

LEARNING EFFECT EVALUATION OF AN EDUCATIONAL TOOL FOR PRODUCT-SERVICE SYSTEM DESIGN

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1. Introduction

Due to advanced commoditization of product business and serious environmental problems, it has become difficult for manufacturing companies to keep up their competitiveness while using product-oriented business models. One key to changing this situation, the concept of Product-Service Systems (PSSs) [Tukker 2006] that combine products and services to create added value, is attracting much attention (e.g. [Shimomura 2009]).

In designing a PSS, it is important to focus on the value created by the whole system composed of a combination of products and services [Meier 2010]. Therefore, the designers who will lead the manufacturing industry of the future must have a new mindset of amplifying value by providing a combination of products and services. For designers who have only learned traditional engineering, however, it is initially difficult to think in this manner. For this reason, many companies have not shifted their business models from product-oriented systems to PSS. To promote the shift to PSS providers in the manufacturing industry, educational methods or tools that enable designers to easily and effectively learn this new way of thinking are required [Shehab 2011].

Against this background, the authors have developed an educational business game named EDIPS (Edutainment for Designing Integrated Product-service Systems) [Uei 2013]. This business game is a kind of "edutainment" tool that has the advantage of effective and enjoyable learning through active thinking in a simulated business environment. Learning effects of EDIPS have been evaluated by using questionnaire in several workshops. In questionnaire research, however, it is difficult to exclude arbitrariness from the results of the evaluation that depends on expression of questions and respondents' subjectivity. Therefore, the evaluation conducted by using the questionnaire is insufficient to evaluate actual learning effects through the game-playing.

In this study, learning effect is defined as "changes in players' cognizance through the game-playing in the direction intended by the game developers." To evaluate actual learning effects of EDIPS, this paper analyses changes in players' cognizance by using test results before and after game-playing. In addition, we analyse players' activity transition during the game-playing by observing behavioural records. On the basis of the results of analysis, the actual learning effects are evaluated and discussed.

The remainder of this paper is organized as follows: Chapter 2 describes how to design a PSS and introduces the outline and characteristics of EDIPS. In chapter 3, existing study on how to evaluate learning effects of business games are presented. Chapter 4 explains contents of how to analyse changes in players' cognizance and activity transition. Chapter 5 reports on the results of the analysis, and chapter 6 discusses the learning effects and remaining issues of EDIPS based on the results of the analysis. Chapter 7 summarizes the outlook of this study.

2. Product-Service System design and its education

2.1 PSS design

PSS aims to fulfill customer needs by creating added-value by providing not only a product but also a combination of products and services [Meier 2010]. Thus, it is important for PSS designers to search for opportunities to deliver value to customers and provide appropriate services throughout the life cycle of the product that includes not only the sale but also the product's use, maintenance, and disposal [McAloone 2004]. Namely, PSS designers should consider not only value to be delivered to customers throughout the life cycle of core product but also how to realize the value by combination of product functions and service activities.

2.2 Concept of EDIPS

The authors have developed a business game named EDIPS that aims to realize effective learning of the new viewpoints mentioned in 2.1 [Uei 2013]. EDIPS is a turn-taking board game for five players (Figure 1). The model of EDIPS is based on the market in which products are sold, and services are offered. Each player assumes the role of either product provider (three players) or service provider (two players) and competes to get the most points (i.e. money) to win. During each player's turn, that player selects and conducts one action which varies according to the player's role (e.g., for product providers: production, sales, shift to PSS provider, etc.; for service providers: development, launch, shift to PSS provider, etc.). Product providers earn points when they sell their own products (three kinds: red, blue and yellow). Service providers earn points when their own four kinds of services are offered to target products. The player with the most points at the time after 90 minutes from the game start is the winner.

