun Ocean, an image–text matching test was adopted as the tool for a learning effect test. The learning effect test contained 12 multiple-choice questions; all the images showed deep sea creatures emerging in Fun Ocean.

Prior to the first operation, the participants' initial ability was evaluated using the abovementioned learning effect test; following the last operation of the interactive digital game, the same learning effect test was conducted again for re-evaluation.

For the learning effect test, experts and senior special education teachers were invited for an expert review and assessment of the content validity.

(4) Learning interest questionnaire

The learning interests produced in the participants through operating the game were explored. Based on a Likert scale, the learning interest questionnaire involved three dimensions: "like," "enjoyment," and "engagement"; each dimension contained three items for a total of nine items. Each item contained five options from left to right: strongly disliked, disliked, neutral, preferred, and strongly preferred. The options originally described with text were replaced and represented with emojis because these were applied to special education students.

For the learning effect test, experts and senior special education teachers were invited to perform an expert review and assessment of the content validity.

3. Research Process

Before operating the game, the students were guided in a pretest on learning effects to obtain the starting points of their cognition prior to the research. This was conducted during a natural science class in the school; each student operated a tablet computer individually and separately. During the learning activity, the researchers sat by the participants to observe and help them operate the tablet; the other two joint teachers helped the participants depending on their needs. Each operation of Fun Ocean lased 20–25 minutes; six sessions were conducted, totaling 120–150 minutes of learning activities. At the 5th and 6th operations, the two-player mode was chosen to let the participants form pairs to jointly defeat the enemy.

During the process, the participants occasionally uttered anything on their minds during the game; the teachers observed and recorded the students' reactions and behavior. In addition, they noted important and particular behavior observed in observation journals whenever necessary.

Following each game-based learning activity, the researchers and two joint teachers guided the participants to take 5 minutes to fill in the learning interest questionnaire. The questionnaire was aimed at understanding their feelings after each game-based learning session and providing a reference for analyzing the participants' interactive digital game-based learning process. Moreover, the researchers wrote a reflection record regarding the participants' behaviors observed that day to reveal problems and provide temporary inferences, which served as references for the subsequent observation on the same learner. After six sessions of the interactive digital game, all participants were subjected to a posttest on learning effects.

(1) Qualitative data analysis

The researchers coded the documentation of observation records and reflection journals, which served as the data for analysis. For example, the code "observation 20161025 [A]" indicated "October 25, 2016 observation record on Case A on proviso." A triangular test was adopted to assess the data validity. A triangular test consists of comparing in the same situation, and discriminating or cross-interpreting data collected from different angles, which enhances the validity of data interpretation [35].

(2) Quantitative data analysis

The office software Excel was used to analyze the participants' quantitative data from the learning effect tests and learning interest questionnaire. The data from said questionnaires were subjected to a time-series analysis for understanding the relationships among the quantitative data, which served as proof for the qualitative analysis.

Results

1. Analysis of the Participants' Respective Learning Effect

Tests were repeated according to the learning effect test. The participants were grouped according to the types of physical and mental disabilities. The number of items in the pretest and posttest on learning effects, as well as the number of difference between them, were organized as in Table 2.

Group	Name code	Disability level	Grade	Pretest	Posttest	Value of progress
ASD group	B	Moderate	1	2	7	5
	K	Severe	1	4	5	1
	M	Severe	2	2	8	6
	T	Moderate	2	6	10	4
	A	Moderate	3	6	10	4
Intellectual disability group	G	Moderate	3	5	6	1
	J**	Moderate	3	4	5	1
Cerebral palsy group	J	Moderate	3	4	5	1
	W	Severe	3	3	8	5
* The value of progress was obtained by subtracting the pretest from the posttest						
** Case J had both intellectual disability and cerebral palsy						

Table 2. Learning Effect Analysis

Table 2 indicates that the intellectual disability group's value of progress was the lowest. The **ASD** group's value of progress was inconsistent; some participants' learning effects were great, whereas those of the others were weak. Similarly, the cerebral palsy group's value of progress was inconsistent. Most autistic students' memory was superior to that of those with intellectual disability, and sight learning was their main learning channel. Operating the interactive digital game yielded the effect of repeated memory enhancement; the learning effect of some participants of the **ASD** group was rather great. Nevertheless, the result of a weak learning effect regarding some autistic participants probably came from their low intelligence or distraction when operating the interactive digital game. The participants with intellectual disability learned slower. Even after operating six sessions of the game, the resulting weak learning effect was expected given their poor short-term memory. The literacy performance of Case W in the cerebral palsy group had remained inferior from the first grade to the first semester of the third grade, yet the learning effect test in this study revealed a great learning effect in her. This result was unexpected and revealed other learning traits of this student, which was a great gain of this study. Student J had both cerebral palsy and intellectual disability, and was highly affected by the intellectual disability; thus, the result of a weak learning effect was not surprising.

