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EGameFlow: A scale to measure learners' enjoyment of e-learning games

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A R T I C L E I N F O

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A B S T R A C T

In an effective e-learning game, the learner's enjoyment acts as a catalyst to encourage his/her learning initiative. Therefore, the availability of a scale that effectively measures the enjoyment offered by e-learning games assist the game designer to understanding the strength and flaw of the game efficiently from the learner's points of view. E-learning games are aimed at the achievement of learning objectives via the creation of a flow effect. Thus, this study is based on Sweetser's & Wyeth's framework to develop a more rigorous scale that assesses user enjoyment of e-learning games. The scale developed in the present study consists of eight dimensions: Immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement. Four learning games employed in a university's online learning course "Introduction to Software Application" were used as the instruments of scale verification. Survey questionnaires were distributed to students taking the course and 166 valid samples were subsequently collected. The results showed that the validity and reliability of the scale, EGameFlow, were satisfactory. Thus, the measurement is an effective tool for evaluating the level of enjoyment provided by e-learning games to their users.

1. Introduction

Digital learning provides students with an environment that allows them to develop skills in self-initiated learning (Oliver & Herrington, 2001). This new type of environment has prompted a change in the role of students from passive receivers into active constructors of knowledge. Since e-learning gives students greater autonomy and control over knowledge construction, self-initiated willingness more strongly influences learning effectiveness.

As a result of enormous progress in learning technologies, digital games have become a feasible e-learning tool. The underlying characteristics of these games, such as entertainment, feedback, mission, sense of triumph, and social interaction, encourage player immersion (Prensky, 2001; Rolling & Adams, 2003), while the challenges they pose, their unpredictability and competition spark players' curiosity and inner motivations. This may explain why online games have become the learning tool that best provides students with a form of enjoyment while increasing the degree of immersion (Ampatzoglou & Chatzigeogiou, 2007; Virou, Katsionis, & Manos, 2005).

Educators have long emphasized the many benefits of games in children's learning processes (Malone & Lepper, 1987), but two different views dominate regarding the future development of e-learning games (Virou et al., 2005). Scholars who support digital games believe that people who have grown up in the era of rapidly advancing technology prefer, and even expect, the incorporation of games into their learning activities in order to balance the monotony of traditional course materials. Other scholars claim to never use game-based learning in didactic approaches because "high quality" educational games are not available (Dondi & Moretti, 2007; Prensky, 2001; Virou & Katsionis, 2008). Thus, the effort on helping to developing qualified games is invaluable.

To better understand how to design the e learning game other outside of principle and guidelines, finding the effective measurement instrument can pinpoint the different qualities between e learning game, commercial games and other style of e learning materials. The evaluation tools developed thus far has targeted usability in commercial games designed for leisure purposes but cannot properly measure e learning materials' main purpose: increasing knowledge or skills. On the other hand, the tools used to measure e learning missed that fun and challenge is essential making the users want to learn (Freitas & Oliver, 2006; Virou et al., 2005). In the past, learning game's measurement studies focused on the heuristics: design guidelines which serves as a useful tool for both designers and usability professionals (Desurvire, Caplan, & Toth, 2004; Medlock, Terrano, Romero, & Fulton, 2007; Zaphiris & Ang, 2007). Dondi and Moretti (2007) list 13 major

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concepts and 61 quality criteria. E-learning games does not have the high budget associated with commercial game development, therefore following strictly with the quality criteria may baffle the developer on where to spend more time to improve the game. The validity of heuristics depends on participation of enough researchers and the problems have high likelihood of detection (Medlock et al., 2007; Sweetser & Wyeta, 2005). A more feasible and economical way to evaluate these lower budget e learning games, is to use learn about learner's emotion and experience via surveys. The results from the survey will easily identify the strengths and weaknesses of the product.

An engaging educational game should not only provide course content, but also can facilitate the flow of experiences of students (Killi, 2005b). At the same time, these experiences should achieve the goal of increasing learner's knowledge. Therefore, this study attempts to combine experience theory in learning and knowledge creation process theory. Game designers can evaluate the quality of e learning games using the factors reported in the literature that may increase learners' engagement and knowledge enhancement of digital games.

2. Literature review

2.1. Performance from game-based learning

The popularity of the Internet has led to advancements in educational technology. Yet most e-learning sequences utilize traditional instruction contents, which are placed on the Internet without modifications that take advantage of the full potential of either the Internet or online technology (Oliver, 2004). In the e-learning environment, a wide array of complex problems is associated with encouraging students' willingness to take the initiative in the learning process. To transform the e-learning environment into something more than a source of information for students, the venue must provide incentives for learners to accumulate learning experience. Thus, the design of a curriculum that is interesting enough for students to immerse themselves in (Virou et al., 2005) and frequently reflect upon is one of the main challenges in the field of e-learning (Kiili, 2005a).

To overcome this challenge, an increasing number of researchers have suggested a fusion of gaming and e-learning in the recent years. The aim has been to alter the student's motivations by taking advantage of the characteristics of games (such as the challenges posed by them), as this may ultimately improve the student's learning experience (Freitas & Oliver, 2006; Brothers, 2007). Based on the research conducted by members of the National Training Laboratories, researchers considered that learning games should fall into the category of practice by doing on the Learning Pyramid[1] See. http://www.acu.edu/cte/activelearning/whyuseal2.htm, which owned 75% retention rate. This is significantly higher than the retention rate produced by traditional-type e-learning approaches, such as lectures (5%), reading material (10%), and audio/visual material (20%) (Dale, 1969; Brothers, 2007). Using six 10–12th grade students playing a modified video game called Civilization VI, the result of experiment found the game improves the ability to immediately recall historical events (Moshirnia, 2007). In another study, researchers used self-made online e learning game as an instrument along with 120 college students in an experiment. The study has shown that e-learning games help students to devote longer periods of time to their studies and to perceive more interesting (Fu & Yu, 2006).

2.2. Self-initiated motivations of learning in e-learning games

According to the theory of knowledge creation spirals, when the environment can provide suitable stimulant, a person's internal knowledge will externalize through interaction with the environment. After combination with self external knowledge and self reflection, even more knowledge will be created. Therefore having more stimulants to start again and again the socialization process can cause knowledge creation process to put knowledge spiral into a continuous growth, as illustrated in Fig. 1 (Nonaka & Takeuchi, 1995; Nonaka, Umemoto, & Sasaki, 1998). Researches into the area of educations also points out that educational settings afford more opportunities for practice, thereby enhancing knowledge acquisition and retention (Ricci, 1994).

