A Multi-modal Digital Game-based Learning Environment for Hospitalized Children with Chronic Illnesses

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ABSTRACT

The aim of this study was to explore the digital game-based learning for children with chronic illnesses in the hospital settings. The design-based research and qualitative methods were applied. Three eight-year-old children with leukemia participated in this study. In the first phase, the multi-user game-based learning system was developed and implemented during the first iteration. Children could create their own or co-construct narratives and play mathematics games in the multi-user system. Then, we developed the multi-modal digital game-based learning activities in the second iteration. Children showed highly motivation to engage in learning activities. A list of key design features related to the digital game-based learning for children with chronic illnesses emerged from the data. The results supported that the multi-modal digital game-based learning provided the social interactive processes and learning motivation, which effectively served the learning and psychosocial needs of chronically ill children.

Keywords

Children with chronic illnesses, Digital game-based learning, Bedside teaching, Elementary education

Introduction

Digital games are rapidly becoming important tools for education, training, and even healthcare. Many people use these media for entertainment purposes and to escape the difficulties of social life (Sherry, 2004). Pivec (2007) indicated that the Digital Game-Based Learning (DGBL) model provides a complex learning opportunity, increases learners' motivation, and offers a different mode of interaction and communication. Recently developed health-related games have been shown to effectively facilitate healthy behaviours, such as healthy lifestyle habits, behavioural modifications, self-management of illnesses and chronic conditions, and physical activity (Ferguson, 2012). The effectiveness of DGBL is not limited to the general student population, but extends to students with special needs. DGBL has been shown to improve the motivation of students with learning disabilities (Ke & Abras, 2012), the attention of children with cognitive disabilities (Rezaiyan, Mohammadi, & Fallah, 2007), the psychomotor skills of slightly mentally disabled children (Karal, Kokoç, & Ayyıldız, 2010), and the social problem-solving skills of students with attention deficit hyperactivity disorder (Goldsworthy, Barab, & Goldsworthy, 2000).

Educators face the challenge of meeting the individual needs of students with very diverse backgrounds and educational requirements. Given the high incidence of childhood illness, supportive programmes to maintain students' motivations to learn during extended absences due to chronic conditions are needed (Leger & Campbell, 2008). However, young children with chronic illnesses have attracted little attention and support from educational communities (Wilson-Hyde, 2009). Students with chronic illnesses share the need for equal access to the same educational outcomes, academically and socially, as their healthy peers (Shiu, 2001). DGBL is a valuable instructional strategy for increasing students' motivation and providing opportunities for interaction and communication among students (Pivec, 2007). Despite increased interest among educational professionals in the use of digital games to support children's learning, research on examining the potential of DGBL for children with chronic illnesses is extremely limited.

This study explores the potential of DGBL to facilitate learning motivation and social interaction for hospitalized children with chronic illnesses. The study question is: what are the features of DGBL that promote learning motivation and prompt social interaction for children with chronic illnesses? By drawing upon observations and discussion with ill children, their parent, and a bedside teacher, the current study illustrates the needed support for the hospitalized children during the DGBL activities.

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Background

An estimated 2% of children in North America have severe chronic conditions, and an additional 3% have multiple chronic conditions (Newacheck & Stoddard, 1994). The incidence of illnesses such as asthma (Peat et al, 1994), diabetes (Kelly, Russell, Jones, & Byrne, 1994), and leukaemia (American Cancer Society, 1994) has increased in children. In Taiwan, there were about 0.06% of K-6 graders with severe chronic conditions (MOE, 1995). Consideration of the special needs of students with chronic illnesses must take into account academic and social aspects of the school setting (Shiu, 2001). Chronic medical conditions severely limit children's ability to participate in normal educational and recreational activities. These students have no learning impairment, but their ability to regularly attend school is limited (Ruland, Starren, & Vatne, 2007). The Ministry of Education in Taiwan required all children with chronic illness to accept beside teaching or home schooling services while they were absent from school. However, a family can only receive one weekly session (Tsai, 2006). The hospitalized children often struggle to understand and complete school work without assistance. The lack of support impedes learning opportunities and hardly sustains their learning motivation. An empirical study on children would have done in school (Charlton, Pearson, & Morris-Jones, 1986).