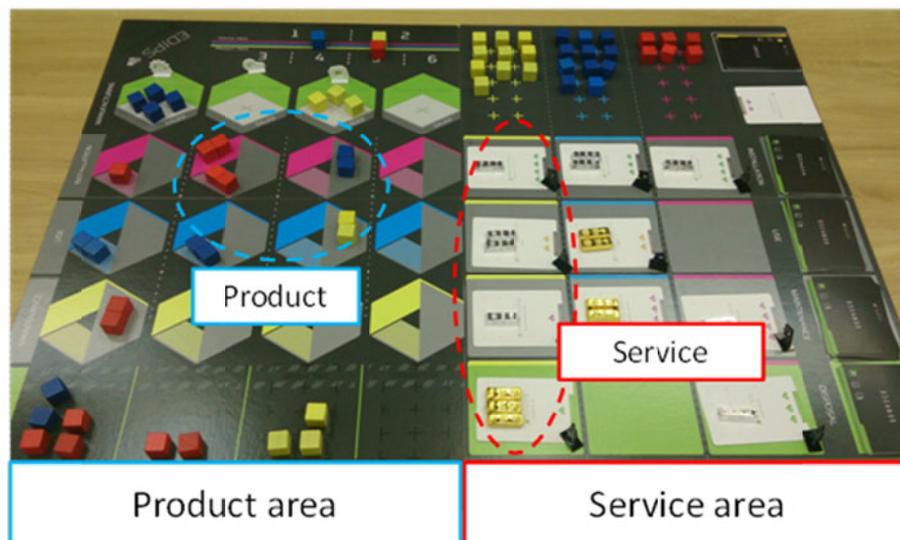


Figure 1. Game board of EDIPS

2.3 Design of EDIPS

Figure 2 shows the conceptual structures of EDIPS. The highest layer of Figure 2 indicates the educational objective of this game. More concrete learning contents to realize the educational objective are associated and deployed into sub-contents. The lowest layer of sub-contents (Figure 2: 1~4) are connected with game mechanisms to learn them (Figure 2: A~F). EDIPS was developed assuming that players learn the learning contents by playing the game [Uei 2013].

As shown in Figure 2, educational objective of EDIPS is "value amplification by combination of products and services." The learning contents are designed by deconstructing what should be learned in a phased manner based on the educational objective. Furthermore, the lowest learning contents, "(1) basic understanding of the product's life cycle," "(2) searching for services offered in each life cycle

phase," "(3) importance of cooperating with others to enhance the value of products or services," and "(4) strategy selection based on features of own product or service and circumstance," are associated with basic mechanisms of the game (e.g., "a product passes through its life-cycle phases in every turn of the game (Figure 2 A)," and "different products move in different ways through the life cycle (Figure 2 B)").

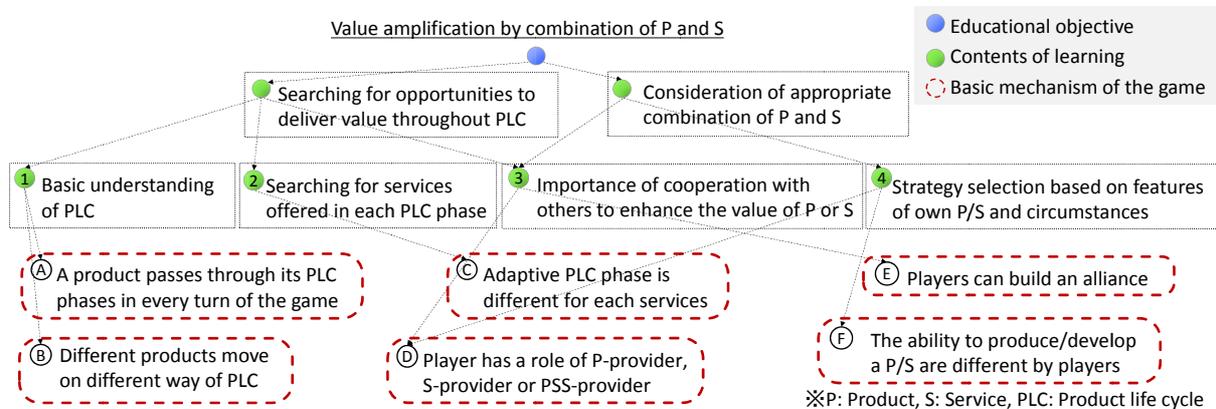


Figure 2. Learning contents and mechanisms of EDIPS

2.4 Features and expected educational benefits of EDIPS

This section mentions features of EDIPS and their expected educational benefits. There are basically two different features as follows: Feature 1, "Life cycle and service," corresponds to the basic mechanisms from A to C in Figure 2; Feature 2, "PSS provider and alliance," corresponds to the basic mechanisms from D to F in Figure 2.

