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Cognitive Flexibility of Students Learning with Constructivist Learning Environment Model Enhancing Cognitive Flexibility in Higher Education

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Abstract: Cognitive flexibility is an individual competency for solving complicated problems. It uses flexibility to weigh multiple alternatives in solving a problem. It also involves the capacity to adapt knowledge in other situations, which is necessary, especially in the fields that deal with complicated problems. This study was aimed to examine the learner mechanisms of the cognitive flexibility using the constructivist learning environment model at a tertiary level, in which cognitive flexibility was enhanced. The target group comprised 43 students who enrolled in the course, 410201 System Analysis and Design under computer education program during the second semester of 2010 in the at the Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University. A pre-experimental design was employed. Using the One-Shot Case Study method, followed the qualitative and quantitative data collected. The quantitative data was statistically analyzed using means and standard deviations, whereas protocol analysis and interpretation were used to analyzed the qualitative data. The findings indicated the cognitive flexibility of the learners were found in moderate level (X14.97,S.D. 2.61). Interview results revealed three stages in the learners' cognitive flexibility mechanisms, namely: (1) knowledge selection (2) knowledge deconstruction, and (3) adapted knowledge reconstruction.

Keywords: Cognitive flexibility, Knowledge selection, Knowledge deconstruction, Adapted knowledge reconstruction, Constructivist Learning Environment Model, Ill-structured problem solving

1. Introduction

Cognitive flexibility is an individual competency to solve complicated problems using flexibility to weight various alternatives. This includes adapting knowledge in other situations, for example, design information technology system and its programming especially in computer education where theories have to be practically applied. For instance, system analysis and design as well as programming, require knowledge in related theories, such as analyzing needs of users, analyzing and designing various ill-structured systems. System designing should answer the target objectives and meet the needs of users. Additionally, the knowledge acquires must be adapted for analysis and design systems in other applications.

Cognitive flexibility is in fact important for all professions. Jonassen (2004) showed that medical students need to investigate a lot of patient cases and apply cognitive flexibility with other information sources in order to treat other patients. Lacking cognitive flexibility, these students have to begin by learning the information of new patients since they are not able to apply former knowledge and adapt it for solving the problem. Cunningham (2004) found that some education

students who passed professional training and gained experience from an institution were not able to apply learned concepts to actual classroom instruction. The problem is a lack of competency in solving complicated problems, where solutions lead to impact on other issues, requiring consideration of related contexts or flexibility in selecting from multiple alternatives—the so-called cognitive flexibility. Research reports have indicated that cognitive flexibility is composed of case-based learning, which supports the 5 principles of Spiro and Jacobson's cognitive flexibility, namely: (1) Substituting multiplicity of knowledge for comprehensive thought, (2) Connecting concrete concepts with different cases, (3) Having complex boundaries, (4) Emphasizing links to various websites, and (5) Enhancing compilation of knowledge. Besides, the principle of Case-based Reasoning (CBR) of Aamodt & Plaza was applied in the design and development of teaching media (Schmidt and Boncella, 2007) to encourage knowledge acquisition at an advanced level. Here, problem solution is based on construction of a Hypertext Learning Environment designed by the theory of cognitive flexibility (Jonassen, 1992).

Moreover, efficiency of cognitive process using media upon the learners depends on the media attribution and symbol system. The twos enhance cognitive flexibility include the web-based learning environment in which the principle of cognitive flexibility integrates with hyperlink, hypertext and hypermedia (Chaijaroen, 2004; Kozma, 1991), hence multi-dimensional and crisscrossing connections. These characteristics support cognitive process to solve problems with complicated connections; such as problems in one system may lead to negative impacts on another system.

With these reasons, the research on enhancement of the cognitive flexibility aimed for computer education learners, especially in system analysis and design is necessary. Learners should be able to adapt their knowledge in solving other problems and create new operation models which are important to operations and professional development.

2. Purpose of the study

To examine the mechanism of cognitive flexibility of learners learning with the constructivist learning environments in higher education.