Children with chronic illnesses also face many challenges, such as repeated invasive procedures and treatments, changes in daily routine and relationships with family members and peers, and increased emotional insecurity and disturbance. A previous study indicated that children with cancer may be more knowledgeable and mature than healthy children in some respects due to their experience with the illness, but that they are more immature in other respects due to dealing with a life-threatening illness, treatment disrupts some aspects of their daily lives, and dependence on others (Ruland, Slaughter, Starren, & Vatne, 2006). Children with long-term or chronic illnesses often have difficulty maintaining social contacts with their peers, which increases their feelings of social isolation and loneliness (Lightfoot, Wright, & Sloper, 1999). The lack of social support makes these children more vulnerable than children in general (Shiu, 2004). Issues of how technologies may be utilized in a hospital context to provide real-time, interactive, and educational experiences for young students with chronic illnesses deserve more concerns.

Technology for students with chronic illnesses

Technology is an efficient means for children who are physically constrained to maintain social connections. Isolated children may communicate with others or engage in activities via web-based technology, which presents various opportunities to form peer groups or virtual communities. Evidence indicates that computer technology can address the psychological needs of children with chronic illnesses.

Bers (2001) created the Zora system, a three-dimensional (3D) multi-user computer environment, to help children who had undergone organ transplantation form virtual communities to share their experiences and combat the isolation created by their medical situations. This system allows paediatric patients to build virtual rooms, converse with others in real time through an avatar, and post messages or stories. By engaging in these activities in virtual communities, patients develop senses of belonging and group identity. Participating patients found that the Zora system helped them make friends and feel connected with the social world (Bers, 2001). They also responded positively to synchronous as well as asynchronous communication. Bers (2001) stated that internet technologies that enable the formation of virtual peer communities present unique opportunities for possibly isolated children.

Similarly, research also explored the feasibility of technology-mediated interaction for sustaining academic continuity between children with chronic illness and their teachers at school. Fiore et al (2008) developed an interactive community platform that integrates various synchronous communication components in a virtual 3D environment, allowing children with chronic illnesses to communicate with their classrooms. These components include two-way, synchronous video streams of lessons; digital diaries and timetables; asynchronous lessons; homework exchange; exercises, tests, and marks; and a virtual playground. Implementation of this platform dramatically improved social bonds between ill children and their peers and teachers (Fiore et al, 2008).

Fels and Weiss (2001) developed the PEBBLES (Providing Education by Bringing Learning Environments to Students) video-mediated communication application to link hospitalised children with their regular classrooms. One component of the system was located in the classroom, and the other component was located in the dialysis unit of a

hospital. Analysis of video data obtained during a 6-week case study revealed that the participating hospitalised child spent most in-class time on academic tasks. Use of the PEEBLES system increased her classmates' understanding and awareness of what she endured, as well as positive interactions with her (Fels & Weiss, 2001).

The aforementioned studies demonstrated technological possibilities for linking the chronically ill children to the learning and interactive opportunities with school teachers and peers. However, teachers-participants have highlighted that they struggle to find additional time beyond their regular workloads in sustainable way (Fels & Weiss, 2001; Fiore et al, 2008). The issues about such technology use, however, extend beyond the mere technical potential of new technologies to their pedagogical implications and feasible implementation.

Despite the potential effectiveness of technological support for children with chronic illnesses, only a few older children use it frequently (Fiore et al, 2008). However, the overall prevalence of childhood chronic conditions is similar in younger (aged < 10 years) and older (aged 10–17 years) children (Newacheck & Taylor, 1992). Hospitalised children have reported that computers are their favourite educational tools (Lombaert, Veevaete, Hauttekeete, & Valcke, 2006). Play is essential in children's lives, and computer games provide a vehicle for play not only as a diversion, but also as an integral part of their education and social lives (Prensky, 2001). Our pilot study indicated that the synchronous communication enhanced healthy children's sense of agency and facilitated a supportive partnership with other players. Perceiving self as an active learner and having companionship are in tune with the needs of hospitalized children. The effectiveness of DGBL for chronically ill children has not been well documented. Therefore, this paper investigated the potential of DGBL for supporting social and educational engagement among students with chronic illnesses.

Methods

This study seeks to initiate a discussion about the design and implementation of DGBL for hospitalised children with chronic illnesses following design-based research and a grounded theory approach.

