

A Development of Game-Based Learning Environment to Activate Interaction among Learners

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SUMMARY Many studies and systems that incorporate elements such as “pleasure” and “fun” in the game to improve a learner’s motivation have been developed in the field of learning environments. However, few are the studies of situations where many learners gather at a single computer and participate in a game-based learning environment (GBLE), and where the GBLE designs the learning process by controlling the interactions between learners such as competition, collaboration, and learning by teaching. Therefore, the purpose of this study is to propose a framework of educational control that induces and activates interaction between learners intentionally to create a learning opportunity that is based on the knowledge understanding model of each learner. In this paper, we explain the design philosophy and the framework of our GBLE called “Who becomes the king in the country of mathematics?” from a game viewpoint and describe the method of learning support control in the learning environment. In addition, we report the results of the learning experiment with our GBLE, which we carried out in a junior high school, and include some comments by a principal and a teacher. From the results of the experiment and some comments, we noticed that a game may play a significant role in weakening the learning relationship among students and creating new relationships in the world of the game. Furthermore, we discovered that learning support control of the GBLE has led to activation of the interaction between learners to some extent.

key words: game-based learning environment, interaction among learners, learning support control, motivation, pedagogical agents, junior high school

1. Introduction

In recent years, the popularity of computer games has grown enormously. The number of people using such games has increased not only due to the development of portable games, which users can play anywhere and anytime, but also due to new types of game software which involve various new techniques such as the functions of comfortable manipulation, touch screens, and speech recognition.

On the other hand, many studies and systems that use “pleasure” and “fun” as inherent aspects of games to improve learners’ motivation have been developed in the field of learning environments [2], [4], [12]–[15]. Although it is often overlooked, one of the earliest intelligent tutoring systems actually played the role of coach in a computer game called WEST, which is a game-based system that lets students learn elementary arithmetic skills [3]. In that system,

the player tries to go to his hometown by making operational expressions that include different operations with three numbers obtained by using a roulette and by deciding on an advanced number. Then, the computer coach monitors the actions, intervenes minimally, and encourages the student to try new strategies against the computer opponent. Of course, the real aim was not to teach the game, but to let students learn elementary arithmetic and operator precedence skills.

Another example is, JULASSIC, a game-based education system that helps foreigners learn Chinese character idioms [8]. This system introduces a fighting-type game to a learner. The learning environment is established and planned by using competition elements, puzzle elements and clever rules. The learner is enabled in the game with a computer-created player in the learning environment, too. In addition, the system designs a situation where the learner must come up with the most suitable method in each scene. The controls in this system help the learner concentrate on the game environment, and as a result, they increase his motivation.

Furthermore, workshops and special sessions about “edutainment” have been held recently in international conferences, and various arguments have been presented for these games, not only from technical points of view, but also from pedagogical, social and ethical points of view [5]. In addition, there are many studies and practice lessons about games that use “pleasure” and “fun” as inherent elements. However, few are the studies of situations where many learners gather at a single computer and participate in a game-based learning environment (GBLE) and where the GBLE designs the learning process by controlling the interactions (such as competition, collaboration, and learning by teaching) between learners and others who are learning by observation alone. Therefore, the purpose of this study is to propose a framework of educational control (involving interaction control between learners) that induces and activates interaction between learners intentionally to create a learning opportunity that is based on the knowledge understanding model of each learner. Furthermore, we implemented this method with an agent system that incorporates a “learner support agent” to support each learner and a “game control agent” to control the game [1], [6], [7], [11].

In this paper, we first explain fun and learning volition in a game. Secondly, we describe the design philosophy and the framework of our GBLE, called “Who becomes the king in the country of mathematics?”, which incorporates four viewpoints for the fun of the game, and we explain the

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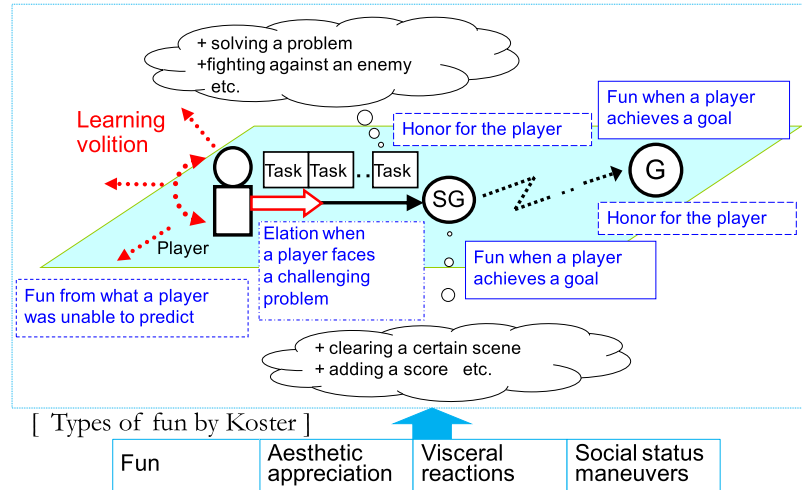