3. Cognitive flexibility

Cognitive flexibility refers to the ability of learner to solve complicated problems. The mechanism of its consists of 3 stage as following: Knowledge selection – learners selected to use prior knowledge by retrieving it. Knowledge deconstruction — each of selected prior knowledge as the theories and cases, is deconstruction into piece of knowledge. Adapted knowledge reconstruction – learners adapt and reconstruction their knowledge by linking with the new situationalproblem. If the knowledge can be readily applied in the new situation confronted or if they need to adapt and reconstruct the knowledge in order to solve another complicate problem solution.

4. Research methodology

4.1 Research design

The one-shot case study method was used in this research, emphasized on qualitative data collection.

4.2 The Target Group

The target group was consisted of 43 second-year undergraduate students in Computer education who enrolled in the course 410201 System Analysis and Design under computer education program

during the second semester of 2010 at the Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University.

4.3 Research Instruments

The research instruments used in this study consisted of the following:

1) The constructivist learning environment model enhancing cognitive flexibility.

2) A cognitive flexibility test form constructed by researchers based on Spiro and Jehng's (1990) concept of cognitive flexibility.

3) Interview form of cognitive flexibility to conduct with learners. This unstructured interview was used in the in-depth interview.

5. Data Collection and Analysis

The researchers collected information and analyzed it through the following steps:

1) Dividing learners into small groups of 3-4 students; introducing them on how to learn with the constructivist learning environment model, where the topic was "the design of context and data flow diagrams".

2) Introducing to the lesson by linking prior knowledge of learners to the topic, "the design of context and data flow diagrams".

3) The learners learned with the constructivist learning environment model by studying a problem situation. This component is called the cognitive building center. They then attempted to find solutions or answers by learning components in the environment model called the cognitive bank. Scaffolding and coaching were called as the system analysis community. Collaboration in problem solving was called a specialist's clinic. For similar cases, learners applied cognitive tools to find the answers and may study in the cognitive flexibility enhancement room.

During the lesson, learners cooperated to search solutions and share cognition in order to determine and summarize the solution according to the learning tasks. The teacher performed as a coach, encouraging, advising, supporting and activating learners to develop their cognitive flexibility. The study was conducted twice, 4 hours each session.

4) The teacher and the students concluded the learning concept together at the end of each period.

5) The cognitive flexibility test was administrated. The researchers interviewed them regarding the mechanisms of cognitive flexibility. The data obtained from the cognitive flexibility test was analyzed using descriptive statistics, i.e., percentages, means ( ), and standard deviations (S.D.). The qualitative data obtained from the interview was analyzed via the protocol analysis and interpretation.

6. Result

The study showed that the cognitive flexibility of the learner measure by the test was =14.97, S.D.= 2.61. This indicated that the learners' cognitive flexibility was in moderate level. Furthermore, the qualitative data revealed that there are two folds of findings: a) three stages of the cognitive flexibility b) three types of cognitive flexibility as following:

6.1 Three stages of the cognitive flexibility

Three stages of the cognitive flexibility revealed as follows:

Knowledge selection – It showed that learners selected prior knowledge regarding system analysis and design by retrieving it. They were found to be able to retrieve prior knowledge by stating and describing what they learned before. They could select the symbols for analyzing and precisely designing operating system in a context and data-flow diagrams as in a real system. They

could explain in details regarding how tables are used for data storage; what kinds of data are related, how much data is there on one table that are related; how many tables are there in one database; and how they are related. The learners could use their prior knowledge to design some parts of an operating system. But they could not design and analyze the whole system, as in the System Analysis and Design course, in which the processes of a system have to correspond to each other. The system design was done by analyzing the system process and then they designed the context diagram according to the principle and theories (Yourdon,1989; Gane and Sarson,1979). Then the symbols for the design of an operating system were to be selected. The evident procedures conducted by learners are as follows: the learners decided in their group what symbols they would use to analyze and design context and data flow diagrams. They compared the symbols with ones already learned from the Database system course in which symbols are used to design a database. This was put into an Entity-Relationship Diagram. Then the difference between the two sets of symbols was compared and a decision was made. Some learners reported, the empirical evidence were shown as following the interviewed data:

"Before thinking and analyzing to design the context diagram and the data flow chart, we needed to study the component called cognitive bank in order to investigate the symbols for designing the contextual diagram and the data flow diagram."