Blending knowledge creation theory and learning pyramid produces a theory that practice by doing style of learning in a e learning game is more effective because it can provide the motivation to promote the socialization process. How much motivation is needed to cause the learner to reach their learning goal? Also, what are these motivations? Because e learning games is a tool to let learners to learn by doing, therefore it is essential to late the learners concentrate upon playing. Csikszentmihalyi (1991) said the flow experience as a situation of complete absorption or engagement in a activity. He also proposed that the activity that can produce flow experience required a few characteristics: (1) have clearly defined goals with manageable rules; (2) make it possible to adjust opportunities for action to our capabilities (autonomy); (3) provide clear information on how the participants are doing (feedback); (4) screen out distraction and make concentration possible (Csikszentimihalyi, 1993, p.xiv). Another research in the same time frame proposed similar ideas, but are not as complete as the research by Csikszentimihalyi (1993). Malone and Lepper (1987) proposed that a good learning game should have the qualities of challenge and control. The game must incorporate various rules of control. For example, according to the contingency rule, feedback must be given regarding the learner's response. The choice rule ensures that the learner consciously decides on the order in which things are learned and the difficulty level. The power rule affects how the student's learning experience is accumulated (Malone & Lepper, 1987).

Sweetser and Wyeth (2005) combined various heuristics on usability and user experience in games into a concise model of enjoyment in game evaluation, named GameFlow. They considered that player enjoyment is similar in concept to flow, therefore enjoyment (or flow) is a standard for design and evaluating games. GameFlow includes factors that could cause flow experience proposed by Csikszentmihalyi, such as immersion, clarity of goal, autonomy, feedback, concentration, challenge, and skill, as well as the additional factor of player interaction. Also to develop a heuristics to turn factors that could affect enjoyment into the guideline for designing game. Clear goals, including overall game as well as intermediate goals, autonomy (player feel a sense of control over their action in the game) and feedback (player receive appropriate feedback at proper time) are heuristics to remind the designer interface design should not impede on user enjoyment and allows the player be able to concentrate on the game. The heuristics provided by the four factors such as immersion (players experience deep but effortless involvement), challenge (game should be sufficiently challenging and match the player's skill), provide opportunity for social

[1] National Training Laboratories.(no date) Learning Pyramid, Bethel, Maine.

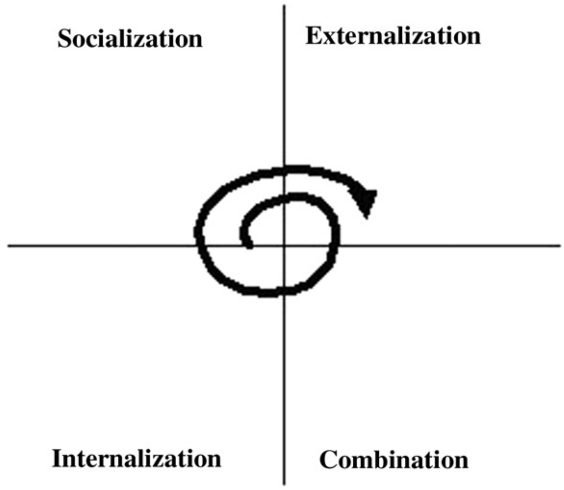

Fig. 1. Knowledge spiral and evolution.

interaction reminds the game design needs proper narrative or it may negatively influence player's pleasure. Player skills factor illustrate that the game design should be able to support player skill development and mastery.

Providing an adequate level of challenge has long been viewed as a key reason why players experience "flow" from a particular game (Csikszentmihalyi, 1991). However, challenge doesn't necessary causes flow. Csikszentmihalyi (1998) emphasized the importance of the balance between an individual's skills and difficulties of the tasks. The player will feel bored or frustrated if his or her existing skill exceeds or falls short of the challenge at hand. Sweetser and Wyeth (2005) stated that players' perceived skills are very important and they should match the challenge supported by the game. The game must reflect the right balance of challenge and ability in order to facilitate and maintain flow during gameplay and to keep players inside the Flow Zone (Pilke, 2004). This is true for both 'mini-games', where players achieve quick outcomes, and of complex games, which have goals and sub-goals. These games should adequately provide appropriate challenges so that the player's skill level can be easily matched by varying the level of difficulty to keep an appropriate pace (Mitchell & Savill-Smith, 2004). Kiili, 2005a applied challenge into the design of education game circulatory system model: the challenges provided by games are like heart pumping blood, which continually invigorate the learning circulatory system. Only in the presence of an adequate level of challenge will the player experience the condition of flow and become unaware of the passage of time (Kiili, 2005a). The adequate level of challenge refers to the challenge provided by the game is balanced with the players' skills. A gamed called IT-Emperor was used to demonstrate this model (Kiili, 2005b).

Pleasure has always been considered as a critical motivation to engagement (Tiger, 2000). According to transportation theory, the narrative is the story that is told by the game, which is acted out by the player going through a series of planned interactions. Narrative provides the "why" for the game, giving the player background and motivation to become involved with the game world and its inhabitants (Sweetser, 2006). Players who triumph in a game will experience psychological pleasure. In addition, games often offer the chance to compete or cooperate with fellow players. In this process of competition or cooperation, students can enjoy the game and engage in pleasure derived from social interactions while acquiring the knowledge and skills that other players use in game-playing (Sweetser & Wyeth, 2005). A game's entertainment value (Rosas, Nussbaum, Cumsille, Marianov, & Correa, 2003; Tiger, 2000), the engagement in a virtual reality, and other, similar sensory pleasures also lead to the learner's unwitting involvement (Tiger, 2000). Factors sparking the player's motivation to learn, such as competition and cooperation, are derived from interaction processes and further stimulate the self-initiated motivation to learn (Kiili, 2005a).

2.3. Evaluation of e-learning games

There has been little research into evaluation of e-learning games, perhaps due to the fact that e-learning has little traction until recently. In the past, researches provided simple guidelines at most, such as identifying the relationship between knowledge type and game style (Prensky, 2001). However, the numerous types of learning and respective suitable game styles as listed by Prensky (2001) are too complicated to be empirically applied to quality evaluation. Uni-Games, based on the result of their project, proposed six different learning objectives for game genre (Dondi & Moretti, 2007). This differentiation, applied with respect to a game's required features and appropriate typology, try to provide researchers with easy to use evaluative approach. Other current researchers evaluate the development of a high quality or effective e-learning game include assessing the applicability of using e-learning games in corporations based on cost-effect analysis (Margolis, Nussbaum, Rodriguez, & Rosas, 2006) or employing quantitative and qualitative checklists to determine the effectiveness of e-learning games (Ampatzoglou & Chatzigeogiou, 2007; Freitas & Oliver, 2006; Dondi & Moretti, 2007).