Fig. 1 Fun and learning volition in educational game.

rules and the flow of the game in the GBLE. Furthermore, we describe the method of learning support control in the learning environment. Finally, we report the results of the learning experiment with our GBLE which we carried out in two junior high schools, and include some comments by a principal and a teacher.

2. Fun and Learning Volition in Games

It is said that the “fun” of a game depends on the situations in it. The game developer and the expert about the game have been performing the various classifications and definitions about “the fun of a game” [9], [10]. Although they are going to describe the framework of “the fun of a game”, the common framework has not been completed yet. For example, Koster considers the game as a learning process which solves the given game task and skill by trial and error, and tries to solve the framework of “the fun of a game” from a viewpoint of cognitive formation of a game player [9]. He has stated that the following four tasks that must be mastered exist in the learning process, and “the fun of a game” arises in the mastery process and success experience of these tasks [9].

- Fun is the act of mastering a problem mentally.
- Aesthetic appreciation isn’t always fun, but it’s certainly enjoyable.
- Visceral reactions are generally physical in nature and relate to the physical mastery of a problem.
- Social status maneuvers of various sorts are intrinsic to our self-image and our standing in a community.

Furthermore, he has focused on “fun” and “social status maneuver”, and described that it is required to incorporate the following game elements as a point of the design in which we make game development successful [9].

- A variable feedback system in order to change an experience into a learning experience.
- The mastery problem must be dealt with.

C) Failure must have a cost.

While these are the points of the game design, we can also consider them as the elements of learning supports which must be examined when offering learning supports from a viewpoint of Intelligent Learning System. Based on these classifications and definitions, we classified the fun which a learner feels in an educational game into the following four types

- *Fun when a player achieves a goal*
In other words it is the good feeling a player has when he has achieved a goal. For example, “a player solves a certain problem,” or “a player competes with another player and wins.” We believe that the basic fun in a game comes from the good feeling of achievement.
- *Fun from what a player is unable to predict*
In other words, fun is the intellectual or aesthetic feeling that occurs at the time of an unpredictable happening. For example, in the context of a story, it is a situation in a scene that the reader was unable to predict.
- *Elation when a player faces a challenging problem*
In other words it is the surging feeling when a player faces a challenging problem or goal - for example, before a player steps on a roller coaster, or when a player considers whether he can solve a difficult problem or achieve a difficult goal.
- *Honor for the player*
It is the feeling of satisfaction when a player receives social praise or honor, such as “the player is praised” or “the player wins first place.” However, the player does not always have a feeling of fun at the time of receiving the honor.

These four types of “fun” in an educational game lead to the maintenance and improvement of a learner’s motivation, and we believe that they give a game and the learning from it advanced power (see Fig. 1). Therefore, in the design of a GBLE, it is important that we incorporate these four viewpoints of fun into the scenes or phases of the game and the learning that comes from it.

3. Design Principles in GBLE

In a GBLE, it is effective for the maintenance and the improvement of a learner's motivation to develop the support which utilizes the fun which a learner feels in an educational game. In this research, we have examined the design principle of a board game based learning environment for schoolchildren and junior high school students. Therefore, we set some design principles based on the four types of fun, which the learner feels in the educational game, in the development of the educational game design and learning support function design in the GBLE. These design principles are as follows:

- *Fun when a player achieves a goal*
 - [Principle1-1] Existence of various types of grids
 - [Principle1-2] Setting a reward by clearing the given event (For example, "prize" or "increasing the mark of a parameter")
 - [Principle1-3] Selection and question of a learning subject according to the situation of each learner
 - [Principle1-4] Setting the number of problems according to the situation of each learner
 - [Principle1-5] Setting a time limit of problems according to the situation of each learner
 - [Principle1-6] Motivation for fun when a player achieves a goal
 - [Principle1-7] Setting a collaborative and competitive learning style
- *Fun from what a player is unable to predict*
 - [Principle2-1] Setting a grid in which a special event occurs
 - [Principle2-2] Selection of new learning style (such as by a time trial, or having to check answers for other players) in the learning grid
 - [Principle2-3] Selection and question of new learning subject
- *Fun from what a player is unable to predict*
 - [Principle3-1] Setting the increase in the number of problems
 - [Principle3-2] Setting a learning subject to which the degree of difficulty becomes high
 - [Principle3-3] Shortening the time limit of problem solving
 - [Principle3-4] Setting a cost when a learner fails in a learning subject

[Principle 3-5]

Motivation for challenge

[Principle 3-6]

Setting a collaborative learning style

- *Honor for the player*

[Principle4-1]

Setting players' ranking at the time of ending

[Principle4-2]

Motivation for aiming at a championship

We have created an educational game design in the GBLE based on these all design principles explained above [16], [17]. Moreover, we have designed and implemented the function and mechanism of the learning support based on the design principle and the support elements referred to literature (including Koster's suggestion mentioned in Sect. 2) as an educational control described in Chapter 5. In addition, we accept that the case where concrete design principles differ according to the difference in the subject domain and learning style of a GBLE exists. Examination of the design principle in a different game form and learning style is future work.

4. Outline and Rule of "Who becomes the king in the country of mathematics?" Game

The game developed in this study is a board game with a roulette in which there are four players (learners). The winner can become the next king of the mathematics kingdom.

From the roulette, the learner receives a number to determine her/his forward movement. She/he then replies by trying to solve a calculation formula in the roulette with an unknown value. If the learner solves the problem correctly, she/he can advance only by the number of the answer. Next, the learner carries out an event, such as learning or the game, on the grid on which she/he stopped. The learner can increase the mark of a parameter (the learning power and the power of zest for living) of the character (avatar) that the learner operates by clearing the event.

The learner that has the highest general marks (general marks = [learning power] x [power of zest for living] + [bonus points]) becomes the winner when all learners have reached the goal grid. At the end of the game, the first place learner becomes the king of the mathematics kingdom. The second, third, and fourth place learners are given a post depending on their general marks and the marks of two parameters (learning power and power of zest for living) for each learner.

There are several types of grid in this GBLE: a "Learning grid," a "Zest for living grid," an "Item grid," a "Mini-game grid," and a "Special grid" (see Fig. 2). The "Learning grid" has to do with solving a problem for the subject domain. We set the subject domain as the linear equation and prepared five learning items about it in this environment. A calculation problem or word problem is set to each grid. When a learner stops on a learning grid, a learning form based on her/his learning situation is set to the grid. The

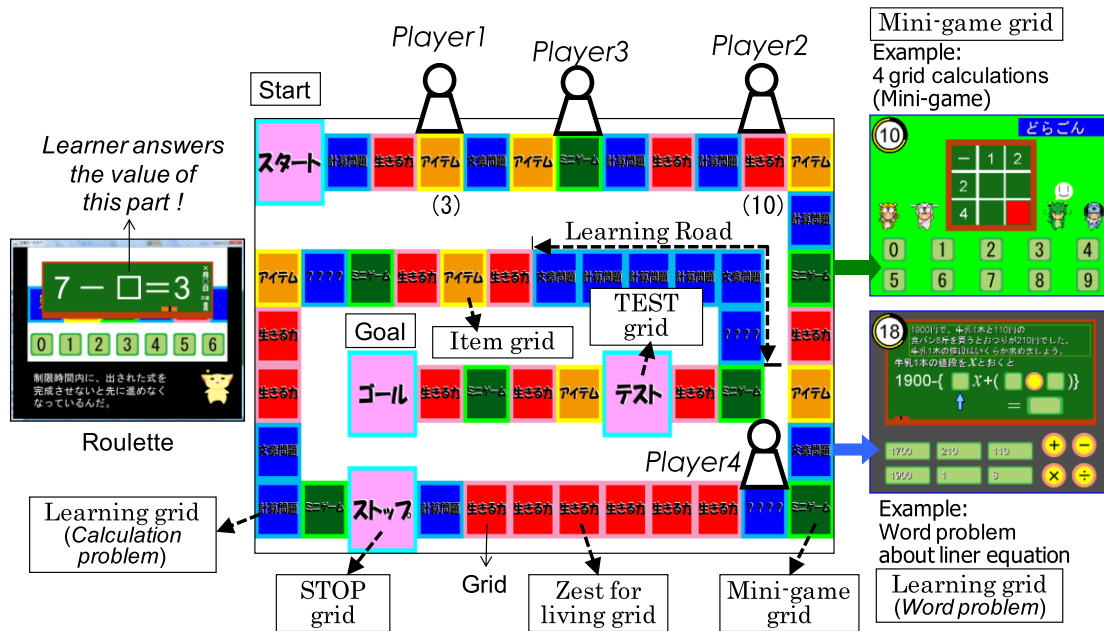


Fig. 2 Image of game-based learning environment for a linear equation.

