Development and Evaluation of Multiple Competitive Activities in a Synchronous Quiz Game System

Li-Jie Chang, *National Central University, TAIWAN*
Jie-Chi Yang, *National Central University, TAIWAN*
Fu-Yun Yu, *National Cheng-Kung University, TAIWAN*
Tak-Wai Chan, *National Central University, TAIWAN*

SUMMARY

Competitive learning activities are among the various learning activities that play a significant role in online learning environments. A competitive learning environment obviously stimulates different feelings in winners and losers, and it is imperative to consider how to design such an environment so as to motivate users. This work describes the design of an online competitive learning environment which involves three basic competitive forms and sixteen competitive activities. A system called "Joyce" has been implemented, in which users can compete with either a computer agent or real life user(s) on a single computer, or alternatively can play via the Internet. Because of the format of the item bank being sets of multiple-choice questions, the system is not restricted by the age of its target users. In a game-learning environment, learning is a side effect of participating in the game. In the present example, learners are motivated to read more materials to win the game. The system attempts to involve students in a competitive gaming-learning environment that simulates their motivation to learn. Three studies have been conducted to examined of how users responded to the novel system and obtained the following analytical results: first, users were found to be highly motivated to use the Joyce system; second, more able users had a greater chance of winning the game, while less able users still had some chance of winning; third, users are inclined to take risks and have the control of the game in their own hands.

INTRODUCTION

Humans are instinctively competitive, and while excessively competitive learning activities can have some negative effects (Kohn, 1992) competition is generally considered an effective technique to motivate people to learn and to excel (Julian and Perry, 1967; Malone and Lepper, 1987; Whittemore, 1924; Yu, 2000). Adding an element of competition is widely believed to be a motivation-enriching strategy in play, work, and education (Deci *et al*, 1981). Additionally, competition has been suggested as a method of motivating students to participate in initially uninteresting or routine educational activities, and has also been seen as a way to stimulate user involvement and interest (Malone and Lepper, 1987; Yu, 2001). Online competitive learning activity is important in online learning, and thus it is imperative to consider how to design an online competitive learning environment that motivates both winners and losers.

A competitive learning environment naturally stimulates different feelings in winners and losers. Winning is the most powerful confirmation of success, while losing represents a crisis of being extinct. Furthermore, just as winning generally encourages further progress and improvement, losing may cause disappointment and subsequently damage confidence and interest, meaning that ideally all participants should have a chance of winning and thus remaining motivated. This is the main purpose and intention underlying Joyce design. The following sections briefly described the history of the Joyce system, outline its design features and different game activities, and then evaluate the system.

JOYCE: A QUIZ GAME SYSTEM

A history of the Joyce system

Table 1 summarizes the history of the Joyce system, which originally evolves from a classical intelligent tutoring system (ITS) system called WEST that was designed in 1977. “How the WEST was won” (WEST) is a computer board game that was designed by Anderson in the Elementary Mathematic Project PLATO, led by Dr. Robert Davis, at the University of Illinois (Sleeman and Brown, 1982). The WEST game is intended to exercise arithmetic skills. The players participate in a race to their hometown. During each turn, the spinners in the board game are given three random numbers. The players must then determine the number of spaces they can move by using these numbers to compose an arithmetic expression that involves two different operators. The game is designed such that moving the largest number of spaces in not always the best strategy, because of the existence of shortcuts and the possibility of bumping back an opponent. This feature of the design encourages players to explore different ways of combining the numbers with arithmetic operators, and becomes the principal design guideline of the Joyce system.

Insert table 1 about here

The system was enhanced by the addition of a computer coach in a study by Burton and Brown (Burton and Brown, 1979). The coach advises students when they make non-optimal moves during play. This coach represents the first inclusion of a

computerized agent in the system design.