There have already studies on players' self-motivation and psychological status but were targeted toward commercial games. Flow, in particular, is one of the most frequently mentioned concepts in this stream of discussions. Since enjoyment motivates the continuation of work and study, whether or not the player experiences enjoyment or flow should be seen as a key criterion in determining a game's effectiveness.

Csikszentmihalyi (1991), Csikszentmihalyi (1993), Csikszentmihalyi (1998) attempted to understand enjoyment and flow of a activity through interviews and surveys. He found that the experience of flow comprises several core factors, such as the activity, concentration, the challenge to player skills, control, clear goal, feedback, and immersion. The concept of flow was applied in researches into game development, such as Flow Zone (Pilke, 2004), and factors that influence computer game flow in children (Inal & Cagiltay, 2007). Sweetser and

Table 1
The differences between user questionnaire and heuristics

Heuristics	User questionnaire
Mostly measuring: usability	Our measuring: enjoyment, pleasure, fun of use
Expert view	'Subjective' and users' view
Instant data	Self-reflection after the events happened
Observed behavior/ emotions	Self-evaluated emotions
Interpretation of context	Self interpretation context
Only few of experts' view been collected	A lot volume of users views been collected

Wyeth (2005) used these concepts to integrate and synthesize the existing literature on computer games and subsequently developed "GameFlow", a series of criteria which can help the designers to measure the enjoyment of a game. GameFlow consists of an evaluation checklist for every factor, mainly for the purpose of assessing a player's level of game enjoyment and thus facilitating improvements in a game's application and design.

GameFlow should be looked upon by researchers as an important literature to evaluate games in recent history. This is demonstrated in one of the main topics of ACE'07 International Conference sessions, which is Methods for evaluating games – How to measure usability. The workshop editor Bernhaupt, Eckschlager, and Tscheligi (2007) concurs that the GameFlow concept by Sweetser & Wyeth (2005) is a viable concept to evaluate user experience in games. In addition, this literature has been referenced by many other researches into computer games, such as Inal and Cagiltay (2007) referenced GameFlow to explain how to facilitate flow experiences. Chen (2007) used the concept GameFlow to develop the idea of the Flow Zone.

The main goal of e-learning games and commercial games are slightly different. E-learning games are trying to convey knowledge through the gaming experience, therefore the effectiveness of raising knowledge is an important criterion in evaluation of e-learning games (Freitas & Oliver, 2006; Fu, Wu, & Ho, 2007). The concept of GameFlow Sweetser & Wyeth (2005) GameFlow have incorporated the concept of measure improvement of players' skill. However, it is used to measure the player's skill at playing the game; therefore it cannot adequately describe the increase of knowledge. The most widely accepted criteria by researchers for increasing knowledge is Bloom Taxonomy of Educational Objective classified into six levels: memorization, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1984). Chu, Hsieh, and Fu (2006) further developed these aspects in measuring the improvements in knowledge derived from e-learning games. An improvement in knowledge can be considered as an enjoyable experience that is conferred by an e-learning game on a player (Tiger, 2000). Consequently, this aspect should be added to GameFlow's eight criteria.

Past evaluations of games use heuristics, which introduces subjectivity of the expert or researcher into the research. Even though it can attain results quickly, researches may attain different results due to the subjective nature as well as can be costly. Beside game design and challenges, there may be other possible factors that may influence enjoyment or flow, such as sex (Inal & Cagiltay, 2007), personal skill (Kiili, 2005b) and game type (Dondi & Moretti, 2007). Survey is cheap tool to get large quantity of subjective opinions directly from the gamers. There are advantages to both techniques, therefore a combination of heuristics and survey can make the evaluation more effective. The comparison between survey and heuistics illustrated as Table 1 which was adjusted based on Zaman & Shrimpton-Smith (2006).

This research reformats the checklist for GameFlow into a questionnaire and added the factor of increasing knowledge, then combined with the questions on knowledge improvements from e-learning games developed by Chu et al. (2006). The result is a scale to measure e-learning game called EGameFlow. Surveys on the games will used for validation of the scale. Statistical analysis will be used to remove irrelevant, redundant or contradictory questions.

3. Methodology

3.1. The process of scale development

The methodology of our approach is based on scale-development theory and the methods proposed by DeVellis (1991), who described eight steps of scale development: clearly defining the concept to be measured, creating a list of items, determining the format of measurement, asking professionals to review the drafted scale, considering the addition of reliability-testing items, choosing a sample and pre-testing the items, evaluating the items, and deciding on the length of the scale. Once the scale is developed, it must be tested for validity and reliability. Validity testing consists of assessing content validity, construction validity, criterion-related validity, convergent validity, and divergent validity (Burns & Grove, 2001). Reliability indicators are: internal consistency reliability, test-retest reliability, alternate-form reliability, and split-half reliability.

Scale development in this study consisted of three stages. In the first stage, the validity evaluation of the scale items was valuated; the second stage comprised a pre-test, a reliability test, and a validity test; formal testing of the scale's reliability and validity was done in the third and final stage. During the first stage, a scale was drafted based on those already described in the literature. The draft was then assessed for its content validity in an attempt to construct a scale for pre-testing. Key points in this assessment were: relevance of the items, choice of wording, adequacy of the dimensions, convenience in coding, order of the items, grammar and flow of the items, and variability of the content covered by the items.

After the content was assessed for its validity, a modified version was used for the pre-test, the reliability test, and the validity test. The greatest challenge at this stage consisted of pre-testing, retesting, and designing the final scale. Questionnaires retrieved from the pre-testing underwent factor, reliability, and item-total correlation analyses. The retest was conducted after a period of 10 days and the data collected were subjected to another reliability test. Results from the four analyses were used to predict the power of the scale and to identify factors that lower its efficiency. Then, items of each dimension were added or deleted and the wording was altered to better suit the purpose of the scale. The modified version became the official scale, which was used to con-