2. Analysis of the Participants' Learning Interest

The nine items in the learning interest questionnaire were in three dimensions, namely "like," "enjoyment," and "engagement";

each dimension contained three items. Each item contained five level options: strongly disliked, disliked, neutral, preferred, and strongly preferred from left to right. Following each operation of the interactive digital game, the research participants filled in the learning interest questionnaire. The questionnaire contents for the six operations were analyzed using the time-series technique, and they are presented in the following six subsections, respectively:

(1) Case B

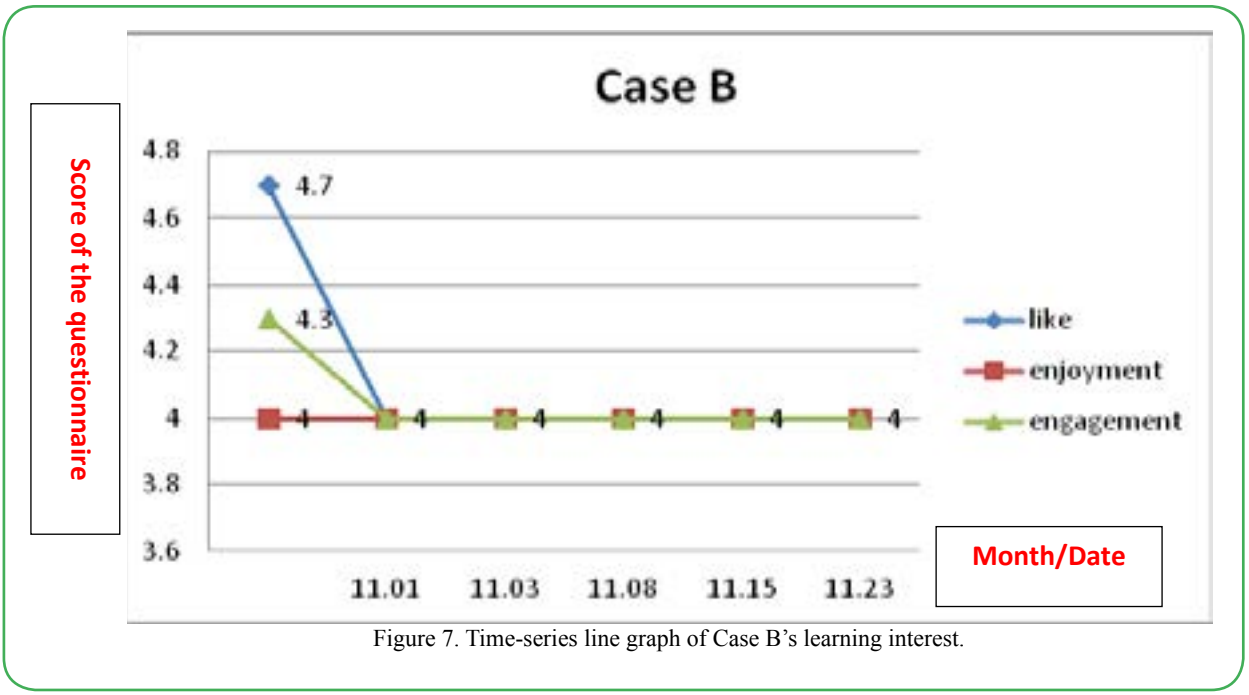

Figure 7. Time-series line graph of Case B's learning interest.

Throughout the six operations of the interactive digital game, Case B was able to sit well on his seat. Some help was provided only during the first session of the game, and he was able to interact independently by following the game instructions. The teacher once attempted to help, and Case B said, "B would press it by myself" (observation 20161101 [B-3]). During the operation, he watched with concentration and exhibited a delighted expression. When a tablet computer with a purple shell was available on the day of the game operation, Case B happily pointed to the tablet computer and said, "B wanted the purple one" (observation 20161025 [B-1]; observation 20161103 [B-1]; observation 20161115 [B-1]). The time-series graph reveals that no great fluctuation occurred in Case B's learning interest between the situation with a tablet computer with a purple shell and that without such a tablet. Similarly, there was barely any fluctuation in his emotion during operation, and he smiled all the time. At the fifth and the sixth operations, the researchers arranged for Case B to collaborate in the game with another case, and his emotions and reactions barely differed from those at previous operations. During the process, he followed the game instructions, and did not interact with the classmates in the same group.

A learning interest questionnaire was filled in following each game operation. Case B always circled the smiling face representing "preferred" regardless of how the teachers explained the items. According to the observation record and the behavior and emotion actually exhibited, the participant was in a happy mood, which conformed with the results presented in the time-series graph. The time-series line graph indicates consistency in the three dimensions of learning interest (i.e., "like," "enjoyment" and "engagement").

Case B was able to learn the subjects of Mandarin and mathematics and had good cognitive ability. He obtained 5 points in the learning effect test in this study, placing him in the high-score group. This game cast an effect on Case B's learning.