At the start of the 1990s, a series of distributed peer social learning systems were developed at the Learning Technology Lab, National Central University, Taiwan (Chan, 1996). The first system in the series is a redesigned version of WEST with a coach system, and is called "Distributed WEST" (Chan *et al*., 1992). This Distributed WEST system differs from WEST, and WEST with coach, in that it is a distributed system designed to help freshmen in the computer science and information engineering department learn how to convert binary numbers into decimal numbers. Computers in the system are connected via RS-232, a serial communication link device, to create the Distributed WEST system. Students use the RS-232 can thus play against one another, and the system also includes a simple tutor to advise students. This stage of the design implements networking technology.

The second version of Distributed WEST is called "Distributed WEST with Multimedia". Distributed WEST with Multimedia is designed to exploit the usefulness of multimedia technologies to users of human computer interfaces, especially in game environments. One of the most notable features is the use of multimedia technologies in this stage. Back in 1992, multimedia technologies were still a new concept and were seldom found practice.

The third version of Distributed WEST is called "DWEST," and was designed in 1996 (Fan, 1997). DWEST includes some enhanced functions: (1) DWEST is implemented in Java and thus can be run on any platform; (2) DWEST emphasizes the networking environment and thus can be run on the Internet; (3) DWEST conducts drills in the

form of multiple-choice questions, rather than binary number conversion, a simple approach that allows lots of drill subjects to be included in practice activities in the DWEST system.

Since 1999, the authors have been focusing on game and agent design. Numerous different competitive activities have been developed (Chang *et al*., 2001), and the new system, called "Joyce", also integrates a computerized agent. Joyce is a computerized, competitive board game system that allows students to compete against each other or against a simple computer simulated agent. Joyce retains all the major features of the previous systems, including game design, dyad competition, use of multimedia, domain independency, a simple competitive agent, and so on. Besides these features, the Joyce system also includes sixteen different competitive activities classified into three basic forms: single or team competitions, face-to-face or non face-to-face competitions, and rotating or time-constrained competitions.

Joyce system board game

The main interface of the Joyce System comprises five parts: Item Showing Area, Answering Area, Agent Window, Game Map, and Game Information Window as illustrated in figure 1.

- ③ **Item showing area:** Multiple-choice questions are posted to users via the item showing area.
- ③ **Answering area:** User(s) or agents answer the multiple-choice questions via the answering area.
- ③ **Agent window:** The agent selected by user is displayed in the agent window.

③ **Game map:** Users and their competitor(s), who are either computer simulated agents or real human beings, participate in a competitive activity on the game map.

③ **Game information window:** The game information window displays all the information regarding the game during the competitive activity.

Insert figure 1 about here

Game design

The design of the game map in the Joyce system is similar to that in the WEST system. At the start of the game, the icons of the user and her/his competitor(s) are placed at the "chateau." Both the user(s) and her/his competitor(s) then answer multiple-choice questions posted by the computer, and are assigned a random number ranking from 0 to 5 each time they choose a correct answer. The user can move her/his icon after accumulating two numbers. The features of the game are described as follows:

(1) General questions: A multiple-choice question on a specific subject is displayed when a players reaches the general question position.

(2) Funny questions: A humorous multiple-choice question is displayed when a player reaches the funny question position.

(3) Random numbers: A user is given a random number ranking from 0 to 5 upon choosing the correct answer.

(4) Movement rules: A user can move her/his icon after accumulating two numbers,

with the combination of the two numbers being the number of steps she/he can move forward. Three kinds of combinations of the two numbers exist, namely number one plus number two, number one minus number two, and number two minus number one. User can choose whatever combination is most advantageous to them, with the number specified by the result of the combination being the number of spaces that they can move their icon forward/backward.

(5) Shortcuts: A user jumps forward ten steps upon reaching the shortcut position.

(6) Bumping: When two icons share the same position, the first icon to reach that position will be bumped back ten steps.

(7) Reaching the "chateau" position: A user must place her/his icon on the "chateau" position to win the game. If the move that takes an icon onto the chateau position has too many steps, meaning that the move does not finish on the chateau position, then the icon should turn around and use the additional steps to move backwards.