Table 2
Scale of EGameFlow

Factor	Item no.	Content
Concentration	*C1*	*The game grabs my attention*[a]
	C2	*The game provides content that stimulates my attention*[a]
	C3	Most of the gaming activities are related to the learning task
	C4	No distraction from the task is highlighted
	C5	Generally speaking, I can remain concentrated in the game
	C6	I am not distracted from tasks that the player should concentrate on
	C7	I am not burdened with tasks that seem unrelated
	C8	Workload in the game is adequate
Goal Clarity	G1	Overall game goals were presented in the beginning of the game
	G2	Overall game goals were presented clearly
	G3	Intermediate goals were presented in the beginning of each scene
	G4	Intermediate goals were presented clearly
	G5	*I understand the learning goals through the game*[a]
Feedback	F1	I receive feedback on my progress in the game
	F2	I receive immediate feedback on my actions
	F3	I am notified of new tasks immediately
	F4	I am notified of new events immediately
	F5	I receive information on my success (or failure) of intermediate goals immediately
	F6	*I receive information on my status, such as score or level*[a]
Challenge	*H1*	*I enjoy the game without feeling bored or anxious*[a]
	H2	*The challenge is adequate, neither too difficult nor too easy*[a]
	H3	The game provides "hints" in text that help me overcome the challenges
	H4	The game provides "online support" that helps me overcome the challenges
	H5	The game provides video or audio auxiliaries that help me overcome the challenges
	H6	*My skill gradually improves through the course of overcoming the challenges*[a]
	H7	*I am encouraged by the improvement of my skills*[a]
	H8	The difficulty of challenges increase as my skills improved.
	H9	The game provides new challenges with an appropriate pacing
	H10	The game provides different levels of challenges that tailor to different players
Autonomy	*A1*	*I feel a sense of control the menu (such as start, stop, save, etc.)*[a]
	A2	*I feel a sense of control over actions of roles or objects*[a]
	A3	*I feel a sense of control over interactions between roles or objects*[a]
	A4	*The game does not allow players to make errors to a degree that they cannot progress in the game*[a]
	A5	*The game supports my recovery from errors*[a]
	A6	*I feel that I can use strategies freely*[a]
	A7	I feel a sense of control and impact over the game
	A8	I know next step in the game
	A9	I feel a sense of control over the game
Immersion	I1	I forget about time passing while playing the game
	I2	I become unaware of my surroundings while playing the game
	I3	I temporarily forget worries about everyday life while playing the game
	I4	I experience an altered sense of time
	I5	I can become involved in the game
	I6	I feel emotionally involved in the game
	I7	I feel viscerally involved in the game
Social Interaction	S1	I feel cooperative toward other classmates
	S2	I strongly collaborate with other classmates
	S3	The cooperation in the game is helpful to the learning
	S4	The game supports social interaction between players (chat, etc)
	S5	The game supports communities within the game
	S6	The game supports communities outside the game
Knowledge Improvement	K1	The game increases my knowledge
	K2	I catch the basic ideas of the knowledge taught
	K3	I try to apply the knowledge in the game
	K4	The game motivates the player to integrate the knowledge taught
	K5	I want to know more about the knowledge taught

[a] Item underlined was deleted after validity and reliability tested.

duct an online survey. A total of 166 valid samples were collected. The reliability and validity of the scale were officially tested at the end of data collection.

3.2. Scale design

The scale, named EGameFlow, developed in this study consists of eight dimensions: (1) Concentration (6 items): games must provide activities that encourage the player's concentration while minimizing stress from learning overload, which may lower the player's concentration on the game. (2) Clear Goal (4 items): tasks in the game should be clearly explained at the beginning. (3) Feedback (5 items): feedback allows a player to determine the gap between the current stage of knowledge and the knowledge required for ultimate completion of the game's task. (4) Challenge (6 items): the game should offer challenges that fit the player's level of skills; the difficulty of these chal-

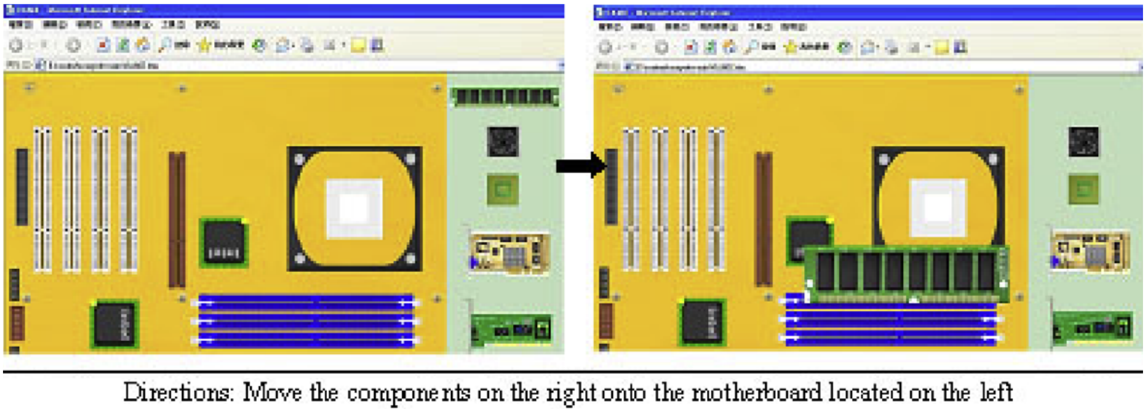

Fig. 2. The motherboard-assembly pairing game.

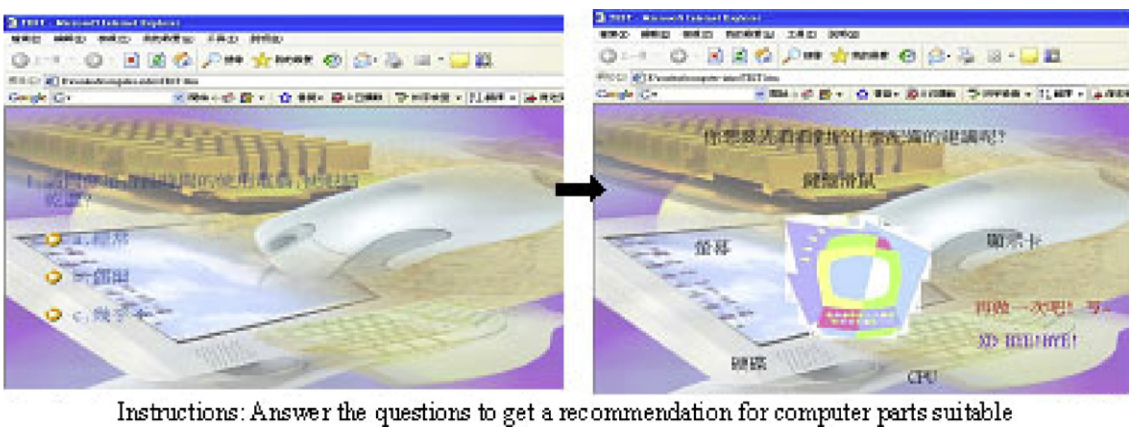

Fig. 3. The game describing computer parts.