“Zest for living grid” concerns solving a problem about intellectual, physical and moral competency. When a learner stops on the “Zest for living grid,” a story about a problem that is chosen based on the experience situation of the learner’s learning forms occurs, and the problem is shown (for example, a problem about information morality or dietary education). The learner must solve the problem by using a method indicated by the computer. The “Item grid” is given by an item card which allows the learner to advance only according to the number written on the card. The learner can use the item card after her/his next turn. The “Mini-game grid” is about learning ability or the zest competency for living. The learner continues to play the game with activity such as “4 grid calculations” or “let’s go out with me” either alone or while she/he competes or collaborates with other learners.

On the “Special grid,” every learner must stop forcibly. There is a “STOP grid” and a “TEST grid,” which are special grids in the developed game environment. On the “STOP grid,” the learner plays rock-paper-scissors with the computer. If she/he wins, a bonus point is given at random. On the “TEST grid,” the learner must answer all the questions for each learning item correctly. If she/he makes a mistake, then she/he must return to a certain grid specified by the computer.

5. Method of Educational Control in GBLE

This game is a type of educational game. Therefore, we need to control the game educationally in order to activate the interaction between learners and to be able to acquire the desired knowledge and skill for learners.

We have studied the interaction among groups, the direct support for each learner, and lesson support for a teacher

as the extension of this GBLE to support the group. In this environment, we need the system configuration using agent which can support each learner or group, and interact with other learning supporter flexibly. So, we have been developing the system with agent model. In this GBLE, the learning and educational control is performed by two kinds of learning support agents (one “Learner Support Agent” per learner and one “Game Control Agent” in GBLE) (see Fig. 3) [16], [17]. We have designed and implemented the function of the learning support in these learning support agents based on the design principle of the fun which a learner feels in an educational game and learning support function described in Sects. 2 and 3.

In this section, we explain the task and relationship among “Grid Content Repository (GCR),” “Learner Support Agent (LSA)” and “Game Control Agent (GCA)” which have important roles in a method of educational control in GBLE.

5.1 Outline of Grid Content Repository

The GCR is a place that has accumulated and managed grid contents. The grid type and the name and various attribute data of the content are added to each group of grid contents. Furthermore, it is possible to introduce a relational structure among grid contents. For example, we structured the learning item corresponding to a learning grid based on the degree of difficulty in the developed game environment. Moreover, we assigned the number to the learning content within a learning item, and decided allotment of marks based on degree of difficulty.

The GCR makes a grid content object according to the request of the grid contents object from GCA, and provides it to the learner. The answer information of the learner from