(2) Case K

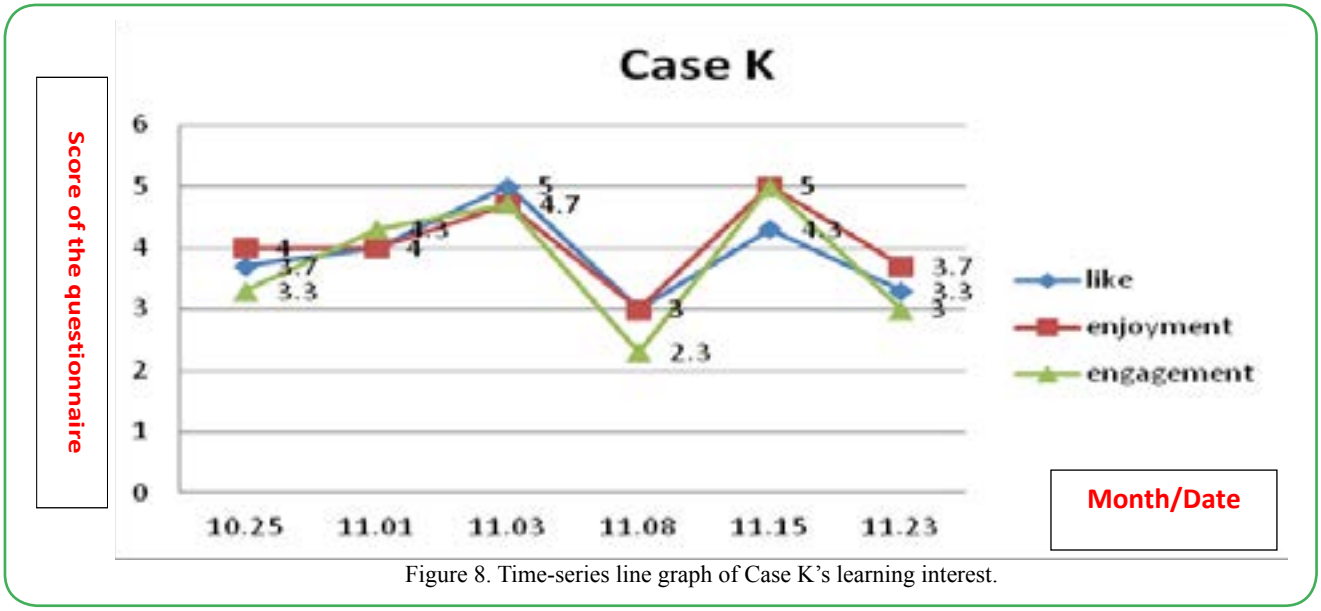

Figure 8. Time-series line graph of Case K's learning interest.

According to the observation record, before the first three operations, Case K exhibited great interest as soon as the teachers took out the tablet. In the observation record, the following was written: "Case K's eyes were wide open; he stared at the tablet computer with a smile on the face. He stretched his hands forward and wanted to grab the tablet computer soon" (observation 20161025 [K-1]; observation 20161101 [K-1]; observation 20161103 [K-1]). According to the record on the fourth operation, "Case K was not feeling well today and was spiritless" (observation 20161108 [K-1]). The two-player mode was used at the fifth and the sixth operations; the observation record revealed that Case K liked to operate alone, and even pushed the teacher's hands away (observation 20161101 [K-2]; observation 20161103 [K-2]; observation 20161108 [K-2]), presumably because the fifth session was the first operation in the two-player mode, and the freshness led to greater learning interest; the sixth operation remained in the two-player mode, which went against Case K's personality of being inclined to operate alone, resulting in decreased learning interest (reflection 20161103 [K]; reflection 20161115 [K]; reflection 20161123 [K]). The time-series line graph demonstrates consistency in the three dimensions of learning interest (i.e., "like," "enjoyment" and "engagement").

Case K learned other subjects more slowly. His cognitive ability was weak and he knew very few words. He obtained 1 point in the learning effect test in this study, placing him in the low-score group; the game cast a less significant effect on Case K's learning.