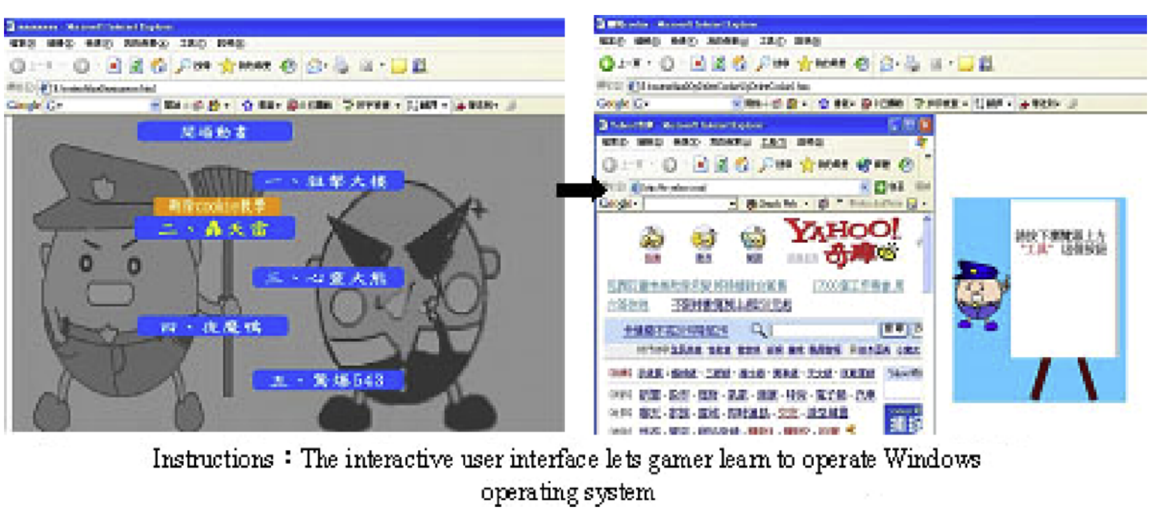

Fig. 4. The hands-on OS game.

lenges should change in accordance with the increase in the player's skill level. (5) Autonomy (3 items): the learner should enjoy taking the initiative in game-playing and asserting total control over his or her choices in the game. (6) Immersion (7 items): the game should lead the player into a state of immersion. (7) Social Interaction (6 items): tasks in the game should become a means for players to interact socially. (8) Knowledge Improvement (5 items): the game should increase the player's level of knowledge and skills while meeting the goal of the curriculum. The factor of player skill in the concept of GameFlow, proposed by Sweetser and Wyeth (2005), is modified to Knowledge Improvement from the measurement of e-learning games. Details of these items are shown in Table 2.

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To summarize, the scale contains 56 items presented in Likert-type scales, with 1 and 7 respectively representing the lowest and highest degree to which respondents agree with the items. After the respondents complete the survey's 42 items, they are presented with itemized criteria to rate their "overall sense of enjoyment" on a visual analogue scale between 0 and 100.

3.3. Games tested

Four games with different types of knowledge and style were chosen to obtain data on player experience: (1) a motherboard-assembly pairing game, (2) a game involving a description of computer parts, (3) a hands-on OS game and (4) a bear-cub's computer game.

The motherboard-assembly pairing game is designed both to lead students to remember computer components by looking at realistic photographs of the equipments and to simulate them to assemble a motherboard in an interactive venue (see Fig. 2). According to Dondi's & Moretti's (2007) game-based learning typology, this game stimulates a player's memory of factual knowledge and incorporates memory, actions, and time limits in its design.

The game describing computer parts was developed with the purpose of guiding the student to understand how to purchase computer accessories based on his or her personal needs (see Fig. 3). In Dondi's & Moretti's (2007) learning typology, this game teaches decision-making in that computer parts are selected to match the user's needs. In terms of game design, the game showcases factors of role-playing, detecting, and explaining.

The purpose of the hands-on OS game is to acquaint the student with common problems associated with a computer's operating system (see Fig. 4). Following Dondi and Moretti (2007), this game enhances player's dexterity with respect to certain skills. The game design makes use of adventure.

The bear-cub's computer game basically introduces the player to a wide range of computer software and imparts basic knowledge regarding the software. Several flash games, such as Connect the Dots, Guess Who, and EYEZMAZE, are placed in the instruction material. These mini-games not only increase the fun of learning but also hold user's attention to the extent that flow status is easily achievable, thus enhancing the player's retention of what he or she learned in the game (see Fig. 5). The game's design simulates scenarios in the typical usage of computer application software. In Dondi's & Moretti's (2007) game-based learning typology, the game improves skill dexterity.

The development cost associated with the four games was low. The first three games examined in this study were developed by students in the class called "project of information systems development" for their project. The fourth game was developed by an assistant for the cost of 1500 US dollars. All the learning goals were set by the professors of the class. Flash, Director MX, and PhotoImpact were used in the development of these games. All of the games can be presented in a Web-based format.

3.4. Sample

This study was conducted on students who took the online learning course "Introduction to Software Applications" during the fall semester of 2006 at a national university in northern Taiwan. The purpose of the research was explained to the six instructors of the course, who agreed to assist in the study. The e-mail addresses of all participating students were then obtained and an open letter was sent seeking participation in the survey, with gifts offered as incentives. The following criteria were established:

- Research participants were required to have played at least one of the four games selected by this study.
- In responding to the survey, each participant was limited to evaluating only one of the four games. The survey could not be responded to more than once.
- Participants were required to possess basic computer and online skills.
- Participation in the survey was voluntary.

3.5. Data analysis methods

The following methods were used to in this study to test the reliability and validity of the scale:

- Item analysis. Three tests and five indicators were used to form an overall evaluation (Wang & Hong, 2002; Chiu, 2003). The tests were:

Fig. 5. The bear-cub's computer game.

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a. Descriptive statistic tests: mean and standard deviation.
b. Extreme group comparison.
c. Test for homogeneity: after correction, the correlation between a single item and the overall score was >0.4; loading on the original single factor in the principle factor analysis was >0.3.

- Validity test: construct validity, divergent validity, convergent validity, and criterion-related validity were tested.
- Reliability test: internal consistent reliability and test-retest reliability were examined.