A competition game stimulates different feelings in the winners and losers. The design of the Joyce system aims to increase the uncertainty of the game outcome, ensuring that while more ably users have more chance to win, but less able users still have some chance of winning. The outcome of a quiz game should be influenced by the ability of players with subject matter. However, in badly designed games more ably users will always win while less able players will never do so. The game design of the Joyce system attempts to give more able players a greater chance of winning, while ensuring that less able players also have a chance of winning. Study 2 examined the game design, and the results of this examination are described below.

DESIGN OF MULTIPLE COMPETITIVE ACTIVITIES

As stated previously, the system design involves sixteen competitive activities which based on three types of competition: (1) single or team; (2) face-to-face or non face-to-face; and (3) rotating or time-constrained competition.

(1) Single or team

The system allows user to play against with him/herself, as well as to play with others in a team setting. In the team competition, users cooperate together to answer the question, working on a single computer or via the Internet. To support team interaction, the authors use a special input device called "EduClick" (Huang *et al*., 2001). EduClick is a wireless remote control device, and each user uses one of these devices, which resemble TV remotes, to answer the question by pressing buttons. The device then sends the answers to the receiver while users continue to key in answers to subsequent questions.

(2) Face-to-face or non face-to-face

Users can play the game face-to-face on a computer or non face-to-face via the Internet.

(3) Rotating or time-constrained competition

The quiz game activities can be categorized into two types: (1) rotating competition, where players at both ends answer the questions by taking turns, and (2) time-constrained competition, where both players compete answer the question asked by the computer.

Insert figure 2 about here

The competitive interactive activities are classified into 3 types, each of which is further divided into otating' or ime-constrained' modes.

(1) Interaction with computer agent, as shown in figure 2 (A), involving a user or team vs. an agent.

(2) Face-to-face interaction, as shown in figure 2 (B) involving user vs. user, user vs. team, and team vs. team, all face-to-face.

(3) Non face-to-face interaction, as shown in figure 2 (C), involving user vs. user, user vs. team, and team vs. team, all non face-to-face.

Table 2 summarizes these 16 competition activities.

Insert table 2 about here

SIMPLE ANSWERING MULTIPLE-CHOICE QUESTION AGENT DESIGN

Computers play various roles in learning environments, for example as teachers, students (Ur and VanLehn, 1995), troublemakers (A鮭eur *et al*., 1997), learning companions (Chan and Baskin, 1990), and so on. A computer-simulated agent is important in an online competitive game-learning system because some players prefer playing against an agent to competing with real life users. Computer-simulated agents are also important to individuals who are unable to find any real competitors to play against. Numerous approaches to designing an agent exist. In the Joyce system, the authors have designed a simple agent that can compete with users in multiple choice question activities. After the computer presents a question, the user(s) or agent

answers this question in different competing ways, and thus the activity proceeds. In the Joyce system, the authors have focused on simulating the agent behavior in answering questions (Chang *et al*., 2000). Agents must consider two issues: (1) response time: the time between the posting of the question and an answer being supplied; and (2) answering ability: the agent level of ability in the subject.

Collecting the answering information of users

To have adoptable response to users, agents must know who they are interacting with. Agents have three ways of understanding user response, namely:

(1) User log files

The activities of users during play are automatically saved in the system database.

(2) Directly questioning of users

During the game, the agent can ask users about their feelings, for example answering question like “Am I answering the question too quickly?”, “Am I answering the question quickly enough?”, “Am I answering the question all right?”, “Am I answering the question too slowly?”, etc. Similarly, the agent can ask users, “My answering ability is very powerful, isn it?”

(3) Direct comments from users

Users can use the dropdown menu to convey their feelings about the activities of the agent, for example telling the agent “Your response is too quick”, and so on.

Response time of the agent

A quiz game, involves many different variables that influence the response time of players, such as the length and difficulty of the item, and agent design must take these

variables into account.