(3) Case M

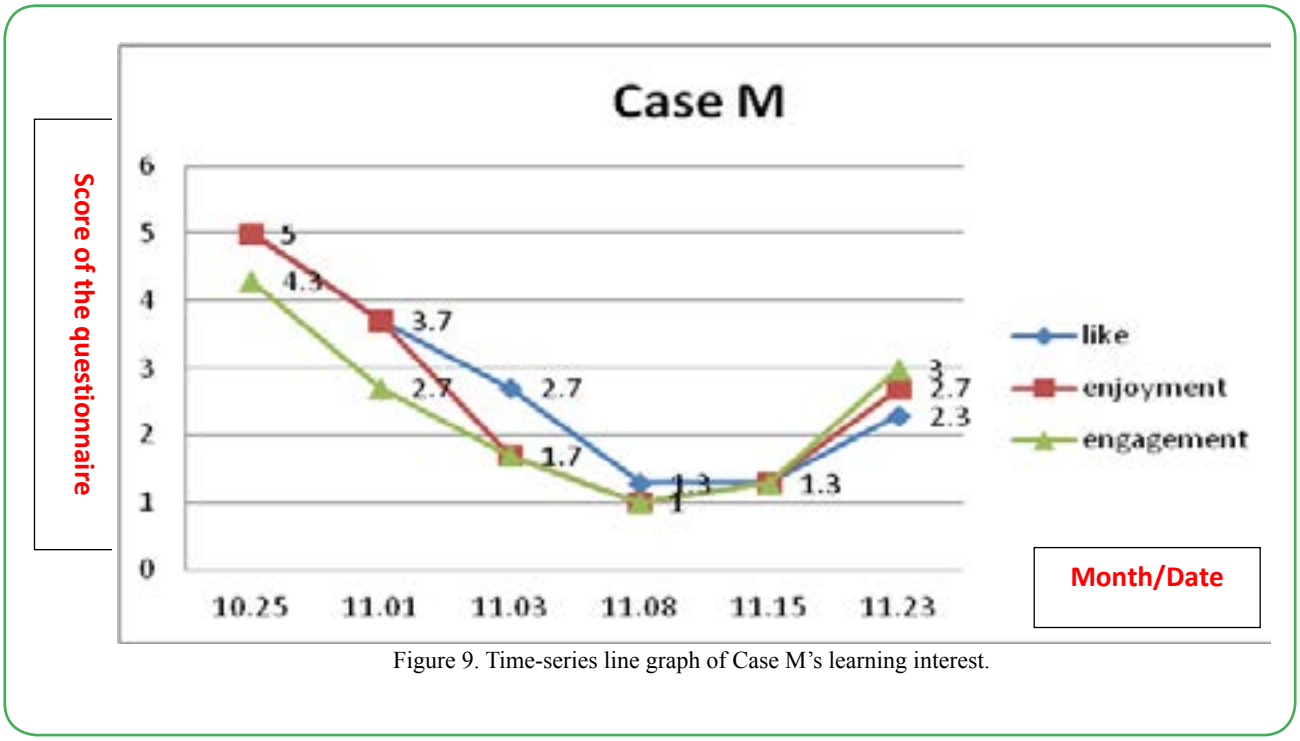

Figure 9. Time-series line graph of Case M's learning interest.

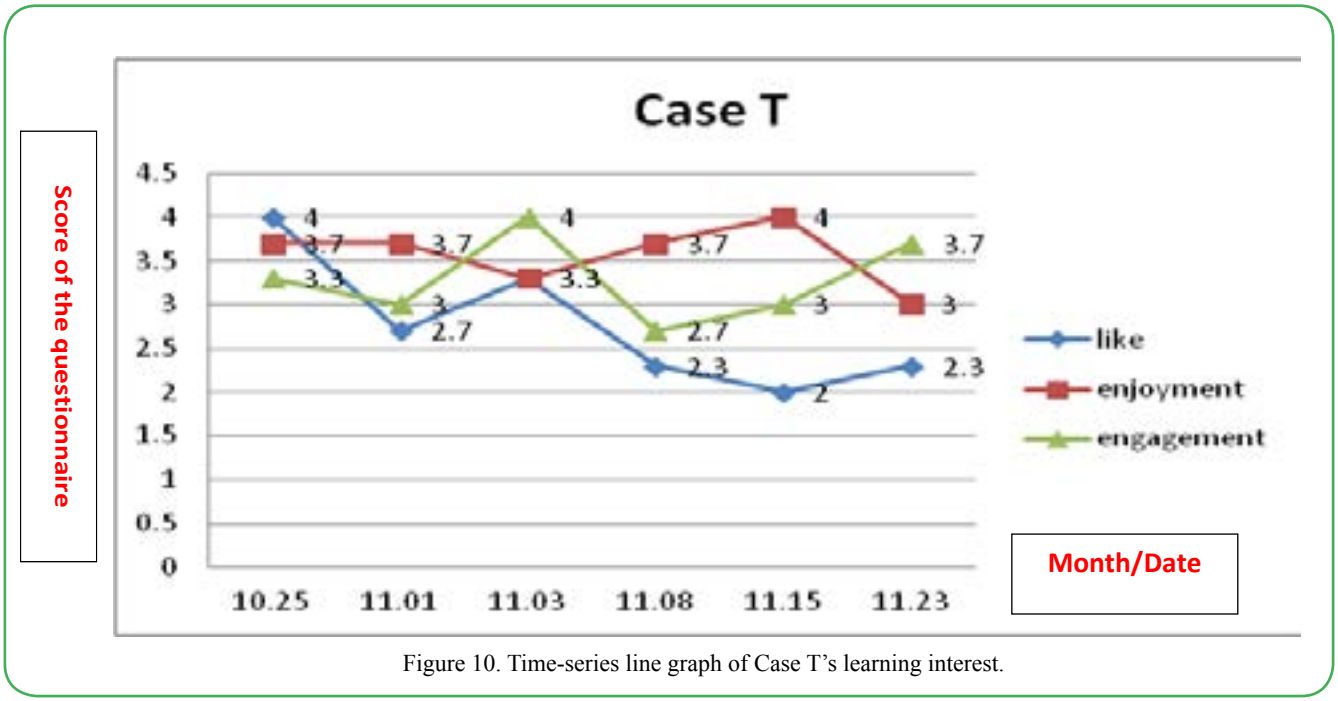

Figure 10. Time-series line graph of Case T's learning interest.

Case M became familiar with the game operation quickly. During the second operation, after approximately 10 minutes, she already began to feel distracted and was unwilling to operate the game; her eyes gazed elsewhere or seemed dazed (observation 20161101 [M-2]). At the third operation, having played for 10 minutes, she began to exit the game interface and check other apps on the tablet computer (observation 20161103 [M-2]). During the fourth operation, she exited the game interface after playing for 5 minutes and clicked on other apps on the tablet computer (observation 20161108 [M-1]). At the fifth operation in the two-player mode with a classmate, her eyes continually looked elsewhere, and she was unwilling to follow the game instructions to operate; she only clicked with the teacher's help (observation 20161115 [M-1]). At the sixth operation, the researcher encouraged her by saying that she could rest after playing for a short while this time. Case M laughed and briefly touched the researcher's hands before continuing to operate (observation 20161123 [M-1]). During the six operations, she was often distracted. Case M did not leave her seat and was willing to follow the teacher's verbal instructions to operate.