Table 3
Item analyses

Factor	Item no.	Mean	SD	*t*-value	*r*	Factor loading
Concentration	C1	4.86	1.13	−18.51	.64**	.65
	C2	4.78	1.14	−17.99	.68**	.62
	C3	5.28	1.06	−16.88	.70**	.60
	C4	5.30	1.05	−22.43	.65**	.57
	C5	5.03	1.13	−20.85	.66**	.56
	C6	4.91	1.17	−21.32	.67**	.58
	C7	5.37	1.04	−17.56	.64**	.44
	C8	*5.72*	1.06	−17.54	.63**	.57
Goal clarity	G1	4.97	1.27	−16.96	.78**	.52
	G2	5.29	1.05	−12.08	.72**	.45
	G3	5.04	1.27	−16.96	.84**	.55
	G4	5.33	0.95	−11.64	.75**	.41
	G5	5.49	1.01	−13.80	.53**	.55
Feedback	F1	5.16	1.04	−18.86	.71**	.62
	F2	5.16	1.00	−17.45	.69**	.59
	F3	5.01	1.17	−18.55	.73**	.66
	F4	5.10	1.11	−15.45	.76**	.63
	F5	5.34	1.03	−15.94	.68**	.53
	F6	4.74	1.11	−19.68	.47**	.56
Challenge	H1	4.76	1.31	−19.72	.61**	.72
	H2	5.04	1.30	−20.76	.57**	.62
	H3	5.16	1.29	−16.26	.70**	.69
	H4	4.37	1.21	−18.30	.66**	.59
	H5	4.97	1.12	−18.45	.66**	.70
	H6	5.03	1.02	−19.32	.69**	.74
	H7	4.93	1.12	−17.78	.69**	.72
	H8	4.53	1.28	−19.82	.74**	.65
	H9	4.64	1.21	−20.20	.74**	.66
	H10	4.33	1.33	−20.25	.71**	.63
Autonomy	A1	4.60	1.35	−20.15	.48**	.45
	A2	4.64	1.34	−20.23	.68**	.45
	A3	4.55	1.26	−18.29	.69**	.47
	A4	5.11	1.17	−18.45	.27*	.35
	A5	4.79	1.25	−22.83	.12	.11
	A6	4.51	1.25	−19.26	.67**	.44
	A7	4.37	1.37	−18.85	.64**	.47
	A8	4.84	1.16	−19.07	.58**	.55
	A9	4.66	1.28	−18.90	.61**	.55
Immersion	I1	3.97	1.21	−16.79	.80**	.57
	I2	3.92	1.24	−18.15	.79**	.50
	I3	3.87	1.26	−20.43	.84**	.56
	I4	4.04	1.27	−19.64	.78**	.59
	I5	4.48	1.13	−19.18	.77**	.64
	I6	3.99	1.26	−19.41	.82**	.62
	I7	3.90	1.39	−18.20	.81**	.67
Social Interaction	S1	*3.29*	1.43	−16.62	.86**	*.19*
	S2	3.74	1.28	−17.28	.87**	*.20*
	S3	4.15	1.24	−19.07	.79**	*.26*
	S4	*3.21*	1.43	−19.18	.85**	*.14*
	S5	*3.14*	1.39	−19.56	.84**	*.16*
	S6	*3.12*	1.40	−19.44	.77**	*.25*
Knowledge improvement	K1	5.11	1.01	−16.71	.67**	.57
	K2	5.20	1.01	−16.59	.82**	.69
	K3	4.98	1.11	−15.51	.74**	.65
	K4	5.02	1.04	−18.43	.77**	.65
	K5	5.05	1.03	−20.01	.72**	.64
All scale		4.57	0.67	–	–	–

* $p < 0.05$.
** $p < 0.01$.

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- Based on the these validity and reliability testing methods, the study coded all collected data and entered them as input into SPSS for the purposes of filing and statistical analysis purposes. The following statistical measures were included as a part of the study's data analysis:
- An independent sample *t*-test was used in the discrimination of scale items.
- Factor analysis was applied in determining factor loading and the construction validity of a single item.
- Pearson's product moment correlation coefficient was used to analyze both the correlation between and the criterion-related validity of single items and the sub-scales/complete scale, and the relationship between each sub-scale and the full scale.
- The discrepancy in the level of psychological enjoyment between subjects with gaming experience in different games was determined by an independent sample single-factor ANOVA.
- Cronbach's alpha was used to assess the consistency between items in each sub-scale and in the full scale.
- An intraclass correlation coefficient (ICC) was used to evaluate the stability of the scale tested by test-retest reliability.

4. Results and discussion

4.1. Demographics of the subjects

The pre-test was conducted on students in one of the seven classes held for the online learning course "Introduction to Software Application." Fifty-two valid samples were collected from the 85 students in the class. For the official data collection stage, the 502 students in the remaining six classes comprised the study population. From this population, 166 valid samples were obtained, yielding a 33% response rate. The majority of those respondents was female (108, 65%), and the largest group consisted of freshman (56, 34%). Business majors outnumbered students from other majors (88, 53%). Regarding experience with computers, about half of the group (85, 51%) started using computers between the fourth and sixth grades. Most of the respondents (139, 84%) had no e-learning experience until college, but many of them (52, 31%) started playing online games in junior high. As for e-learning games, 70 respondents (42%) reported never having played this genre of games until college. The sample demonstrated a low frequency of participation in online gaming activity, with 54 (33%) of respondents stating that they played online games less than four times a month and 52 (31%) claiming to almost never play online games. Regarding the four types of games chosen for this study, 41 (25%) participants opted to answer questions based on their experience in the motherboard-assembly pairing game, ten (6%) preferred the game describing computer parts, 21 (13%) used the hands-on OS game, and 94 (57%) selected the bear cub's computer game.

4.2. Result of analyses of scale items

This study used item analysis to evaluate the adequacy of the questions and to determine whether a specific item should remain in the final version of the scale. The item analysis included descriptive statistics (mean and standard deviation), extreme group comparison, and a test for homogeneity (correlation, factor loading) (Table 3).

The mean of the single items showed that most questions in the scale were adequate (within ±1.5 SD of the scale's overall mean); five items showed a strong deviation (exceeding ±1.5 SD from the scale's overall mean). This may have been due to the high scores achieved for in items measuring workload during learning, as the mechanisms of the four games were fairly simple. The four items assessing social interaction may have yielded lower scores because of the four games' inherent lack of social interactive mechanisms (such as cooperation, chatting, and an online community).