In the Joyce system, the agent response time depends on the following formula:

(1) R1 (t) = initial response time or response time from past user log data

(2) R2 (t) = length of the item

(3) R3 (t) = difficulty of the item

(4) R4 (t) = indicates the current state of the user

Response time of agent R = p1 * R1 (t) + p2 * R2 (t) + p3 * R3 (t) + p4 * R4 (t), where p1 + p2 + p3 + p4 = 1.

Tuning the weight of p1, p2, p3, and p4 allows the response time of different kinds of agent to be simulated. For example, if we want an agent to read each item very carefully, then the weight of p2 can be adjusted, increasing the response time of agent as they receive a lengthier item.

Agent answering ability

As described earlier, the agent response time can be simulated by an equation, and this method of simulating agent response time can then be applied to agent answering ability.

In the Joyce system, agent answering ability depends on the following formula:

(1) A1 (i) = initial answering ability

(2) A2 (i) = item difficulty

(3) A3 (i) = current state of the user

Agent answering ability A = p1 * A1 (t) + p2 * A2 (t) + p3 * A3 (t), where p1 + p2 + p3 = 1.

Tuning the weight of these parameters allows different kinds of agent to be simulated, and the response functions can also be updated if necessary.

JOYCE SYSTEM ARCHITECTURE

As described earlier, this work attempts to develop a system that offers different competition activities to users to engage in drills and practice. The item bank of the system can be managed by users. The item bank is a loose item bank and the items eventually repeat. The Joyce system is designed as a three-tier architecture: database, game server and game client. The database records all the Joyce system data, including the item bank, user portfolio and the player rankings. The game server manages the grouping and dispatches messages to the game clients. The game client simulates the interactive environment presented to the players.

Game client

Insert figure 3 about here

Figure 3 presents the architecture of the game client, which contains five main components that collaborate with one another to make the game client operate as

designed.

- ③ **Game component:** Game component includes the game interface and game module. Users play through the game interface, and changes the interface can create many different variations of the game (same style, different interfaces). The game module takes charge of all the play states.
- ③ **Database component:** Database component includes the item bank module and user portfolio module. Users can download the latest items from the game server item bank to update items on the game client. The user portfolio module collects the actions of all users' during their interactions with the game. All data are recorded in the item bank database or user portfolio database.
- ③ **Agent component:** The agent component only includes the agent simulation module which simulates the agent response time and answering ability.
- ③ **Hardware device component:** As described above, EduClick is a hardware input device which resembles TV remotes. In team activities, group users use this device to input their answer. The hardware device component handles the messages inputted from EduClick.
- ③ **Network module component:** The network module offers connectivity and protocols to and between the client and server.

Game server and database

The Joyce game server is an event-driven server. The server receives all events sent from all game clients, and then fires up some actions according to the events sent by the game clients. Table 3 partially lists the server events. The system database stores all the data required by the game server.

Insert table 3 about here

System flow

The system flow is enumerated as follows:

(1) Users register to use the system, and are assigned an ID number after registration. This ID number is used to identify users, and a log of all interactive histories is stored during system operation.

(2) Users start up the Joyce game client, which is connected to the Joyce server.

(3) Users select one of the sixteen competitive activities to interact with the Joyce system.

(4) If the activity is run on a single computer, the Joyce server passes all the game information to the Joyce game client. Otherwise, the Joyce server finds some other group in the server to make a dyad.

(5) The Joyce server monitors all connections to handle the requests of users.

(6) The Joyce server will connect to the database if the Joyce client requests some data.

EVALUATION

Three studies were conducted to collect empirical data concerning the effectiveness of the Joyce system. The following sections describe the purposes, methods and results of each study.