Design-based research attempts to combine theory-driven design with empirical analyses of learning environments using a multi-step iterative cycle proceeding from design to evaluation and refinement to connect interventions with outcomes (Collins, Joseh, & Bielaczyc, 2004). The grounded theory approach (Glaser & Strauss, 1967) was used to inform the processes of data collection and analysis during the iterative cycle. This study involved two iterations: in the first iteration, we developed the "Kala Forest" multi-user DGBL system and implemented it with ill children; in the second iteration, we refined the model to create a multi-modal DGBL system for children with chronic illnesses.

Participants

There were three chronically ill children participating in this study who were referred from Taipei City West Special Education Resource Center. The children were hospitalized in a children's hospital in Taipei. We obtained consent from the parents and from the bedside teacher before data collection.

Two 8-year-old boys with leukaemia (John and David; all names are fictitious) and one with neuroblastoma (Ted). These children indicated that they missed the classroom experience; John had attended a public elementary school for 1 month, and Ted and David had never been to elementary school due to their medical conditions. These children were repeatedly hospitalised. The mean duration of hospitalisation was 19.3 ± 12.5 days, during which the special educational service centre administered by the Taipei city government provided bedside teaching services. When they were not hospitalised, the children received home schooling.

The children's parents provided them with notebook computers and wireless connections while they were hospitalised. Additional information about the participants is provided in Table 1.

Table 1. Participants' information		
Subject	Characteristics	
John	Mathematics, reading and writing skills reported by the bed-side teacher are at the first- to second-graders' level. Observed behaviors indicated that John was extrovert. Due to the medical treatment his ametican any stable. He likes to also construct a second	
Ted	Basic mathematical concepts. Reading and writing skills reported by the bed-side teacher are	

	at the first graders' level. Observed behaviors showed that he had introvert personality. Great parental supports for reading experiences. He can read the instruction and play with game independently.
David	Mathematics, reading and writing skills reported by the bed-side teacher are at the second graders' level. The parents insisted living by the same daily schedule as the school when
	David was in the hospital. David's mother taught him most of curriculum content. He needs one-to-one instruction for understanding the game rules. David participated in this study one
	month later than John and Ted did.

Data collection

Data collection- involving children with chronic illnesses adds dimensions of complexity and challenge. The data collected in this study included observational field notes and artifacts during the implementing DGBL sessions and interviews with participating children, their parents, and the bedside teacher.

First iteration: Implementation of the Kala Forest DGBL system

In the first iteration of this study, we investigated whether the Kala Forest DGBL system contributed to the social and learning processes of children with chronic illnesses in a hospital setting.

Kala Forest: A multi-user digital game-based learning system for children with chronic illnesses

To accommodate the needs of children with chronic illnesses, we sought to create an easy-to-use system that was not cognitively or emotionally demanding. Although there were some commercial systems available, these systems were not suitable for the ill children. For example, most of the drawing systems did not provide the graphical objects related to hospitalized children's life experiences. Moreover, children with chronic illnesses were sensitive and alert to strangers. The existing online systems open to all public users could not meet their needs. Therefore, we intended to develop the multi-user DGBL system which could engage the ill children in playing, learning, and sharing. The conceptual design of the Kala Forest system was as follows:

- Enhance children's sense of agency.
- Provide learning opportunities to sustain children's motivation to learn.
- Support the development of skills at the children's own pace as they progress through the game.
- Offer opportunities to engage in storytelling and elicit personal narratives.
- Provide opportunities to make contact with other patients and engage in synchronous communication.
- Support cooperation between learners.
- Reward children who seek challenges and take goal-attaining actions



Figure 1. The framework of the Kala Forest DGBL system

To enhance children's interactions with peers, parents, and tutors, the multi-user technique was adopted. The Kala Forest system was developed using the Electro multi-user socket and designed using Adobe Flash and PHP, MySQL, and XML technologies. The system is composed of two subsystems: a narrative co-construction and sharing system and mathematics games. Based on the conceptual design, the system framework of the Kala Forest DGBL system is presented in Figure 1.