The observation record and actual experience of interaction revealed that Case M's preferences for things were clearly demarcated, and she began to feel distracted regarding things that were not interestingfor her. The observation record, the actual interaction process, and the time-series graph revealed low interest from Case M regarding this interactive digital game, which conformed with the results represented in the time-series graph. Said graph demonstrated consistency in the three dimensions of learning interest (i.e., "like," "enjoyment," and "engagement").

Case M's learning of other subjects was affected by her preference for the learning content; her cognitive ability was average, and she knew very few words. She obtained a 6-point value of progress in the learning effect test in this study, placing her in the high-score group. This game cast an effect on Case M's learning.

(4) Case T

During the game operation, Case T always clicked on the next step hurriedly and skipped the explanation by Dot, the game protagonist (observation 20161025 [T-1]; observation 20161101 [T-1]; observation 20161103 [T-1]; observation 20161108 [T-1]; observation 20161115 [T-1]; observation 20161123 [T-2]). Throughout the six operations, Case T was able to sit on his seat and operate, and no longer talked to himself as he often did ordinarily; his eyes moved following the deep sea creatures in the game (observation 20161025 [T-2]; observation 20161101 [T-2]; observation 20161103 [T-2]; observation 20161108 [T-2]; observation 20161115 [T-2]; observation 20161123 [T-3]).

In response to the "Send the partner" instruction during the first operation, the user was required to shake the tablet. Case T repeatedly failed to complete the action because of weak shaking. Case T spontaneously stretched his hands to seek the researcher's help (observation 20161025 [T-3]). During the third operation, the researcher accompanied Case T in operating for some time. The time-series graph revealed that the curves of "like" and "engagement" rose significantly. During the second, third, and fourth operations, after playing for approximately 10 minutes, a great white shark was encountered after Dot guided the player to learn about three deep sea creatures through their silhouettes, and at that moment, Case T exited the game and clicked to check the illustrations of creatures in the game. Such behavior was recurrent. The researcher told him to accompany him in defeating the great white shark, and he pushed the researcher's hands away, saying "I don't want the great white shark" (observation 20161103 [T-3]). Thus, it was inferred that Case T preferred learning creatures to defeating the great white shark (reflection 20161108 [T]). The fifth time, Case T paired with a classmate he usually preferred and they jointly operated the game in two-player mode. The time-series line graph revealed that Case T disliked this digital game even though he somewhat engaged in the process, yet he obtained high scores in the "enjoyment" dimension. The last time he played the game, he said "I don't want to" as soon as he saw the tablet computer (observation 20161123 [T-1]). When the researcher encouraged him to play just for a moment, he accepted and followed the operation. The observation record and time-series line graph revealed that the preference of Case T for the interactive digital game became increasingly lower, and his engagement level was affected by the presence or absence of others' company. Nevertheless, the score in the "enjoyment" dimension was mostly higher than those of the other two dimensions. Case T was good at learning Mandarin and mathematics and knew many words; his level amounted to that of a second grader. He obtained a 4-point value of progress in the learning effect test, placing him in the high-score group; this game cast an effect on Case T's learning.