Study 1

The first study considered the relationship between user motivation and game design for single user versus single user, non face-to-face and rotational competitive activities (Fan, 1997). The users in this study used the system after classes. This study involved two classes from different Taiwanese universities, National Central University and National Yunlin University of Science and Technology. A total of 55 students took Java programming language courses, and were told that use of the system was an assignment in the Java course. Each student earned 500 points for finishing the game, and earned 1,000 points for winning. Students who earned over 10,000 points and filled the questionnaire would obtain full credit for this assignment.

Eight students gave up the game because they did not want the credit. Forty-seven students completed the assignment, but only 42 students filled in the questionnaire. The questionnaire uses five-point scale - strongly agree, agree, no preference, disagree, strong disagree. The questionnaire items and the corresponding numbers of responses in the order (string agree, agree, no preference, disagree, strongly disagree) are as follows.

(1) Do you like this system? (10, 26, 5, 0, 1)

(2) Do you like the interface of this system? (2, 27, 12, 1, 0)

(3) Do you like the flow of the game? (2, 27, 12, 1, 0)

(4) Do you like the questions asked in this system? (3, 19, 17, 3, 0)

(5) Does this system help you learn? (6, 27,9, 0, 0)

(6) Does a competitive learning environment promote learning? (4, 31, 6, 1, 0)

(7) Please offer us any comments on this system (Open question).

Among the fully participating students, 21 earned under 10,000 points, six earned over 10,000 but under 20,000 points, and 20 students earned over 20,000 points. In the

interviews, the students who did not earn over 10,000 points complained that they could not find their companions on online when they connected to the system. Twenty students earned more than 20,000 points, much higher than the set goal of 10,000 points. Most students played the game in order to get the credit, representing an external motivation is attracted, but the 20 who earned more than 20,000 points liked to use the system even the external motivation is satisfied.

The system scores and the questionnaire statistics reveal that the system was accepted by students. In the open question, students suggested that more types of items should be included in the item bank to enable them to practice other subjects. Some students mentioned that they used the system many times in order to beat other students while at the same time acquiring knowledge. They stated that further practice would reinforce them memorize the knowledge. The interviews revealed that the students liked to read more articles, and find the answers from books to win the game.

Study 2

The second study aimed to determine the relationship between the users' abilities in a subject and the game design. Single user versus single user, non face-to-face, and time-constrained competitive activities were employed.

Sixteen students from four different schools, Chien-Kuo senior high school, Hsin-Chu girls' senior high school, Fu-Tan senior high school, and Wuling senior high school, were divided into four ability groups, according to their academic achievements, as presented in their school records. The ability of Team A exceeded that of Team B, while that of team B exceeded that of Teams C and D. Chinese, English, History and

Biology were chosen as the subjects content of competitions. Each student played against three students, one from each different ability group for two consecutive innings in one subject area. That is, student A1 played against students B1, C1 and D1 in Chinese, student A2 played against students B2, C2 and D2 in English, and so on. Table 4 shows the results.

Insert table 4 about here

Table 4 reveals that the team with the highest level of ability won the competition most frequently. However, the winner, Team A, still lost seven innings, while the loser, Team D, still won six innings. This outcome shows that the Joyce system gives more ably participants a greater chance of winning the game; however, less able participants still have a chance to win. Interviews were conducted after this study, and the results show that more able students would have done better if the system had not included "chance-related" mechanisms such as, bumping, shortcuts, funny questions, and others. However, less able participants believed that they could win the game given more attempts. The survey results provide empirical evidence that the Joyce system successfully generates a game environment in which all users have a chance of winning.

Study 3

This study tried to determine which of the 16 different competitive activities included

in the design were preferred by users. Twenty participants came from the Chinese department of National Central University, Taiwan. The subject was Chinese. The students engaged in the 16 competitive activities consecutively. Each competitive activity was played for three rounds. Interviews were held thereafter. During these interviews, students revealed that they were motivated to read material to win the game. Most of the students (18 individuals) stated that they would like to play the game by themselves. Eight students enjoyed face-to-face activity while 12 preferred non face-to-face activity. Most students (19 individuals) liked the time-constrained activity. The survey results show that users preferred to compete with others by him/herself. In the game-question system, users preferred to take more risks, providing a more challenging competition. The results of the interviews were as follow.