A "treasure box" panel is provided on the right side of the screen, where the user can choose an avatar (cartoon figure, e.g., Donald Duck, Superman, Panda) and username. The user can select the status of the room to indicate his/her availability for co-construction activities or to maintain privacy using the "stay open," "agree to open," or "closed" setting. When the room is open, other users may participate in construction by adding words or pictures to the hosts' creations. For example, if a child's room is open and the child writes a paragraph to describe the eating habits of his/her favourite animal, other children can insert words or sentences into the paragraph and co-construct the animal narrative together. Therefore, the narrative co-constructing and sharing system provides children with chronic illnesses the opportunity to narrate their life stories and share with other users as they wish.



Figure 2. (1) The main interface of the narrative sharing system and (2) the treasure box



Figure 3. The narrative co-construction and sharing system includes (1) graphic category icons, (2) graphic objects, (3) the typing area, (4) the sketching area, (5) drawing tools, and (6) the chat room

The mathematics subsystem of Kala Forest contains three games: Apple Catching, Shooting Balloons, and Whack a Mole (Figure 4). In these games, mathematics questions are randomly selected from an item bank drawn from a first–second-grade textbook and displayed. The user selects an answer to the first question to start the game. Every game action is associated with instant reward or feedback, with one "Kala dollar" awarded for each correct answer. To enhance the user's motivation, s/he can play a Poke Fun game by trading 50 Kala dollars for a gift from the researchers. Images of these gifts appear in the user's treasure box.



Figure 4. Mathematics games include (1) Apple Catching (2) Shooting Balloons (3) Whack a Mole

Procedure

John and Ted participated in the first iteration by using the Kala Forest DGBL system in weekly 2-h sessions for 5 weeks. The researchers and three graduate students served as adult tutors. Two adult tutors also bought their own notebooks and interacted with John and/or Ted face-to-face while they used the Kala Forest system. Our team guided the participants in drawing and sharing their experiences on different themes through the narrative co-construction and sharing system. For the mathematics games, the adult tutors assisted participants by explaining the questions, prompting responses, and providing feedback.

Findings

Five themes related to the children's experiences were implemented with the narrative co-construction and sharing system in the first iteration (Table 2). Seven sessions of mathematics games were implemented. Due to differences in the participants' medical treatments, the DGBL sessions were implemented individually, except in the fourth week, when John and Ted played together on the "motel design" theme in the narrative co-construction and sharing system.

The results of this iteration indicated that the narrative co-construction and sharing system stimulated children's memories and motivated them to talk about their experiences with the tutors.

Table 2. DGBL activities for first iteration			
Narrative co-construction and sharing themes	Mathematics games		
My favourite animals	Shooting Balloons		
My favourite cartoons	Whack a Mole, Apple Catching		
My favourite toys	Whack a Mole, Shooting Balloons, Poke Fun		
My favourite gifts, Motel design	Shooting Balloons, Apple Catching		
Places I hope to visit	Whack a Mole, Poke Fun		

In the "my favourite animals" theme, John drew a pig and the tutor drew a lion (Figure 5-1). John talked about the drawing, saying:

Do you know that I can let the pig play on the slide? I and one of my friends played together with my pig toy on the stone slide at my kindergarten. I was very excited when I sat on the top of the slide and slid down.

In addition, the multi-user environment facilitated the children's interactions via both face-to-face and online modes, and their engagement in diverse types of speech acts. In the fourth week, the tutors met Ted in John's hospital ward. Both children were receiving intravenous therapy. They played with the narrative co-construction and sharing system on their own notebook computers side-by-side in the same bed. During the "motel design" activity, John said, "*I am*

waiting for you to login in the main hall... oh... I see your avatar." John dragged and dropped graphic furniture objects into the co-construction sketching area. He said, "Ted, hurry up... you can choose the graphic objects on the left side of the screen." Ted pointed the drawing and replied, "I'd like to put an airplane beside your furniture. I would like my mother to go with me." John seemed very satisfied with their co-construction and said, "It is a wonderful motel that we can visit in the future." (Figure 5-2). The above excerpt showed that children engaged in instructional, explanatory, and commentary speech acts, with acknowledging the intention and affect of the other player.