The results of standard deviation tests showed that all 56 scale items had a high discriminative power (SD > 0.7). To conduct extreme group comparisons, the mean scores reported by the top and bottom 27% of the 166 research subjects (4.14 and 4.99) were used as indicators; these formed the basis for categorizing high and low scores. Independent sample t-tests (assuming different standard deviations) of the scores showed that all items were statistically significant ($p < 0.01, t < 2.64$).

In the homogeneity test, 0.3 was the minimum indicator of inadequately corrected item-scale correlation. Of the 56 scale items, 54 passed the test and 2 displayed correlations <0.3. Five items failed the principle factor loading test due to loading <0.3. Again, this may have been due to the lack of interactive mechanisms in the games rather than a weakness in the scale itself.

After the above indicators were reviewed, an item in the Control dimension was removed. The remaining items that did not meet the testing criteria were temporarily retained in the resulting 55-item scale for use in validity and reliability tests.

4.3. Scale validity

Five validity tests were applied to observe content validity, construction validity, criterion-related validity, convergent validity, and divergent validity.

In the course of scale development, this study attempted to validate content validity through two methods: creating expert validity by asking content-validity professionals to review and modify the scale, and by using data collected in pre-tests to conduct factor, reliability, item-scale correlation, and test-retest. The results were used as references in predictions of the effectiveness of the scale and as the basis of speculations on possible reasons for ineffective scale items. To improve the effectiveness of the scale, items could be cut or added and questionnaire wordings rewritten.

Structure validity was tested through factor analysis. All missing values were disregarded and only the 166 valid samples in the official survey were used in the analysis. Before the structure validity test was initiated, KMO and Bartlett's test of sphericity (BT) were conducted to determine whether the data were suitable for factor analysis. The results of those two tests were satisfactory, with a KMO value of 0.87 and a BT value of 8235.9 ($p < 0.01$) (Hair, Anderson, Tatham, & Black, 1998).

In the next step, factors were extracted by the principal-axis factoring method. An eigenvalue >1.0 was used as the criterion for factor extraction while factor loading after varimax orthogonal rotation >0.4 was set as the breakpoint in the selection of meaningful items in

Table 4
Item analyses

Factor	Item no.	Mean	SD	*t*-value	*r*	Factor loading
Concentration	C1	4.86	1.13	−18.51	.64**	.65
	C2	4.78	1.14	−17.99	.68**	.62
	C3	5.28	1.06	−16.88	.70**	.60
	C4	5.30	1.05	−22.43	.65**	.57
	C5	5.03	1.13	−20.85	.66**	.56
	C6	4.91	1.17	−21.32	.67**	.58
	C7	5.37	1.04	−17.56	.64**	.44
	C8	*5.72*	1.06	−17.54	.63**	.57
Goal clarity	G1	4.97	1.27	−16.96	.78**	.52
	G2	5.29	1.05	−12.08	.72**	.45
	G3	5.04	1.27	−16.96	.84**	.55
	G4	5.33	0.95	−11.64	.75**	.41
	G5	5.49	1.01	−13.80	.53**	.55
Feedback	F1	5.16	1.04	−18.86	.71**	.62
	F2	5.16	1.00	−17.45	.69**	.59
	F3	5.01	1.17	−18.55	.73**	.66
	F4	5.10	1.11	−15.45	.76**	.63
	F5	5.34	1.03	−15.94	.68**	.53
	F6	4.74	1.11	−19.68	.47**	.56
Challenge	H1	4.76	1.31	−19.72	.61**	.72
	H2	5.04	1.30	−20.76	.57**	.62
	H3	5.16	1.29	−16.26	.70**	.69
	H4	4.37	1.21	−18.30	.66**	.59
	H5	4.97	1.12	−18.45	.66**	.70
	H6	5.03	1.02	−19.32	.69**	.74
	H7	4.93	1.12	−17.78	.69**	.72
	H8	4.53	1.28	−19.82	.74**	.65
	H9	4.64	1.21	−20.20	.74**	.66
	H10	4.33	1.33	−20.25	.71**	.63
Autonomy	A1	4.60	1.35	−20.15	.48**	.45
	A2	4.64	1.34	−20.23	.68**	.45
	A3	4.55	1.26	−18.29	.69**	.47
	A4	5.11	1.17	−18.45	.27*	.35
	A5	4.79	1.25	−22.83	.12	.11
	A6	4.51	1.25	−19.26	.67**	.44
	A7	4.37	1.37	−18.85	.64**	.47
	A8	4.84	1.16	−19.07	.58**	.55
	A9	4.66	1.28	−18.90	.61**	.55
Immersion	I1	3.97	1.21	−16.79	.80**	.57
	I2	3.92	1.24	−18.15	.79**	.50
	I3	3.87	1.26	−20.43	.84**	.56
	I4	4.04	1.27	−19.64	.78**	.59
	I5	4.48	1.13	−19.18	.77**	.64
	I6	3.99	1.26	−19.41	.82**	.62
	I7	3.90	1.39	−18.20	.81**	.67
Social interaction	S1	*3.29*	1.43	−16.62	.86**	*.19*
	S2	3.74	1.28	−17.28	.87**	*.20*
	S3	4.15	1.24	−19.07	.79**	*.26*
	S4	*3.21*	1.43	−19.18	.85**	*.14*
	S5	*3.14*	1.39	−19.56	.84**	*.16*
	S6	*3.12*	1.40	−19.44	.77**	*.25*
Knowledge improvement	K1	5.11	1.01–16.71	.67**	.57	
	K2	5.20	1.01–16.59	.82**	.69	
	K3	4.98	1.11	−15.51	.74**	.65
	K4	5.02	1.04	−18.43	.77**	.65
	K5	5.05	1.03	−20.01	.72**	.64
All scale		4.57	0.67	–	–	–

* $p < 0.05$.
** $p < 0.01$.

each factor. Factor loadings of the items ranged from 0.45 to 0.89. Although all loadings were > 0.4, some items either did not load with the expected factor dimension or loaded simultaneously in two dimensions. This problem was resolved by omitting some of the problematic items and re-categorizing the dimensions identified. Thus, 48 items remained after these measures were adopted (Table 4).

Another factor analysis was conducted on the modified scale (42 items). The results yielded KMO = 0.87and BT = 7088.42 ($p < 0.01$). Using an eigenvalue >1.0 and factor loading >0.4 as breakpoints, nine factors were extracted with eigenvalues at 5.47, 5.08, 4.73, 3.93, 3.78, 3.76, 3.49, 3.03, and 2.35. Together, these nine factors explained 74.29% of the total variance in the learner's enjoyment of e-learning games. Individually, the nine factors explained 11.41, 10.58, 9.85, 8.20, 7.88, 7.83, 7.28, 6.31, and 4.91% of the total variance (Table 4). Aside from the control factor, which was divided into two factors, autonomy and self-initiation, the remaining factor dimensions perfectly fit the design of the original scale.