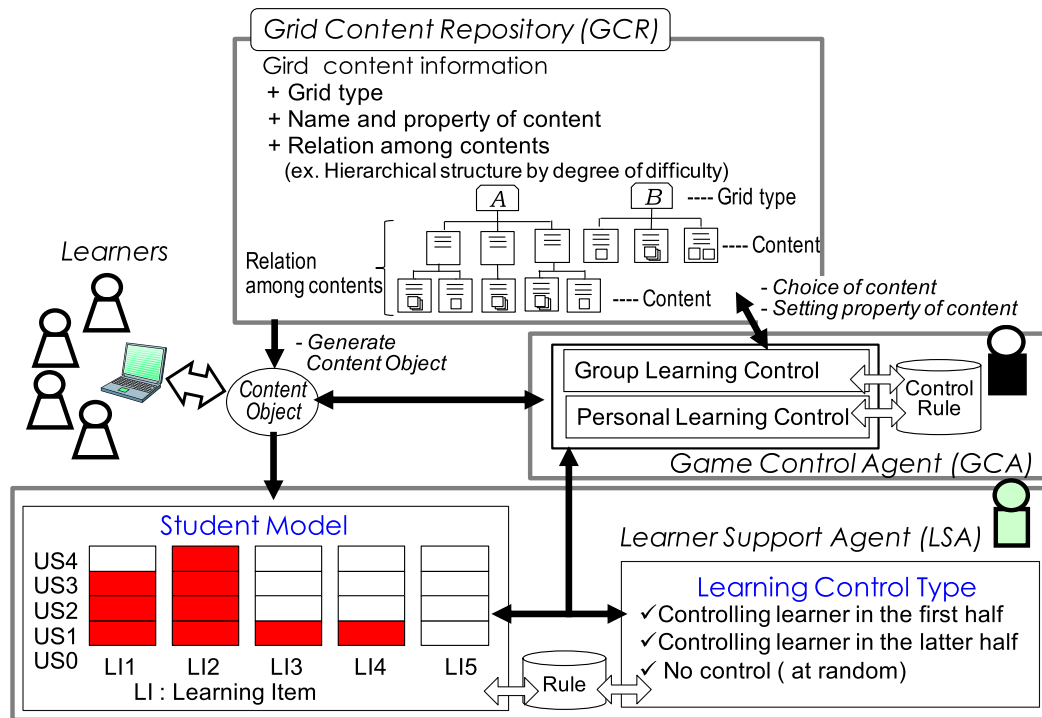


Fig. 3 Task about learning and relation among GCR, LSA, GCA.

the grid content object is reported to LSA or GCA.

5.2 Task and Role of Learner Support Agent

The support function of the learner based on [Principle 1-3, 1-6, 1-7, 2-2, 2-3, 3-2, 3-5, 3-6 and 4-1] is designed and implemented for the LSA. The LSA has three tasks:

The first task is to determine the learning control type of the learner as a method for maintaining or improving the learning volition of the learner. The agent gives four questionnaires for a learner at random before starting a game. The learner replies with yes or no. Then, the agent tries to motivate the learner to increase the learner's learning volition appropriately. Moreover, the agent adds up the mark of four answered items and classifies it in three types (Controlling learner in the first half, Controlling learner in the latter half and No control) based on the total value (see Fig. 3).

The second task is to diagnose the state of understanding of the learner for whom the agent is responsible and has the role of determining an effective learning task based on his diagnosis. This agent recognizes the state of understanding of the learner for each learning item in terms of the following five states by using diagnosis rules.

- **Understanding State 0 (US0):**
Because not all learners solve a problem corresponding to a learning item, the agent cannot recognize the state of the learner.
- **Understanding State 1 (US1):**
Because other learners carry out a problem of a learning item, the agent recognizes that the learner may understand it by observing the situation.

- **Understanding State 2 (US2):**
Because the learner makes one more mistake, although she/he solves a problem corresponding to a learning item, the agent recognizes that the learner does not understand this learning item.
- **Understanding State 3 (US3):**
Because the learner solves all problems corresponding to a learning item correctly, the agent recognizes that the learner understands the learning item.
- **Understanding State 4 (US4):**
When the learner succeeds in a challenge such as a "time trial" or "check answers with each other", the agent recognizes that the learner understands the learning item thoroughly.

The third task is that the LSA requests the learning item from the GCA after determining the next learning item of the learner.

5.3 Task and Role of Game Control Agent

The function of educational control in GCA is implemented based on [Principle 1-2-1-5, 1-7, 2-2, 2-3, 3-1-3-4, 3-6, 4-1 and 4-2]. The GCA performs an educational control of four players (learners) who play the game-based learning. This agent has the following global strategy:

- The agent tries to check that the student has a value of more than US2 for all learning items until she/he reaches the TEST grid.
- The agent tries to make sure that the student stops all learning grids in which the value of the learning item is

Table 1 Pre-questionnaire (Q1–Q3) and results about the game and learning.