Figure 5. The sample artefacts on the narrative sharing system (1) my favourite animals (2) motel design

The interview data with his parents revealed that they had a positive attitude toward DGBL. The parents felt that the DGBL model exerted a good impact on the children's learning in the hospital. They also provided some suggestions. Ted's mother said:

It is a very interesting computer programme. He can make drawings with new tools and have a fun time. The math games also improve his computational skills. I suggest that your team add more curriculum-related content to the programme rather than limited to mathematics. Because the learning opportunities for Ted are limited, I would like him to learn more.

John's father agreed this viewpoint, saying,

It is too easy for him to play online games. The games with learning content are needed. I prefer to increase his learning abilities. Such learning experiences are helpful when he can re-enter school.

John and Ted were strongly motivated to plat the mathematics games at the beginning of the implementation period, but their motivation faded gradually. John had experience with large-scale commercial multi-user games. In the fifth week, he commented:

You can develop many small games inside the Kala Forest. I like sports. Can you design skiing and bowling games? I have played caring-pet games before. You can design some pets for players to take care of. I had a cat in the game. I can give them milk, food, toys, and lots of other things online. When I take care of my cat, his life index gets higher. I think the caring-pet games are good idea for designing games.

The tutor tried to encourage him by saying,

You have a lot of Kala money. Let's try it again.

However, John lost his enthusiasm for continuing the Kala Forest mathematics games. Instead, he suggested that the tutors play new commercial games with him.

After the fifth week of the first iteration, John's health status became critical. Research activities were thus suspended for 2 weeks, allowing us to redesign the model with consideration of the parents' comments and children's suggestions. We interviewed the bedside teacher about the perceptions of DGBL. The bedside teacher's encouraging comments facilitated refinement of the DGBL model.

The bedside teacher, Miss Chen, had 9 years of teaching experience in the hospital. Observations of bedside teaching indicated that the participants anticipated Miss Chen's class. Ted's mother described the structure of Miss Chen's instruction in Chinese language arts, including review, sentence composition, reading, and homework assignment. At

times, Miss Chen gave quizzes on mathematics or Chinese language arts. She noted that the DGBL model could enhance the children's motivation, saying:

Children are eager to learn the curriculum-related content. They like to treat themselves as normal students. DGBL can supplement bedside instruction that these children receive in the hospital or at home.

The results of the first iteration indicated that the DGBL model required more curriculum content. Moreover, we integrated flexible and diverse features into the model to fulfill the needs of children with chronic illnesses. These processes yielded the multi-modal DGBL model proposed in this study. Multimodality is defined as the mixture of textual, audio, and visual modes in combination with media and materiality to create meaning (Kress, 2010). The multi-modal DGBL is defined as using the main interface of the game which integrates various small games for different interactions, such as "Who Wants to Be a Millionaire?" and Monopoly games.

Second iteration: Implementation of multi-modal DGBL model

In the second iteration, we examined the effectiveness of the multi-modal DGBL model for children with chronic illnesses in a hospital setting for ten weeks.

The process was the same as in the first iteration. John withdrew from the study due to his critical health status, and Ted and David participated in the second iteration. Their medical treatment plans differed and they moved back and forth between the hospital and their homes. Ted participated in 14 multi-modal DGBL sessions and David participated in eight sessions separately.

The multi-modal digital game-based learning model

We developed two versions of the "Monopoly-like" board game (basic and adventure versions) (Figures 6) that integrated the Kala Forest DGBL system with face-to-face educational activities. The Monopoly games used 3×3 grids, with each space representing a learning game. The basic Monopoly game consisted of eight activities in the following categories: computer-based Chinese language arts activities (sentence construction, auditory and written vocabulary exercises, multimedia story reading), face-to-face learning games (wood block stacking, origami, bingo), and digital games (a train game involving the ordering of numbers or vocabulary words, a basketball game in which the player shoots for the correct answers). The Adventure Monopoly game comprised eight activities, including four Kala Forest games and other computer games.

Players roll two dice and move clockwise on the basic Monopoly board. The six sides of each die represent one to four move steps and two chances for adventure. If a player rolls a "chance for adventure," he/she switches from the basic to the adventure board game. The player has to roll the dice again. To enhance the children's motivation, we changed activities every 2 weeks.