(5) Case A

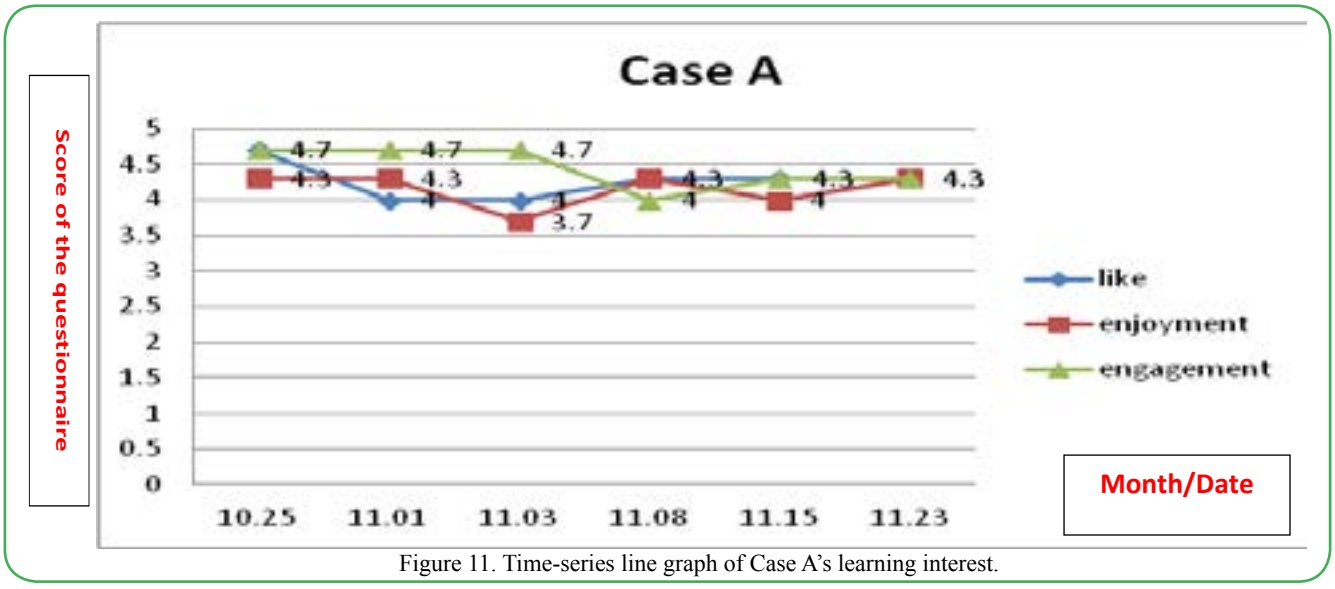

Figure 11. Time-series line graph of Case A's learning interest.

After the researchers demonstrated the game operation to participants for the first time, Case A could follow the game instructions to operate on his own; his movements were mild without rush (observation 20161025 [A-2]). To the question of whether he needed help, Case A replied "No, no." He watched with concentration during the operation (observation 20161025 [A-3]). The time-series line graph revealed consistency among the three dimensions of learning interest (i.e., "like," "enjoyment," and "engagement"), and the scores all belonged to the high-score scale, except for the third test where the scores of the "like" and "enjoyment" dimensions somewhat decreased. The observation record did not note any particular behaviors, emotions, or situations. The reason was probably the rather short interval between the second and third learning sessions.

Case A had favorable achievement at learning Mandarin and mathematics; he knew many words, and his literacy amounted to the level of a second grader. He obtained a 4-point value of progress in the learning effect test, placing him in the high-score group. This game cast an effect on Case A's learning.

(6) Case G

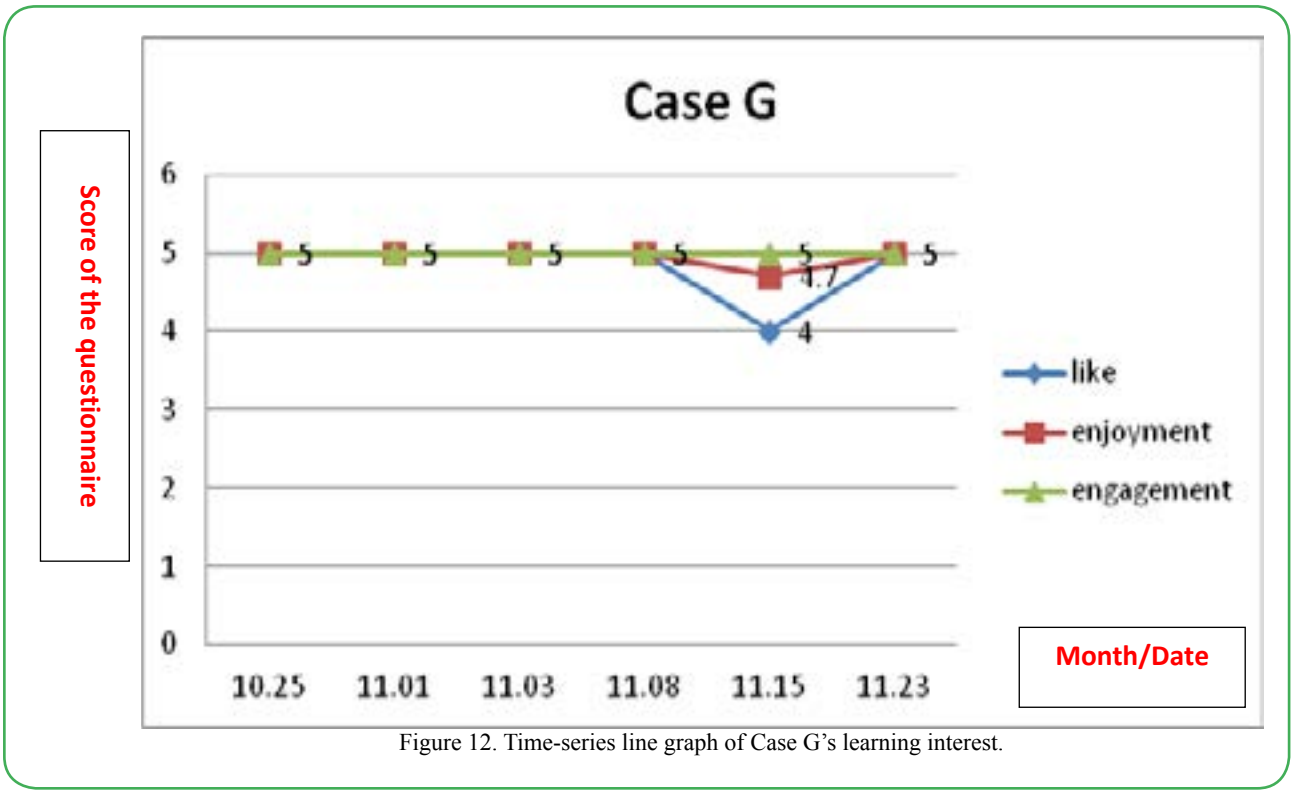

Figure 12. Time-series line graph of Case G's learning interest.