2.4.1 Feature 1: Life cycle and service

The game board is divided into a product area (left side in Figure1) and a service area (right side in Figure 1). These areas represent product life cycle phases (installation, use, maintenance, and disposal) and relationships between a phase in the product's life cycle and a service provided in the phase. Sold products by product providers pass through the following life cycle phases: installation, use, maintenance, and disposal (related to Figure 2 A). Service providers can offer services to the sold products and receive points according to the phase (related to Figure 2 C). Because life cycles differ based on the type of product (e.g., a blue product has a longer period of use, as shown in Figure 3), compatibilities between a product and a service must be determined (related to Figure 2 B). In order to earn points effectively, therefore, it is important for service providers to understand appropriate opportunities to deliver value for each product and to develop a strategy to gain service share for the targeted products.

In addition, product providers who dispose of too many products must pay an ecological tax. If a reuse service is offered in the disposal phase, providers can reduce not only the number of waste products but also the cost of production (related to Figure 2 C). To win the game, it is important for product providers to take advantage of reuse services.

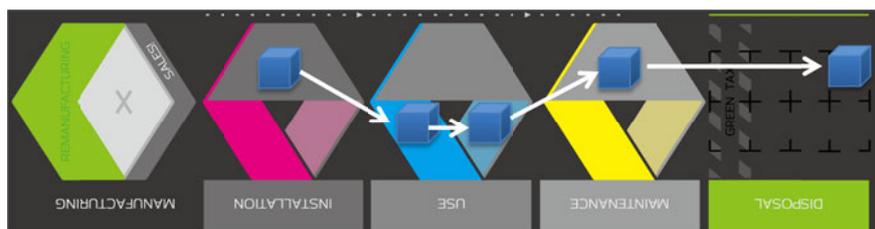


Figure 3. How a product moves through the product life cycle

From these rules, players can learn "(1) basic understanding of the product's life cycle" and "(2) searching for services offered in each life cycle phase." Also, the rules of ecological tax and product reuse help players experience the benefits of eco-friendliness, which is one important aspect of PSS.

2.4.2 Feature 2: PSS provider and alliance

In EDIPS, only one player in each game can become a PSS provider by paying a certain number of points (related to Figure 2 D). The PSS provider conducts actions of both product and service providers. The PSS provider can effectively score many points because he or she can deal in both products and services following his or her individual strategy. On the other hand, the other product provider and service provider can establish an alliance to cope with the PSS provider (related to Figure 2 E). Figure 4 illustrates this situation. Product providers and service providers in an alliance can effectively score many points as with the PSS provider by dealing in their products and services following their cooperative strategy. When and with whom players establish an alliance will be essential to winning the game.

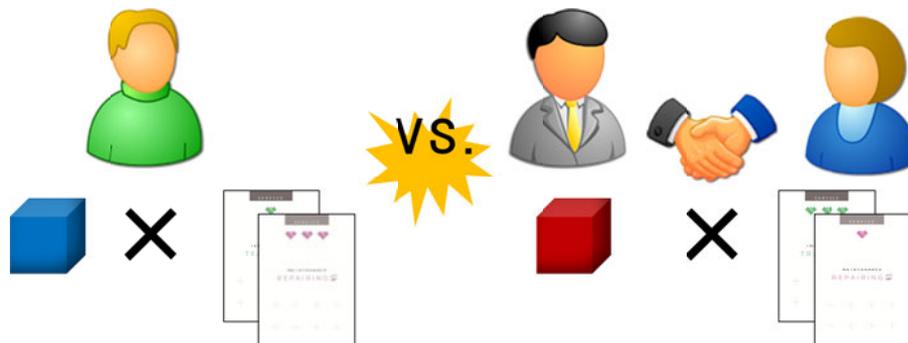


Figure 4. PSS provider and P-S alliance

To provide a valuable and effective PSS, a company needs to cooperate with various partners, such as component suppliers, an IT vendor, and public institutions. Through playing the game, players can experience decision-making in cooperation with others, and learn "(3) importance of cooperating with others to enhance the value of products or services" and "(4) strategy selection based on features of own product or service and circumstance".