Figure 6. The multi-modal board game (1) Basic version (2) Adventure version

We redesigned the reward system. Players earned Kala dollars for each board game activity, which were collected on a reward card that listed gifts and their prices. A player could exchange the indicated number of Kala dollars for a gift, and could accumulate additional Kala dollars to exchange along with an already-obtained gift for a better, preferred gift.

Findings

Three features promoted the children's motivation to participate DGBL activities. First, the multi-modal DGBL model integrated various activities that enriched the children's learning experiences, thereby enhancing their motivation. Ted expressed great satisfaction with the various learning experiences:

I like to stack the wood blocks and play the basketball game. I never played with them before. I hope I can have an opportunity to play a real basketball game with my friends.

The simulated sports game appeared to prompt his wish to move beyond his physical constraints.

Second, the reward system used for the Monopoly board game significantly enhanced the children's motivation to learn. The observation notes indicated that: After finishing the reading activity, the tutor asked David, "Which activity do you want to play next?" David answered,

I would like to move one step on the Monopoly board to play in the Kala Forest narrative sharing system and get 10 dollars. Or, I wish I can move 5 steps to play the train game and get 6 dollars. I need 5 more dollars to trade for a gift (lion mask) that I like.

David was very excited when he threw the dice and moved one step. At the end of the activity he expressed that he anticipated the tutor's next visit.

Third, the refined rules of the Kala Forest mathematics games successfully sustained the children's motivation. The games were redesigned as competitions between the tutor and participants to win the most Kala dollars. As David playing Shooting Balloons, he commented:

I feel that it's not easy to use the space bar for shooting balloons. I saw the tutor playing very smoothly. Now I learned how to control my hands. I have to beat the tutor.

The multi-modal games also facilitated social interactions between the participants and tutors. During the sentence construction activity, Ted told a story about his dog. When asked to construct a sentence using the phrase "grow up," he replied, *I used to have a little dog. The dog grew up very quickly so that I could ride on it. It was my favourite pet One day, it got lost in the park.*" During another session, David expressed his joy about leaving the hospital while making origami. The tutor observed that David drew smiley faces on two origami fishes. He said, "*I can go home today. These fishes are celebrating for me.*" The above excerpts showed that children felt free to share meaningful life events as well as project here-and-now feeling via the ongoing DGBL task.

The multi-modal DGBL model fulfilled the parents' expectations for learning skills in the hospital. Ted's mothers also commented:

The Monopoly board game facilitates Ted's motivation to learn. He usually asks me how to win the games. I saw him always counting his Kala dollars to trading for a gift.

David's mother reported:

The learning activities in the Monopoly board game expanded David's learning experiences. David has never been to school. However, the revised games provide more "school-like" activities. When David goes to school, I believe that these experiences can help him adapt to school.

David recovered from his illness and attended school. The parents reported that the multi-modal DGBL experience contributed to his learning in school.

Discussion and conclusions

This study involved two iterations of design-based research to construct a DGBL model for children with chronic illnesses in the hospital environment. The first iteration revealed the need to enhance the children's motivation and to provide more learning content, leading to the redesign of the model and successful implementation in the second iteration. The second iteration revealed that children with chronic illnesses showed more enthusiasm and preferred the activities included in the multi-modal DGBL model. Thus, this study demonstrated that the use of the multi-modal DGBL model was an effective and feasible educational strategy for children with chronic illnesses in hospital settings.

Children's motivation plays a key role in the successful implementation of DGBL activities. Grossman (1975) indicated that depression and anger were the most common behavioural outcomes of hospitalisation in school-aged children. Participants' emotions in our study were sometimes unstable due to medical treatment, which reduced their motivation to participate in the DGBL activities. These results echo the finding of Inal and Cagiltay (2007) that children's flow experience, referring to a situation of complete absorption or engagement in an activity, is very limited. Csikszentmihalyi (1991) indicated that children's flow lasted only 1-2 minutes and that they were distracted easily by other stimuli during game play. Therefore, the maintenance of chronically ill children's motivation is an important issue in game design.

Game design should focus on motivational factors to promote a positive attitude toward educational games. In line with Malone and Lepper's (1987) recommendations, fantasy, challenge, and rules were applied in this study. In the first iteration, fantasy was incorporated into the Kala Forest through avatar facility and the co-constructive narrative environment. In accordance with Dickey (2007), the character design and narrative environment of online role-playing may foster players' intrinsic motivation and sustain their participation. The avatars available in Kala Forest allowed the children to represent their idealized self. We found that our participants selected the "Superman" avatar most frequently. Such a finding echoed that of Bers (2001) as her participants avoided mention of haemodialysis while in the virtual rooms. This was particularly true for ill children who were motivated to use avatars to escape from their suffering reality.