This study employed a visual analogue scale between 0 and 100 to allow player's to rank their "overall sense of enjoyment." Pearson's product-moment correlation between the criteria, the eight sub-scales, and the overall scale were used to test the scale's criterion-related validity. Accordingly, the correlation between the score of the overall scale and the criteria was determined to be 0.54 ($p < 0.01$). In other words, the better the learner's experience with game-playing, the higher his or her overall enjoyment. The correlation between the eight sub-scales and the criteria was 0.35, 0.14, 0.32, 0.40, 0.30, 0.54, 0.25, and 0.49, respectively. The relationship between the criteria and all sub-scales, with the exception of factor 2 (goal clarity), was significant ($p < 0.01$).

Correlations between the eight sub-scales and the overall scale were 0.62, 0.51, 0.66, 0.81, 0.70, 0.74, 0.44, and 0.72, respectively. All of the relationships were significant ($p < 0.01$), supporting the scale's convergent validity. All but five correlations between the sub-scales proved to be significant ($p < 0.01$); correlations between the eight sub-scales and the overall scale were almost unanimously higher than correlations between the sub-scales themselves. Based on these two observations, the scales clearly demonstrated acceptable divergent validity.

4.4. Scale reliability

Cronbach's alpha was 0.942 for the 42 items as a group and >0.8 for each separate dimension, showing that the scale developed by this study had high internal consistency and reliability (Table 4).

The reliability of the test-retest was evaluated in the pre-test stage; the scale's ICC was measured from the 52 valid samples in the pre-test and the 39 samples in the second test. The results showed that the ICC between the overall scale and each sub-scale was, respectively, 0.63, 0.54, 0.65, 0.60, 0.61, 0.46, 0.50, 0.49, and 0.43, with statistical significance ($p < 0.01$) in each case. Thus, it was concluded that the scale demonstrated good test-retest reliability.

5. Summary and application

Whether or not a game offers enjoyment to the player is a key factor in determining whether the player will become involved and continue to learn through the game. In other words, ideally, the learner, prompted by self-motivation factors, will want to devote his or her time to enjoying the e-learning game offered by an academic course, thus reaching the ultimate goal of learning achievement.

In order to precisely and effectively evaluate the learner's cognition of enjoyment during the playing of e-learning games, survey is an effective method to measure large amounts of subjective opinions. Thus a valid and reliable assessment tool for "the level of enjoyment brought to the learner by e-learning games" is needed. GameFlow Criteria is reorganized into suitable questions in this research and combined with factor of knowledge improvement to construct an appropriate and effective scale called the EGameFlow. This study used four e-learning games containing different levels of knowledge content and different game styles to test EGameFlow.

In the course of scale development, content validity, construct validity, criterion-related validity, convergent validity, and divergent validity were used as validity indicators; internal consistency reliability and test-retest reliability were established as reliability indicators. Statistical analyses showed that the scale developed in this study demonstrates high validity and reliability, which makes it an effective tool for assessing "the level of enjoyment brought to the learner by e-learning games."

The final version of the scale contains 42 items allocated into eight dimensions: (1) Concentration (6 items); (2) Goal Clarity (4 items); (3) Feedback (5 items); (4) Challenge (6 items); (5) Control (7 items); (6) Immersion (7 items); (7) Social Interaction (6 items); (8) Knowledge Improvement (7 items). Factor of knowledge improvement replaced the factor of player skills in the concept of GameFlow by Sweetser and Wyeth (2005) to better suit the goals of e-learning game development.

The survey results utilizing the EGameFlow scale can be used both as a reference for game refined and pedagogical design. EGameFlow can determine the strengths of a game in terms of user enjoyment on students' view points. Developers can compare the difference of opinion between experts and gamers. Table 5 illustrates the four games' mean and standard deviation. The mean of knowledge improvement is roughly 5 points on a 7 point scale. Game game 2 had the highest mean score at 5.42, demonstrated that game 2 was most effective at knowledge improvement. In addition, it had the lowest standard deviation (.614) showing that there are least discrepancy between the opinions of the subjects. The result surprised the researchers because game 2 used was the least technically advance out of the games. The researcher and the game developers assumed that the harder to develop game 1 was the most interesting game. The results showed otherwise. A possible explanation is that the game doesn't have clearly stated goals, which can be easily remedied. Factor of social interaction had low score across the board, mainly because the technical hurdle in developing an interactive game suitable for multiple users.

Table 5
Statistics of the games

Game Factor	Game 1 Mean (SD)	Game 2 Mean (SD)	Game 3 Mean (SD)	Game 4 Mean (SD)
Concentration	5.118 (.764)	5.225 (.612)	5.214 (1.007)	5.153 (.839)
Goal clarity	4.180 (.624)	5.360 (.624)	5.048 (1.223)	5.306 (.897)
Feedback	4.890 (.922)	4.950 (.648)	5.230 (.746)	5.149 (.845)
Challenge	4.654 (.991)	4.880 (1.070)	5.019 (1.081)	4.7638 (.822)
Autonomy	4.686 (.991)	4.880 (1.070)	5.019 (1.081)	4.764 (.822)
Immersion	4.686 (.999)	4.378 (.631)	4.651 (.784)	4.265 (.892)
Social interaction	3.163 (1.598)	3.250 (1.397)	3.365 (1.418)	2.826 (1.425)
Knowledge improvement	4.985 (.984)	5.420 (.614)	5.171 (.945)	5.055 (.832)

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Therefore using competition and collaborative pedagogic design to complement the game can complete the learning experience (Fu, Wu, and Ho, 2007).

In contrast to heuristics, using EGameFlow is an easy and economical evaluation method to survey learners who have used the educational game. This research recommends that survey can be used along with heuristics to gain an insight to the users' opinion. Future longitudinal studies conducted with EGameFlow may help researchers better understand how to improve learner's enjoyment on an educational game. Because of the lower budget of the learning games, it is impossible to spend much money for evaluation. Since the gamers are students, survey would be a much easier and economical method of measurement to help to refine the final product.

Due to the length of the survey, this study did not rank the importance of the factors behind the enjoyment of e-learning games. Future researchers are encouraged to expand the scale by evaluating the priority of each factor. This scale can also be issued to users of a wider variety of e-learning games. To increase the scale's credibility, games of higher complexity should be incorporated as references for future tests.

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