3. Learning effect evaluation of business games

In education by using business games, it is difficult to evaluate learning effects only from performance in a game or players' victory or defeat. This is because players often learn something from their mistakes or defeats caused by their decision-making during game-playing as well as their good performances or victories. In other words, a player's performance in a game does not completely represent players' level of understanding. Therefore, methods to evaluate learning effects by other than performance in a game or result are required.

3.1 Analysis of changes in players' understanding

In the field of educational engineering, in order to evaluate learning effects of business games or card games for education, a pre- and post-test method has been adopted [Koshiyama 2008], [Ikejiri 2012]. In this method, the two tests composed of same question items are conducted before and after using the educational tools. Then, results of them are compared. By observing difference in results of pre- and post-test, changes in players' understanding through the game-playing can be analysed.

In some cases, players rate prepared question items on a scale of 1–5 (e.g., 1 means "cannot learn," and 5 means "can learn well."). Based on differences of the number on that scale in the pre- and post-test, changes in players' understanding can be analysed. In the other cases, players freely describe their answer for question items. Then, the descriptions are scored under certain evaluation criteria. In addition, described contents in the answer are evaluated in a qualitative manner. Based on differences of the score and the described contents in pre- and post-test, changes in players' understanding can be

analysed. For example, Ikejiri adopts a glossary constructed from learning objectives as evaluation criterion of free-answer test [Ikejiri 2012]. The score of a test is calculated by the number of terms which included in both the glossary and answer.

3.2 Analysis of players' behaviour during game-playing

Koshiyama evaluates learning effects of business game in more detail by analysing players' behaviour during game-playing [Koshiyama 2008]. In particular, transition of players' decision-makings and attentions are analysed by using behavioural data of the players (e.g., the number of watching game screen and verbal utterance among players). Moreover, causal relationship between participants' activity and changes in understanding is analysed by comparing the result of the behaviour analysis and questionnaire survey.

4. Learning effect evaluation of EDIPS

In order to evaluate learning effects of EDIPS by other than evaluating player's performance in the game and victory or defeat, pre- and post-tests are conducted in this study. In addition, players' behaviour during the game-playing is recorded. By using the results of pre- and post-tests, we analyse changes in players' cognizance. By behaviour analysis, we clarify what behaviour influences player's cognizance (i.e., factor for changes in players' cognizance). Moreover, we associate the test results with the results of behaviour analysis. This enables us to analyse changes in players' cognizance in the direction intended by the game developers and thus evaluate the actual learning effects of this game.

4.1 Pre- and post-test

To analyse changes in players' cognizance before and after the game-playing, pre- and post-tests, which are composed of same free-answer question items, are conducted. The free-answer question items are as follows:

Q1: From manufacture's point of view, what do you think are the important things in design and development of a new business?

Q2: From service provider's point of view, what do you think are the important things in design and development of a new business?

In these question items, the learning contents shown in the middle of Figure 2 are not implicated. This is to prevent respondents from reading too much into the learning contents from question items. This enables to evaluate the changes in player's cognizance purely from the game-playing.

The form of free-answer questions are adopted in these question items. Also, the question items are abstract. By answering such abstract questions, respondents are stimulated to retrace their thinking and behaviour during the game-playing. Then, by describing answer freely, honest answers based on it can be extracted from respondents.

In addition, respondents' viewpoints are divided into manufacture (Q1) and service provider (Q2). This is because there are roles of product provider and service provider in EDIPS. Therefore, by preparing viewpoints of the both of them, it is expected to prompt respondents to make themselves clear about their knowledge or experience by EDIPS.

4.2 Behavioural record during the game-playing

To analyse players' behaviour during the game-playing, the game is recorded by video camera. This enables us to observe behavioural transition concerning selection of action during the game-playing and changes in a game situation arising from players' behaviour. In addition, this enables us to observe interactions among players in both game world (e.g., competition or cooperation) and real world (e.g., communication among the players).

4.3 Procedure of learning effect analysis

In this study, learning effects are analysed by using data of the pre- and post-tests and behaviour records according to the following procedure: Step 1 is "Analysis of changes in cognizance before and

after the game-playing," and Step 2 is "Analysis of the factors of changes in cognizance by behaviour analysis".