(1) Most students mentioned that playing a game is a good way to learn. The drill-and-practice quiz game allowed them to memorize much knowledge.

(2) The game interface design was very interesting and helped them become involved in the system.

(3) Most of students were satisfied the game flow, but they would have preferred the game flow to have been more complex.

The three studies presented in this paper were preliminary results. Advanced studies on student preference and satisfaction toward network and face-to-face computerized competitive learning environments were implementing, and described in another paper (Yu et al., 2001).

CONCLUSION

Online gaming is becoming increasingly popularity on the Internet. Online competitive game-learning activities are related to both online gaming and online learning activities, and thus designing an online competitive learning environment that motivates both winners and losers is essential. Three basic competitive forms and 16 different competitive activities are presented in the Joyce system which developed by the authors. A simple agent was designed to compete with participants in the quiz game activities in the Joyce system.

Three studies were conducted to obtain empirical data on the efficiency of the Joyce system, and the findings indicated the following.

(1) The Joyce quiz game system increases user motivation.

(2) More able users have more chance of winning, but less able users still have some chance of winning in the Joyce system.

(3) The game design encourages users to take competitive risks, and users prefer to play with a more competitive individual.

The system will be enhanced in the future, particularly in the area of agent design. Specifically, the design will be enhanced to include scenarios such as a single user versus agents and an agent collaborating with a user versus another agent collaborating with another user(s). More accurate evaluation is required in the near future.

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BIOGRAPHICAL NOTES

Li-Jie Chang received his master degree in Information and Computer Engineering from the Chung Yuan Christian University, Taiwan, in 1997. He is a Ph.D. student in

the Department of Computer Science and Information Engineering at the National Central University, Taiwan. His current research interests include online educational game, online learning communities, and online learning platform design.

Jie-Chi Yang received his Ph.D. in Human System Science at the Tokyo Institute of Technology, Tokyo, Japan, in 2000. He is currently an assistant professor in the Department of Computer Science and Information Engineering at the National Central University. His primary research interests include the development of network based learning systems, mobile learning systems, and Computer Assisted Language Learning systems using NLP techniques.

Fu-Yun Yu received her Ph.D. in Instructional Technology from the University of Texas at Austin in 1996. She is an associate professor in the Graduate Institute of Education at National Cheng-Kung University. Her current research interests are computer-supported collaborative learning, instructional design of web-based learning, and application and evaluation of web-based distance education.

Tak-Wai Chan received the Ph.D. degree in Computer Science from University of Illinois at Urbana-Champaign, in 1989. He is a professor in the Department of Computer Science and Information Engineering at the National Central University as well as the director of its Learning Technology Research Center. He is the chief director of the four-year Grand Project for Excellence dedicated to learning technology in Taiwan. He is also an associate editor of International Journal of Educational Telecommunication. His current research interests are intelligent distance learning, social learning theory and systems, and intelligent educational agents.

Address for correspondence: Li-Jie Chang can be contacted at the P.O. Box 9-393, Chung-Li, 320, Taiwan.
Tel: International +886-(3)-4227151 ext. 4843; Fax: International +886-(3)-4261943;
E-mail: jie@src.ncu.edu.tw