At the first operation, after the joint teacher guided Case G in the game operation, she could follow the game instructions to operate with occasional help. She watched with concentration, and her movements were mild (observation 20161025 [G-2]). Observation revealed that Case G sometimes directly pressed without listening to the explanation by the protagonist Dot until the end (observation 20161101 [G-3]; observation 20161103 [G-2]; observation 20161108 [G-2]). She required some help the fifth time to operate in the two-player mode, which probably resulted from the difference in operation from the one-player mode (observation 20161115 [G-1]).

The time-series line graph revealed high consistency among the three dimensions of learning interest (i.e., "like," "enjoyment," and "engagement"), and the scores all belonged to the high-score scale, except for the fifth test where the scores of the "like" and "enjoyment" dimensions somewhat decreased. In the observation record, particular behaviors, emotions, and situations were perceived. By inference, this was probably because the fifth operation proceeded differently from the previous ones. Case G learned other subjects more slowly, and his literacy amounted to that of a first grader. He obtained a 1-point value of progress in the learning effect test in this study, placing him in the low-score group. Thus, this game cast a low effect on Case G's learning.

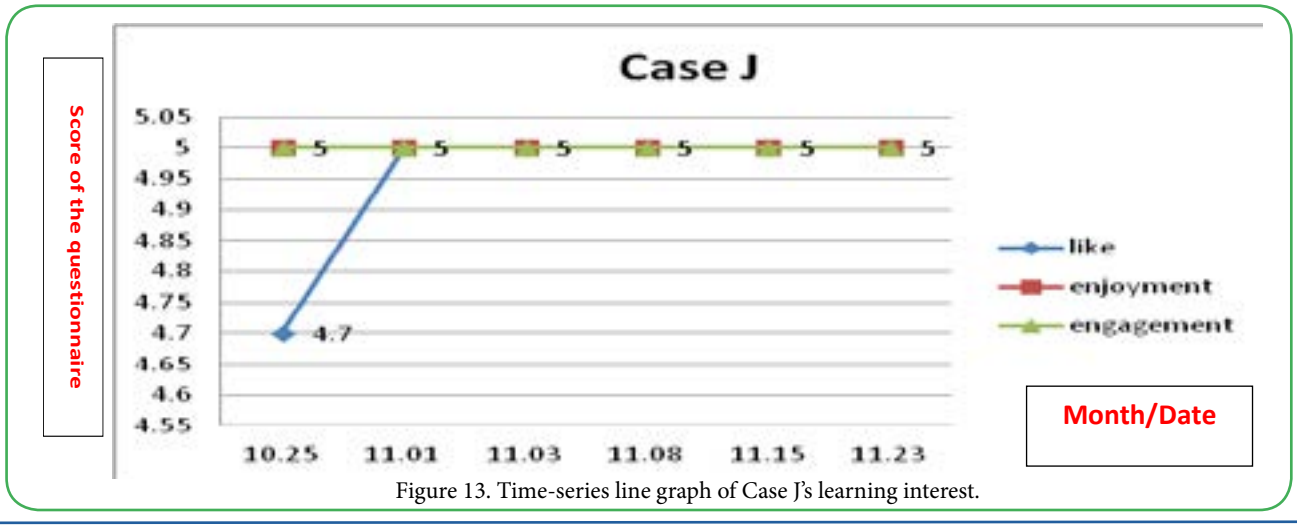

Figure 13. Time-series line graph of Case J's learning interest.

Case J was well behaved and could follow the game instructions to operate. Because of weak grasp and grip forces, a teacher was required to accompany him to shake the tablet computer in response to the "Send the partner" instruction (observation 20161025 [J-1]). Affected by his hand–eye coordination, he used a finger to click a key or a deep sea creature's silhouette and occasionally missed (observation 20161025 [J-2]). His willingness to learn remained unaffected despite his body limitations; he laughed rather happily each time he saw the researcher appear with a tablet computer (observation 20161101 [J-1]; observation 20161103 [J-1]; observation 20161108 [J-1]; observation 20161115 [J-1]; observation 20161123 [J-1]).

The time-series line graph demonstrated high consistency in the three dimensions of learning interest (i.e., "like," "enjoyment," and "engagement), and the scores all belonged to the high-score scale. In cases such as Case G, people with intellectual disability have difficulty with short-term memory. Even after six operations, the random appearance of deep sea creatures in the game influenced the effect of repeated exercises. Case J obtained a 1-point value of progress in the learning effect test, placing him in the low-score group. Thus, this game cast a low effect on Case J's learning.