4.3.1 Step1: Analysis of changes in cognizance before and after the game-playing

In this step, answers in pre- and post-tests are scored under evaluation criteria. The evaluation criteria are whether terms concerning learning contents (1)-(4) shown in the middle of Figure 2 are included in the answer or not. Namely, there are four criteria in this analysis. Hence, each answer is evaluated on a scale of zero to four.

In particular, several analysts read each answer, discuss and determine whether terms related to the criteria are included in the answer. The score is calculated by the number of criteria that are determined as that related terms are included in. The answers for both Q1 and Q2 are scored according to above manner. Moreover, the results of pre- and post-tests are compared. Increased score is regarded as a learning effect of EDIPS.

In addition, tendency of the contents of descriptions are analysed in a qualitative manner in order to discover some educational effects that had not been intended by the game developers.

4.3.2 Step2: Estimation of factors of changes in cognizance by behaviour analysis

On the basis of the result in Step 1, the analysts discuss and estimate what behaviour during the game-playing prompts the changes in players' cognizance. In EDIPS, it would appear that behaviour of alliance partner also effects on the learning. If player had an alliance partner, therefore, the behaviour of the partner is also analysed. According to these manners, it is found out whether the mechanisms of EDIPS works as appropriate factors of desirable learning effects. For example, if a player, who describes terms concerning learning content (3) in the answer of post test, builds an alliance during the game-playing, it can be estimated that the mechanism shown in Figure 2 E serve as a factor to learn the content.

5. Application and evaluation

To evaluate learning effects of EDIPS, several workshops were conducted in lectures at graduate school. Participants in workshops answered the pre- and post-tests mentioned in section 4.1. In addition, video camera was set in each workshop.

The participants were 16 Japanese engineering students (2 of them play the game in a pair) and divided into 3 groups. The students belongs to a department of mechanical system design. Therefore, they were acquainted with traditional engineering technology and product design, while they did not have much knowledge of PSS.

The workshops were conducted for a couple of days. In day 1, the participants first answered the pre-test (10 minutes) and then did a trial of the game (20 minutes) in order to understand rule of the game. In day 2, they played the game in full (90 minutes). After the playing, they answered the post-test (10 minutes).

5.1 Results of analysis of changes in player's cognizance

5.1.1 Example of scoring answers

In the pre-test, one player described "considering process flow around sales phase" for Q1 and "analysis of target customer" for Q2. It could be estimated that the former answer was associated with learning content (1). Therefore, the player got one point on the pre-test for Q1 because only one criterion was fulfilled. On the other hand, in the post-test, the player described "considering product life cycle where the products we sold return to our company" for Q1 and "launching our own services effectively while avoiding a competition with other companies" for Q2. It could be estimated that the former answer was related to learning content (1) and (2). Moreover, the latter answer was associated with learning content (4). Hence the player got two points on the post-test for Q1 and one point for Q2. Namely, the player's increasing score for Q1 was one and for Q2 was two.

5.1.2 Result of analysis of changes in test score

Figure 5 (a) shows scoring results of Q1 in pre- and post-test, and Figure 5 (b) indicates the results of Q2. As shown in Figure 5 (a) and (b), scoring results of both Q1 and Q2 were totally increased after the game-playing. Specifically, the number of respondents who got zero point on pre-test decreased by half in both Q1 and Q2. The average of scoring results in each test were calculated as follows: Q1 (pre-test) 0.5; Q1 (post-test) 0.9; Q2 (pre-test) 0.3 and Q2 (post-test) 0.9.

Figure 6 shows increasing rate of score for each learning content. In Figure 6, scoring results of Q1 and Q2 are counted up according to each learning content. As shown in Figure 6, the increasing rate of score for learning content (3) "importance of cooperating with others to enhance the value of products or services" was the highest, and the increasing rate for learning content (1) "basic understanding of the product's life cycle" was the lowest.