Challenge was implemented in the second iteration. Abiding by the participating children's expectation, a composition of learning and commercial games was provided. In line with Facer et al. (2004) and Papastergiou (2009), a more sophisticated gaming environment was preferred by children. Moreover, Inal and Cagiltay (2007) indicated that children preferred switching among games when they played alone. The Kala Forest system provided only three mathematics games and thus few switching opportunities were available. In contrast, the incorporation of diverse games of the multi-modal DGBL system sustained the children's motivation.

Moreover, we found that children with chronic illness were attracted by the simulated sports games in the second iteration. Due to their health condition, the children had been deprived of opportunities to engage in outdoor activities for a long time. Playing the sports games were novel experiences and thus challenging to these children. In addition, such games may relieve hospitalized children's stress of a constrained body. As with Bers' (2001) findings with Zora, the computer environment facilitated the patient to bring back their self-image as an active agent. Playing with the simulated sports games helped children move beyond the constraints in reality.

The game rules of DGBL promoted the children's interest. The reward scheme redesigned in the second iteration intensified competition between the children and tutors. The awarding of points in an ascending scheme corresponding to levels of difficulty of the games facilitated the children's engagement in challenging competitions with the tutors. Furthermore, according to Sutton-Smith (1997), the rhetoric of play as power views play as a representation of conflict and a way to establish and enforce the power status of winning players. The game rules that lead hospitalized children to resume a powerful identity are an important feature of the DGBL model.

In this study, a one-to-one tutor-pupil didactic strategy was used. In the hospital, time for play is unpredictable and not all children can engage in DGBL or participate in a virtual community at the same time due to the requirements

of their medical treatments (Bers, 2001). In our study, only one opportunity for two participants to play together occurred, and the two boys did so with enthusiasm. Inal and Cagitay (2007) found that children were highly motivated when they played games with other children or adults. The results of the present study support the ability of side-by-side tutoring to fulfil children's social needs. Wilson-Hyde (2009) indicated that consistent interaction with teachers is important for the educational progress and social development of young students with chronic illnesses.

The parents of participants in this study anticipated that the multi-modal DGBL model would have major learning outcomes. Our result was consistent with Lynch, Lewis and Murphy's (1992) finding that parents with chronically ill children often express needs for tutoring services and home schooling to enhance children's academic achievement. According to Ashton and Bailey (2004), many parents of children with chronic illnesses would like them to be treated as normal students and not differentiated from others, particularly when they return to school. Active participation in normal life experiences is one of the most effective ways to promote the mental health of children with chronic illnesses (Patterson & Geber, 1991). Activities encouraging children's active engagement with others (e.g., peers, family members, and adults) promote the accomplishment of developmental tasks and contribute to psychological and social competence (Patterson & Geber, 1991). These experiences foster development by improving social skills, self-awareness, and identity. Future studies should examine ill children's interactive experiences in larger communities of tutors and/or peers for longer periods of time.

The present study is inspiring to DGBL researchers. Future studies should explore the features of game design that incorporate multiple games into one large-scale game for promoting the motivation of children with chronic illnesses. Moreover, Kafai (1998) found significant differences in game design preferences between boys and girls. All participants in this study were boys. Gender-based preferences for game design should also be considered in future studies. Because few technological intervention studies targeting chronically ill children have been published, comparing our findings with those of other studies is limited. Future studies should incorporate large samples to obtain statistically significant results.

In sum, our findings suggest that DGBL provides new possibilities of learning continuity for children with chronic illnesses. The DGBL model in the current study incorporates the inspiring features including multi-modal activities, an ascending awarding scheme, and one-to-one tutor-pupil didactic strategy, which constitute a challenging game environment for ill children. Given the constrained experiences in daily lives, the hospitalized children not only earn learning experiences but also resume their interaction with social world. Future research should continue to explore the specific effects of the multi-modal DGBL model on children with chronically illnesses in diverse environments.

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