"The difference between the two systems was in process symbols. Storage symbols also differ, but only slightly."

This was evident when learners could name the system learned both from the System Analysis and Design course and the Database System course that aims at database design. That is Knowledge selection in the first stage of cognitive flexibility.

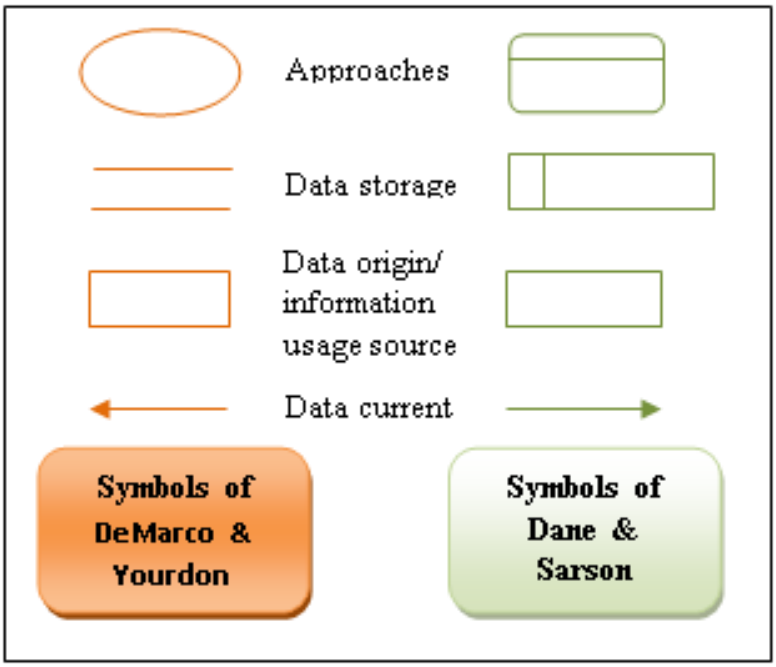

Figure 1. Comparison of symbols used in diagram design between Yourdon's and Gane and Sarson's

Knowledge deconstruction – It showed that the learners were able to deconstruct their thinking and drafted an outline of the context and data flow diagrams, which could be seen from the evidence stated above. The learners were able to think together in their group to deconstruct the major process of work in each system, which differs from one another. The thinking process involves reasoning and retrieving of information from the resource called a cognitive bank and from using cognitive tools to study the software to be used in the decomposition diagram, context diagram and

the data flow-chart diagram. The decomposition diagram was thus exemplified for using in different operating systems. The empirical evidence was illustrated in Figure 2, showing evidence of learners' outlining of the decomposition diagram.

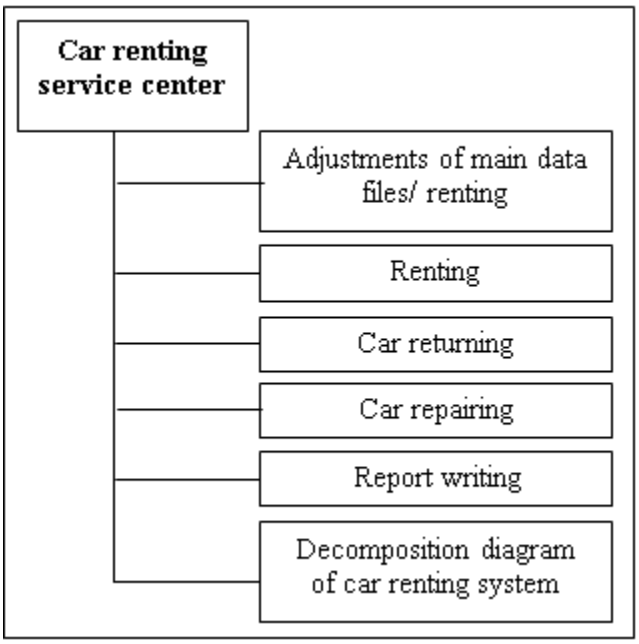

Figure 2. The learners' drafting of the decomposition diagram for a car-renting system