Question	Answer	A Junior High School			B Junior High School		
Q1: Do you like the game ?	I like the game very much	3			3		
	I like the game	12			7		
	either	3			7		
	I don’ like the game	1			0		
	I dislike the game	0			0		
Question	Answer	A Junior High School			B Junior High School		
Q2: How do you play the game ?	I do not play	1			1		
	1 time/month	1			0		
	2-3 times/month	3			3		
	1 time/week	4			2		
	2-3 times/week	4			1		
	4-5 times/week	6			4		
	every day	0			0		
Question		A Junior High School			B Junior High School		
Q3: Which characteristic of the game is there fun for?		Strongly agree	Agree	Disagree	Strongly agree	Agree	Disagree
(A) I can play the game with my friend funny.		7	8	4	9	4	0
(B) I can play the game alone.		4	4	11	2	3	8
(C) I can improve my game skill alone.		3	8	8	2	3	8
(D) We can improve, while my friends and I teach each other.		3	9	7	3	5	5
(E) I can get into the world of the game.		2	4	13	1	2	10
(F) I can get what I can’t have in the real world.		5	8	6	3	6	4
(G) I can have common topics with my friend.		3	10	6	5	5	3
(H) I can defeat some enemies.		2	4	13	1	5	7
(I) I can clear some sub-goal (stage, phase etc) and goal.		6	6	7	1	5	7
(J) I have good a feeling (I did it, Goody, etc), when I achieve some goal.		8	6	5	5	4	4
(K) I can get the feeling that occurs at times when I can’t predict something.		2	4	13	1	5	7
(L) I can get the surge of the feeling when I challenge some problem.		3	11	5	2	4	7
(M) I can get the honor (champion etc), when I have finished.		1	4	14	2	2	9
(N) I can study and learn various things (subject matter etc).		2	6	11	1	5	7

less than US1.

- The agent tries to ensure so that the learner can experience various learning forms in the game.

Based on these strategies, the GCA advances the game-based learning by using control rules such as questions, individual learning and group learning.

Concretely, the GCA receives information about the understanding state of learner and requests the next learning item from each LSA. The GCA determines the learning item for the learner for her/his next turn and carries out the turn. When the learner needs learning control, the GCA decides on a calculating formula and the answer by means of the roulette. This GCA has three learning forms: *personal learning* in which the learner himself solves a learning problem, *collaborative learning* in which the learner competes or collaborates with other learners, and *observation learning* in which the learner learns from other learners' problem solutions. The GCA chooses a learning form based on the state of the learner's understanding of the next turn and other learners' understanding.

6. Evaluation of Learning Experiment with GBLE

6.1 Participants and Procedure

We have already carried out some learning experiments for the developed GBLE, called "Who becomes the king in the country of mathematics?" [16], [17]. As two examples of learning practice, we report the learning experiment in A junior high school and B junior high school. The subjects of A junior high school were 19 students. The subjects of B junior high school were 13 students. We performed pre-tests, post-tests and an evaluation experiment using the method described below.

- (1) A pre-test and questionnaire survey about the game.
- (2) An experiment in some groups (basically, one group of four students, but one or two university students participated in one or two groups). We carried out one class (50 minutes per day) for two days.
- (3) A post-test and questionnaire survey about the game

Table 2 Pre-questionnaire (Q4–Q10) and results about the game and learning.

Question	B Junior High School				
	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree
Q4: Are you good at explaining or teaching your friends something?	2	1	3	7	0
Q5: Can you speak about your opinions or ideas actively in the group learning activity?	4	4	1	3	1
Q6: Are you good at mathematics?	1	4	3	4	0
Q7: Do you like studying together with your friends?	4	3	3	2	1
Q8: Do you like performing a game together with your friends?	12	0	0	1	0
Q9: Do you like performing a game alone?	4	4	0	3	2
Q10: Do you like studying alone?	4	4	4	1	0

environment and study.

6.2 Learning Experimental Results

The two junior high schools' results from the pre-questionnaire survey for the game showed that many students liked the game, and more than 50% of the students played a certain game on multiple days in one week. The subjects gave the following answers to the question about "the fun of the game" (see Table 1): "Because I had a good feeling when I achieved a certain goal," "Because I had an interesting time with my friend," and "Because I was very excited about whether I would clear the stage or not, or whether I could defeat a mini game in the GBLE". From this investigation, because our learning environment has the following characteristics, we think we can conclude that the game is fun: "students can get marks by clearing the game and its problems ([Principle 1-2])", "the game has a time limit and various learning and game forms ([Principle 1-1, 1-5, 1-7, 2-2, 3-3, 3-6])" and "students can be active while enjoying the game with group members because the system offers collaborative activities or opportunities to check answers with each other ([Principle 1-7, 2-2, 3-6])" (see Tables 1 and 2).

Next, we report some results from the question items in the post-questionnaire survey. Although we carried out the experiment in two days in each school, about 20% of the students studied the linear equation which is the subject matter of the game in the evening of the first day. In addition, for a question about the role of the GBLE, almost all students used the tool to learn the linear equation (see Q16 in Table 3).