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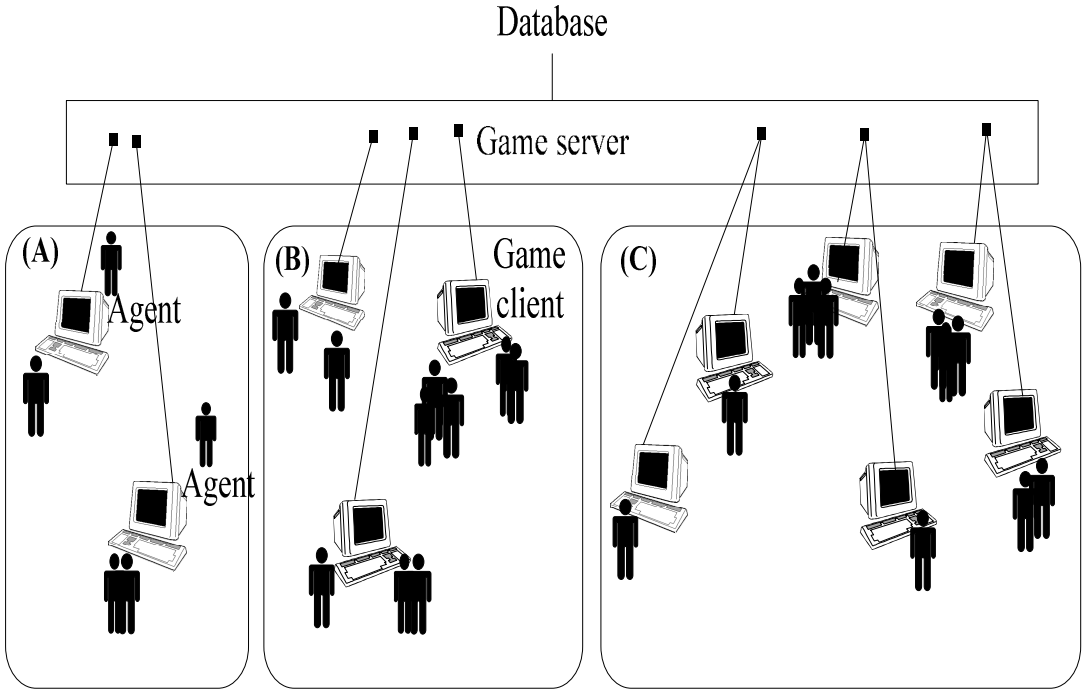