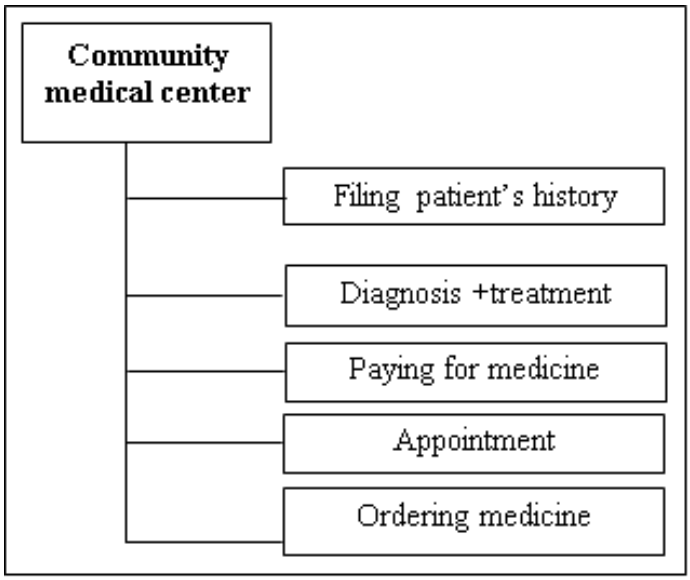

Figure 3. The learners' drafting of the decomposition diagram for a people's library

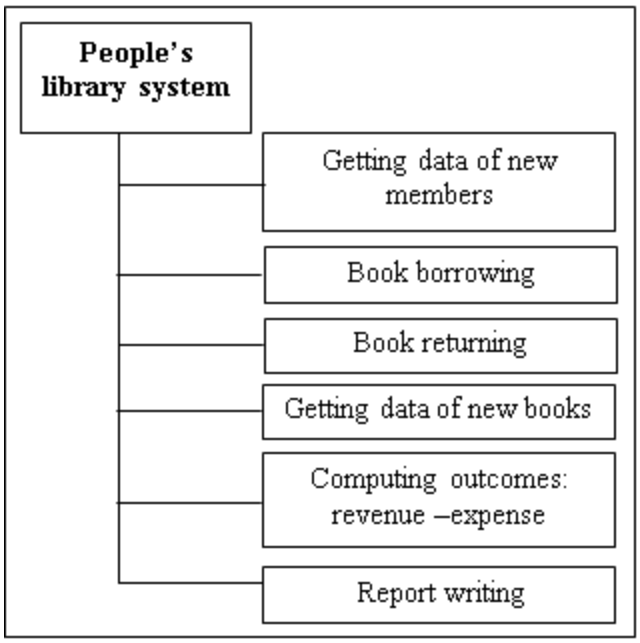

Figure 4. The learners' drafting of the decomposition diagram for a community medical center

Adapted knowledge reconstruction – It showed that learners were able to adapt their knowledge and relate it to the new situational problem. Whenever relationship exists, the knowledge can be used to solve the problem in a new situation. However, learners had to consider whether reconstruction was required. If they are able to reconstruct the knowledge in various ways, then it proves that learners are competent in developing cognitive flexibility. This is depicted in Table4, the analysis and design of a car renting system in a contextual diagram, and Figure 5, the flow chart of the car renting system.