Those times when the students talked to group members, they gave the following answers: "when others talked I couldn't understand the problem" (five students), "when the behavior of the game was interesting" (four students), "when I solved a problem" (three students), "when I talked about how to solve a problem" (two students) and "when my friend has trouble", and "when we encourage each other." In

addition, from the following answers, we were able to observe situations in which students were concerned with each other: "my friend tells me how to solve the problem" (seven students), "my friend gave me advice", "my friend considers problems with me", "my friend talks about her ideas even if she does not understand how to solve the problem." Furthermore, concerning the question of being praised by a certain friend or the GBLE, the following descriptions were provided: "when my answer was correct", "when my calculation was very fast," "when I was able to solve the problem although my friend did not know it," and "when I solved the problem alone." We found that active interaction among the students was developed by one computer being used in the situation of the game process.

The students performed the game, and in the scene which they thought "great", the following answers were provided: "when I solve a problem" (four students), "when my answer is correct" (four students), "when I become the king" (three students), "when I can solve the problem that I couldn't before" (two students), "when I won the battle with my friend", "when the mark is too high", "when I stopped on the grid I liked". In addition, with regard to the scene in which "I was so surprised", the surprise was described in part of the element in the following game: "I can get a mathematical performance with this board game", "this game has the function of rock-paper-scissors", and "there are many kinds of posts." Furthermore, concerning the "fun for something a player could not predict" and "elation when a player faces a challenging problem", the following developments about the game were described: "when I thought about where the roulette stopped, whenever I turned the roulette" (five students), "when I thought about what kind of problem made questions" (three students), and "when I thought about who became king at the end" (two students). Finally, for "what is best about this game?", the answers were as follows: this system can teach subject matter in a fun way using a game style – for example, "the point of being able to learn with fun is good" (five students), "the point of gaining mathematical knowledge while playing the game is good" (four students), and "the point of being able to re-

Table 3 Post-questionnaire and results about the game, learning and GBLE.

Question	B Junior High School				
	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree
Q1: Could you play GBLE funny?	13	0	0	0	0
Q2: Was the numerical calculation difficult for you?	2	3	1	4	3
Q3: Was the problem expressed in words difficult for you?	3	5	3	0	2
Q4: Could you learn with GBLE funny ?	12	0	1	0	0
Q5: Have you operated GBLE well using the mouse on the 1 st day?	0	7	2	3	1
Q6: Have you operated GBLE well using the mouse on the 2 nd day?	8	3	1	0	1
Q8: Could you play GBLE funny, interacting among group members?	13	0	0	0	0
Q9: Do you like playing GBLE alone?	1	2	0	4	6
Q11: When you were using GBLE, did you feel the need to continue the game by collaborating with group members?	10	1	1	1	0
Q14: Do you think that you would like to rank 1 st in GBLE?	8	2	0	1	2
Q15: Do you think that you would like to win your friend, if you battled with your friend in the scene of mini-game or learning problem and so on?	7	4	0	2	2

Question	B Junior High School			
	Frequently	Several times	Once or twice	Never
Q10: When you used GBLE, did you wish to collaborate with group members?	11	2	0	0
Q12: When you used GBLE, did you want to give hints or comments to your group members?	8	5	0	0
Q13: When you used GBLE, could you give hint or comment to your group members?	4	4	2	3

Question	B Junior High School		
	1 hour or more	Less than 1 hour	Not studying
Q7: Did you study the linear equation in your school or home, after finishing GBLE?	0	4	9

Question	B Junior High School		
	Tool for playing	Tool for studying	Tool for interacting with group member funny
Q16: What is GBLE for you?	0	9	3

view is good” (two students). This system can provide play, study, and a game with friends – for example, “the point of having fun with friends is good” and “the human relationship between friends can deepen more”.

At last in this subsection, we introduce a case of group activity in B junior high school. The member of this group were 3 school boys (Student_A, Student_B, Student_C) and 1 school girl (Student_D). Student_A and Student_C were active student, and Student_B and Student_D were quiet student. We show the results of pre/post test, and the answers of main pre/post questionnaire in Table 4. The leader of this educational game was Student_C who was not positive in a normal arithmetic lesson. Student_B which is not good at mathematics couldn't give the hints or comments for the given problem through the game based learning. Although there were not many utterances, when a conversation was required, he was speaking to the group member suitably. After this learning, he had answered to post-questionnaire as follows: “When I couldn't solve a given problem, I asked my group member and could solve it”, “I have collaborated with my group member in 4 grid calculation”. As a result, he had taken the good results in the calculation problem of post-test. Moreover, Student_D was not able to become pos-

itive at first in the group with 3 school boys. However, after she taught the group members mathematical knowledge in the collaborative activity, she could gradually concerned with her group members. As a result, when answering the problem of a learning grid, she became a key person in this group. After the end of this learning, all group members answered that they experienced the game learning enjoyably. The control of the GBLE could promote the reciprocal teaching and knowledge sharing, and give a positive attitude to a student from the trigger of an interaction among group members.