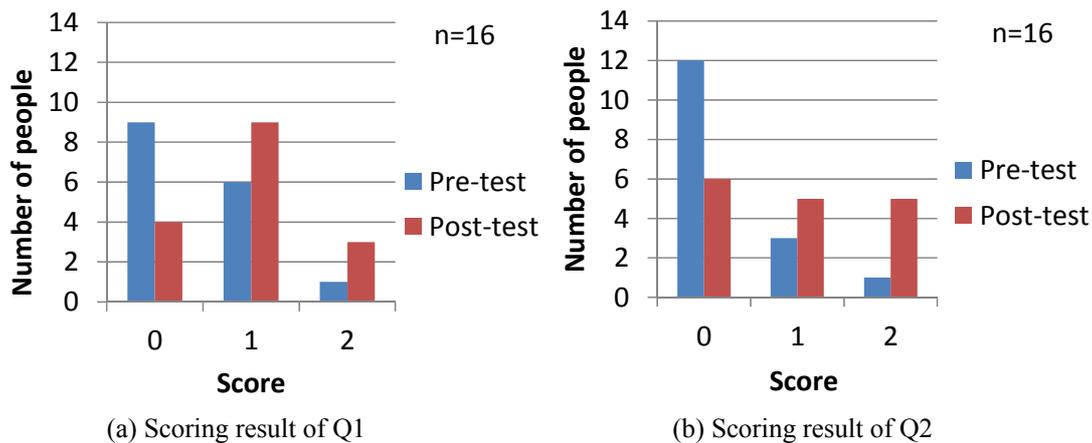


Figure 5. Scoring result of pre- and post-test

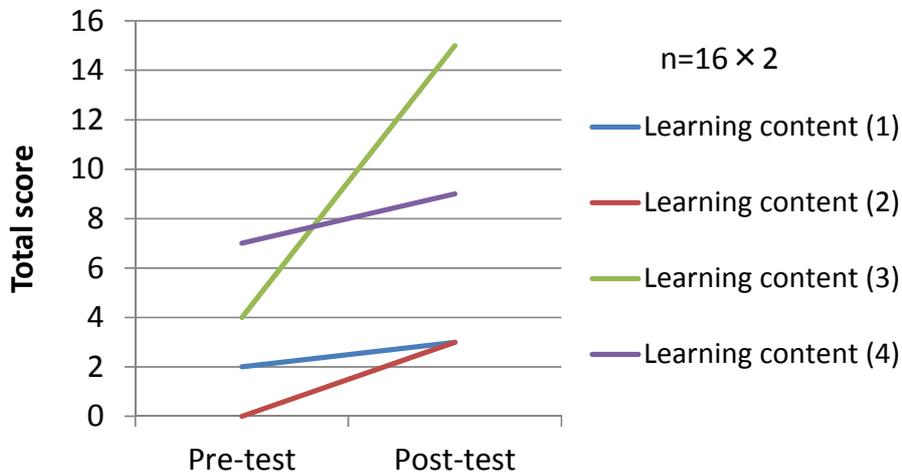


Figure 6. Increasing rate of score for each learning content

5.1.3 Results of analysis of tendency in description contents in test

In the post-test, much score concerning learning content (3) and (4) were given. In particular, there were many descriptions concerning "importance of alliance" or "strategy appropriate for own products or services".

In Q1 (manufacturing's point of view), there were many descriptions concerning "advantages of providing reuse service to own products." On the other hand, the descriptions in Q2 (service provider's point of view) often included "importance of providing appropriate service according to the types of

products." These descriptions were associated with learning content (4). However, concrete description contents differed depending on each point of view.

Focusing on the other common description in both Q1 and Q2, 12 participants wrote "needs of customer or own company" as an answer in both questions in the pre-test. On the other hand, in the post-test, we could find many descriptions "importance of compassing circumstances of competitor" or "strategy formulation in consideration of circumstances of market" (8 participants), which were not related to any learning contents (1)-(4).

5.2 Result of estimation of the factors of changes in cognizance

Focusing on the winner (Player A) in one group who was a service provider in an alliance with a product provider (Player B), he offered reuse service for the Player B's product in disposal phase in the second half of the game. This enabled Player B to reduce the number of waste products and avoid paying an ecological tax. Player B also could reduce the cost of production by reusing the waste. On the other hand, Player A also gained benefits. Player A launched his services for the products sold by Player B in use and maintenance phase. Therefore, both Player A and Player B could earn points effectively by Player B selling his reused products.