Figure 2 Enumerate the Joyce System Competition Activities

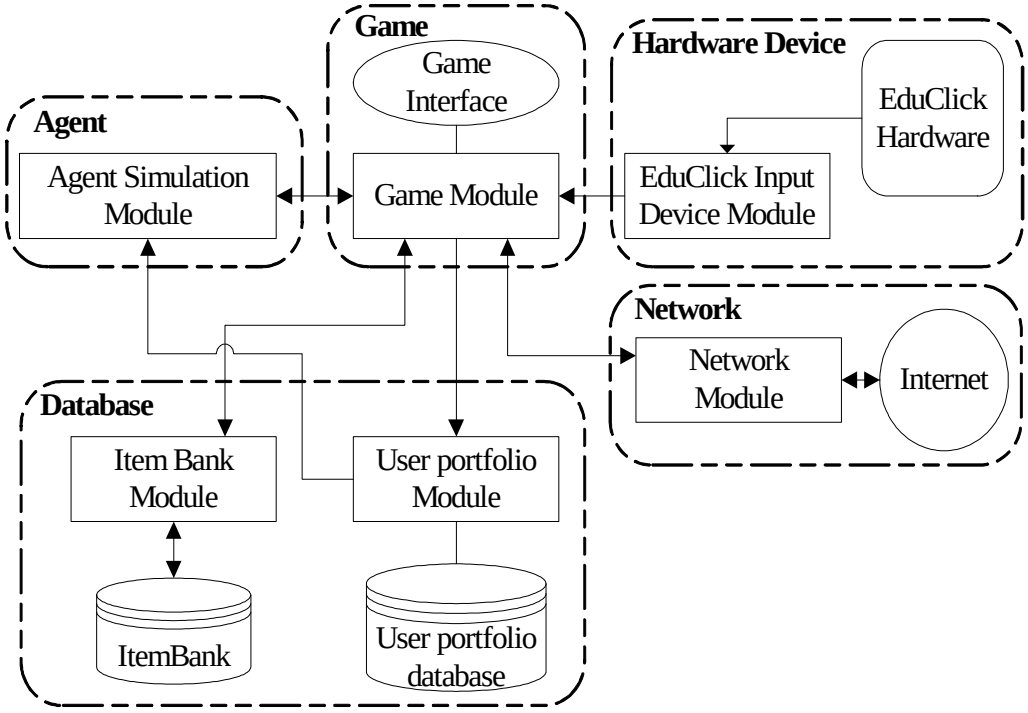

Figure 3 The System Diagram of the Joyce Game Client

Table 1 The Joyce System History

Year	System name	System descriptions
1977	WEST *	Standalone system, arithmetic practices, original game design
1979	WEST with coach**	Intelligent coach
1991	Distributed WEST	Distributed system, virtual learning companion, simple virtual tutor, practice in converting binary numbers into decimal numbers
1993	Distributed WEST with multimedia	Multimedia
1996	DWEST	System design on Web in Java, multiple-choice questions, domain independent
1999	Joyce	TCP/IP based on the Internet, competitive agent, sixteen competitive activities

* WEST was designed by Anderson.

** WEST with coach was designed by Burton and Brown.

*** Distributed WEST, Distributed WEST with multimedia, DWEST, and Joyce was designed at the Learning Technology Lab, National Central University, Taiwan.

Table 2 Sixteen Competitive Activities

#	Single or team	F-T-F (Face-to-face) or non F-T-F	Rotating or time-constrained competition
01	Single vs. computer agent	(Don care)	Rotating
02	Single vs. computer agent	(Don care)	Time-constrained
03	Team vs. computer agent	(Don care)	Rotating
04	Team vs. computer agent	(Don care)	Time-constrained
05	Single vs. single	With F-T-F	Rotating
06	Single vs. single	With F-T-F	Time-constrained
09	Single vs. team	With F-T-F	Rotating
10	Single vs. team	With F-T-F	Time-constrained
13	Team vs. team	With F-T-F	Rotating
14	Team vs. team	With F-T-F	Time-constrained
07	Single vs. single	With non F-T-F	Rotating
08	Single vs. single	With non F-T-F	Time-constrained
11	Single vs. team	With non F-T-F	Rotating
12	Single vs. team	With non F-T-F	Time-constrained
15	Team vs. team	With non F-T-F	Rotating
16	Team vs. team	With non F-T-F	Time-constrained

Table 3 Partial List of the Server Events

Event Number	Description of the Event
10	Server waits for the client to input the user name
20	Server waits for the client to input the password
140	One client broadcasts a message to all the other clients
150	One client sends a message to another client
160	User time out
200	An online user asks a competition to you
250	The competition activity starts
800	Activity logs start to be sent to the server
810	The logs are successfully received
…	…

Table 4 The Statistics of the Study 2

School		**Team A**				**Team B**				**Team C**				**Team D**			
Student		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Subjects		C	E	H	B	C	E	H	B	C	E	H	B	C	E	H	B
1st round		W	W	W	W	W	W	W	W	L	L	L	L	L	L	L	L
		L	W	L	W	W	L	W	W	W	L	W	L	W	W	L	L
2nd round		L	W	W	W	L	L	L	W	W	W	W	L	W	L	L	L
		W	W	W	W	W	W	L	L	L	L	W	W	L	L	L	L
3rd round		W	L	W	W	L	W	L	L	W	L	W	W	L	W	L	L
		L	L	W	L	W	W	L	W	L	L	W	L	L	W	L	W
Total	W	3	4	5	5	4	4	2	4	3	1	5	2	2	3	0	1
	L	3	2	1	1	2	2	4	2	3	5	1	4	4	3	6	5
		17 W 7 L				14 W 10 L				11 W 13 L				6 W 18 L			
Rank		1				2				3				4			

W: Win the game L: Lose the game

C: Chinese E: English H: History B: Biology