6.3 Consideration of Learning Experimental

From the above-mentioned practices and our investigation, it is not easy to believe that this GBLE can provide learning effectiveness as a support tool to increase subject matter abilities. However, we believe that it can be a tool that incites interaction between students because we can see that some students who participated poorly in a normal class became more positive in the class with this environment. In addition, the competitive control in this GBLE provides hope that learners' motivation will improve. Furthermore,

Table 4 Pre/post-test and main pre/post-questionnaire of a group case in B junior high school.

	Types of problem/ Question	Student_A	Student_B	Student_C	Student_D
Pre-Test	Calculation problem about a liner equation (N=8)	6	3	7	8
	Word problem about a liner equation (N=6)	0	0	0	3
Post-Test	Calculation problem about a liner equation (N=8)	5	7	5	6
	Word problem about a liner equation (N=6)	1	0	0	6
Pre-Questionnaire	Q4: Are you good at explaining or teaching your friends something?	Agree	Somewhat Disagree	Somewhat Disagree	Neutral
	Q5: Can you speak about your opinions or ideas actively in the group learning activity?	Agree	Somewhat Disagree	Neutral	Somewhat Agree
Post-Questionnaire	Q8: Could you play GBLE funny, interacting among group members?	Agree	Agree	Agree	Agree
	Q10: When you used GBLE, did you wish to collaborate with group members?	Frequently	Frequently	Frequently	Several times
	Q11: When you were using GBLE, did you feel the need to continue the game by collaborating with group members?	Agree	Somewhat Agree	Agree	Somewhat Agree
	Q12: When you used GBLE, did you want to give hints or comments to your group members?	Frequently	Several times	Several times	Several times
	Q13: When you used GBLE, could you give hint or comment to your group members?	Several times	Never	Several times	Several times

we found that we can expect that the collaborative control of this GBLE can improve problem-solving methods and the feeling of knowledge sharing between students.

6.4 Interview Results and Discussion

Finally, we had an interview with the principal and the teacher about the possibilities of this game-based learning. Their comments were the following:

[Principal]

- The difference between a student that understands and one who does not is obvious in normal learning. But I did not feel there was a difference in ability in game-based learning. So, the student who is weak in the subject can compete with one that is stronger.
- When we see the situation in which a student participates in an educational game, we can understand the actual situation and character of the student.

[Teacher]

- I think the effectiveness of this game is knowledge sharing through interaction among students that play the game rather than knowledge acquisition.
- Even if student relations in the class are fixed, the role of a student who is usually passive may change, if there are some interactions among the players through the game.
- I think that students can establish daily relationships and succeed in the game activities by utilizing the game-based learning. So, there can be a situation where the speaker is easy to talk to, and the listener may establish a relationship with the speaker.

Based on some of the above comments, we noticed that the power of the game has possibility to cause a learning relationship among students to weaken and to proceed to a new relationship in the world of the game. Furthermore, we realized that learning support control of the GBLE has led to

activation of the interaction between learners to some extent.

7. Conclusions and Future Work

In this paper, we explained the design indicator and the outline of our GBLE that incorporated four viewpoints for fun in a game. Then, we described a method for educational control in the learning environment. In addition, we reported the results of the learning experiment with our GBLE which we carried out in two junior high schools, and introduced the comments of the principal and a teacher for our learning experiment.

Based on the results of the experiment and some comments, we noticed that the power of the game has the possibility to cause the learning relationship among students to weaken and proceed to a new relationship in the world of the game. Furthermore, we realized that learning support control of the GBLE has led to activation of the interaction between learners to some extent.

As further work in the future, we need to examine whether the principle of the proposed educational game design and the learning support function design can be adapted for a different game form and learning style, and elaborate their principles. Moreover, it is necessary to consider and implement some learning support functions to build a new relationship among students in the GBLE or to promote knowledge sharing among students.

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