(8) Case W

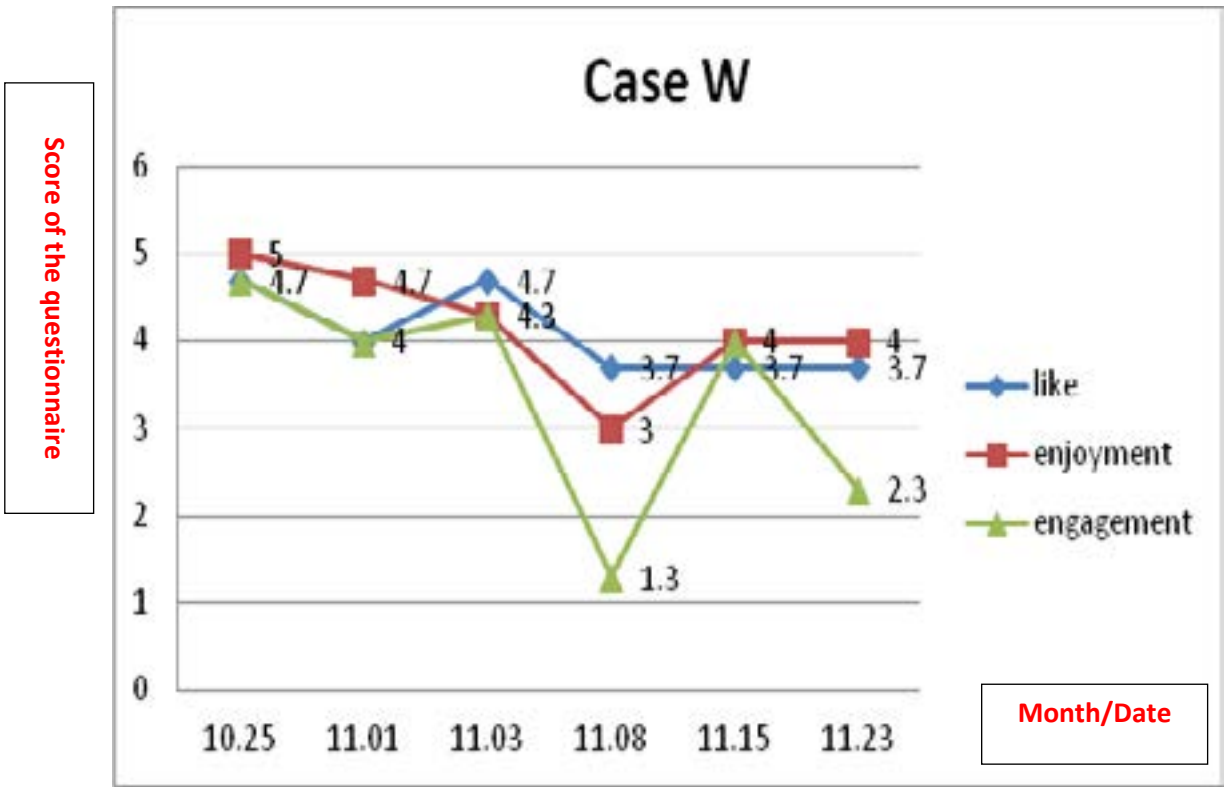

Figure 14. Time-series line graph of Case W's learning interest.

Case W could follow the game instructions to operate. Because of weak grasp and grip forces, he failed continually when required to shake the tablet computer to "Send the partner" at the first operation, requiring a teacher to help (observation 20161025 [W-2]). Affected by his hand–eye coordination, he occasionally missed when using his fingers to press keys or deep sea creatures' silhouettes (observation 20161025 [W-3]; observation 20161101 [W-2]). At the following operations, he gradually became familiarized with the operations, could shake the tablet computer on his own, and successfully sent the partner without any assistance (observation 20161103 [W-3]; observation 20161108 [W-2]; observation 20161115 [W-2]; observation 20161123 [W-2]).

By the fourth operation, Case W was already familiar with the game mode. The time-series line graph revealed that the indices of the "like," "enjoyment," and "engagement" dimensions at the fourth operation had all dropped; the interest in the game decreased significantly because of the lack of surprise. According to the observation record, Case W indeed appeared somewhat uninterested at the fourth operation (observation 20161108 [W-3]). At the fifth and sixth operations, Case W was paired with his good friend for the two-player game mode. Although some reminders from the teacher were required during the process, Case W laughed happily allthe time (observation 20161115 [W-3]; observation 20161123 [W-3]).

The time-series line graph revealed that the curves of "like" and "enjoyment" were rather similar and remained at certain high levels of preference and enjoyment. At the fourth operation, the scores of the three dimensions all decreased due to familiarity with the game. The score of the "engagement" dimension increased for the fifth two-player game, and decreased the sixth time because the freshness was lower.

Case W's learning ability in other subjects was weak and he knew very few words. In terms of numbers, he only knew 1 and 10. Case W obtained a 5-point value of progress in the learning effect test, placing him in the high-score group. Thus, this game cast an effect on Case W's learning. The results differed vastly from his general performance, indicating that Case W's memory through images was superior to that through text, which is more abstract. This study allowed Case W's learning traits to be discovered, which was one of its gains.

Conclusion

The learning effect and time-series analyses on participants' learning interest indicated more or fewer effects and outcomes in the eight participants. In addition to discovering the learning traits of each case, behavioral patterns and characters that differed from those in traditional teaching were observed for each participant, and involved some facets the researchers had never observed in other courses. In addition, the students with attention deficit hyperactivity

disorder were observed to sit well on their seats to operate the game; they watched with concentration, and their eyes moved following the protagonist in the game. In addition to operating the tablets in their hands, they occasionally looked at other classmates to see the parts they were playing, and they were attentive to others. Interactive digital games combine a computer, the Internet, and animation and embody interaction concepts, allowing a wider application of digital technology to special education and achieving a certain extent of learning effect. More new technologies are expected to be integrated in future research and development to assist students with physical and mental disabilities in learning diverse subjects.

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