In the post-test, Player A described "specialty of a service provider in an alliance", which was associated with learning content (3) as an answer for Q1 (manufacturing's point of view). In addition, Player B mentioned "compatibility between own products and partner's services" in Q1 and "strength of alliance partner" in Q2 (service provider's point of view). However, in the pre-test, description associated with learning content (3) were not found out in the answers of both Player A and B.

From the above, it can be estimated that the players' behaviour arising from "player has a role of product provider, service provider or PSS-provider" (Figure 2 D) and "players can build an alliance" (Figure 2 E) worked as a factor for learning content (3). By conducting behaviour analysis for other players who described terms concerning learning content (3), we could found that there was a relationship between behaviour arising from Figure 2 D and Figure 2 E and the description contents in the tests.

5.3 Summary of evaluation

In section 5.1., from changes in test score, it was indicated that EDIPS has specific leaning effects. This is because the post-test mainly had higher scoring results than the pre-test as shown in Figure 5 and 6. Figure 6 indicated that learning content (3) had the highest increasing rate of scoring. On the other hand, the increasing rate of score for learning content (1) was the lowest. In addition, from tendency in description contents in the tests, it was shown that EDIPS enables players to learn "importance of compassing circumstances of competitor or market", which are not directly related to the learning content (1)-(4).

In section 5.2., from description contents in the tests and behaviour analysis, it was indicated that players who effectively combined products and services with his partner described terms concerning learning content (3).

Based on these results, it can be said that EDIPS especially enables players to learn "importance of cooperation with others to enhance the value of products or services" (learning content (3)). Moreover, we could confirm that there are some educational effects that had not been intended by the game developers. On the other hand, we could find out EDIPS has lower learning effects on "basic understanding of product life cycle" (learning content (1)).

6. Discussion

6.1 Leaning effects arising from playing a role of service provider

As shown in Figure 5, the number of respondents who got zero on Q2 (service provider's point of view) in the pre-test was 12 out of 16. By observing concrete content of description, we can guess that it was because respondents considered service business as offering consumer service (e.g., restaurant), and they did not adequately take into account business to business service (e.g., maintenance of sold products).

On the other hand, in the post-test, 6 respondents out of above 12 got a score. Moreover, average of scoring result was equal to that of Q1. The reason of this change must be that engineering students who have only learned traditional engineering could get a mindset of amplifying value by providing a combination of products and services by playing a role of service provider.

6.2 Learning effects arising from player interaction

As mentioned in section 5.3., EDIPS especially enables players to learn "importance of cooperation with others to enhance the value of products or services" (learning content (3)). It can be estimated that the behaviour arising from "player has a role of product provider, service provider or PSS-provider" (Figure 2 D) and "players can build an alliance" (Figure 2 E) is a factor for above result. In addition to this, in the game records, it was confirmed that players in alliance play EDIPS with evaluating and modifying their strategy continuously by several discussions with their partner. Such a discussion among players can be considered as a key to more effective learning of "importance of alliance." Namely, establishing an alliance (Figure 2 D and Figure 2 E) and such a discussion enhances learning effects on learning content (3).

6.3 Remaining issues

In this study, learning effects were evaluated based on the result of analysis of changes in cognizance by using the tests composed of free-answer question items and the result of behaviour analysis. However, some descriptions of the answer in the tests were not associated with behaviour during the game-playing, especially learning content (2). It may be presumed that other date, which was not analysed, also become important factors of the learning effects. This is because the above learning effect was also gained by playing the game like other learning effects. Therefore, learning effect of EDIPS should be evaluated in more detail by recording the thinking of players during the game-playing or the number of utterance and so on.

7. Conclusion and outlook

In this paper, we analysed changes in players' cognizance before and after the game-playing and factor of it by using pre- and post-test and analysing players' activity transition during the game-playing. On the basis of the results, the effectiveness of EDIPS and remaining issues concerning learning effect evaluation of EDIPS is discussed.

Future work should include acquisition of more data by increasing the number of workshops. Moreover, learning effect of EDIPS should be evaluated in more detail by analysing not only changes in cognizance or activity transition but also utterance data.

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