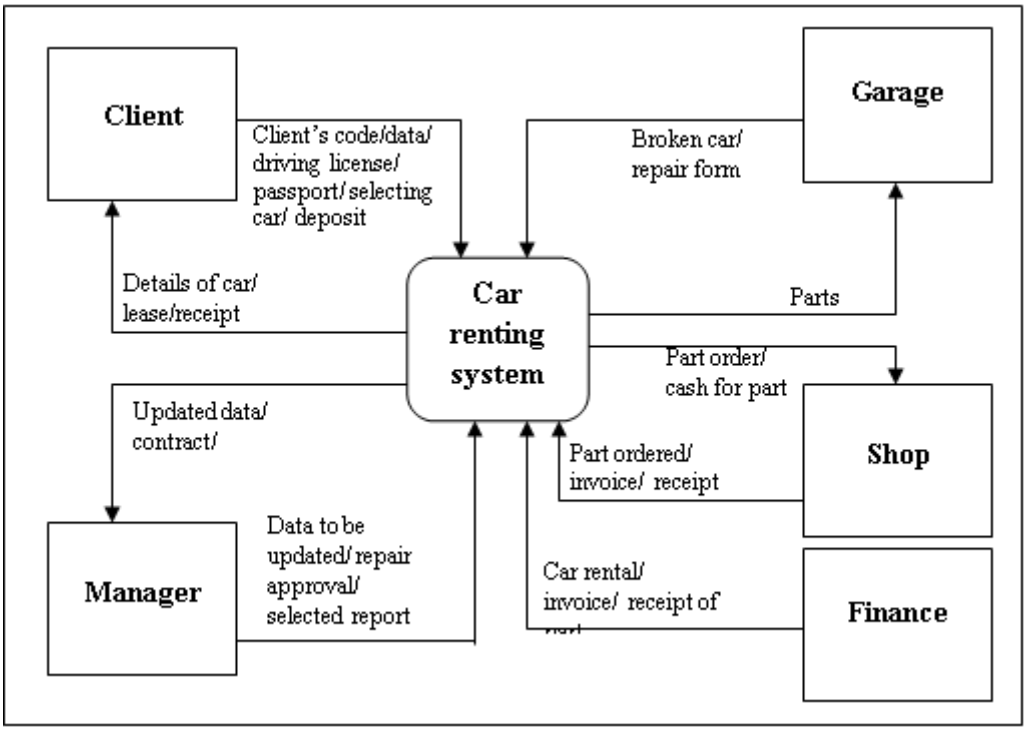

Figure 5. Designing the contextual diagram for a car renting system

However, reconstruction was to be carried out in order to create knowledge in the design of data flow that was truly suitable for the car renting business. The adaptation was done by adding the external entity symbol for officers in the system. Learners in this respect adapted and applied it in their construction of a flow diagram in the new context, as shown in Figure 6.

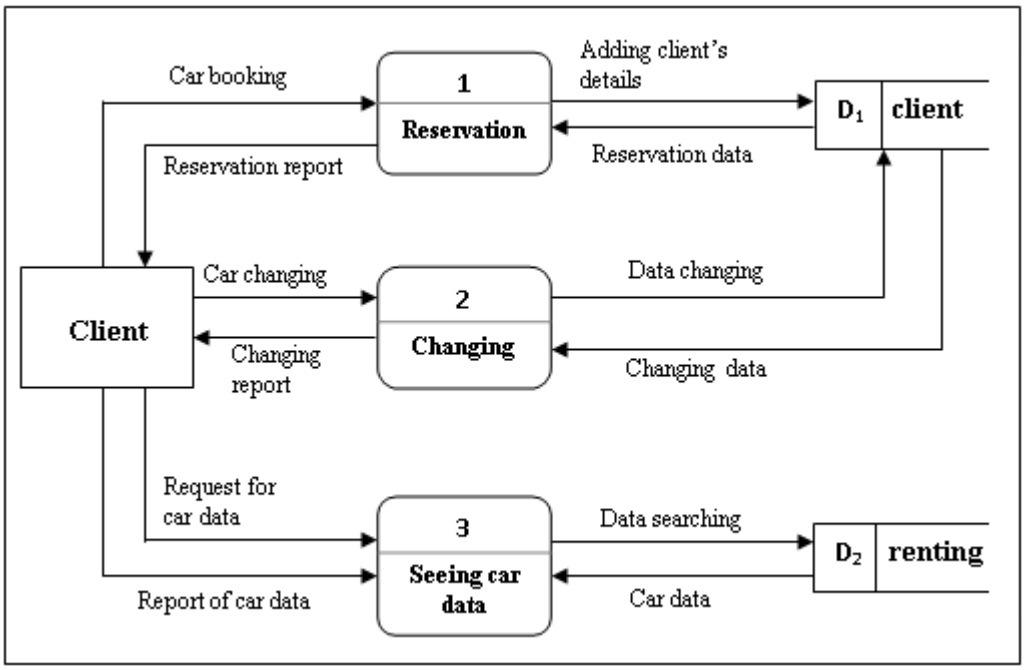

Figure 6. Designing data flow diagram in the context of a car renting system

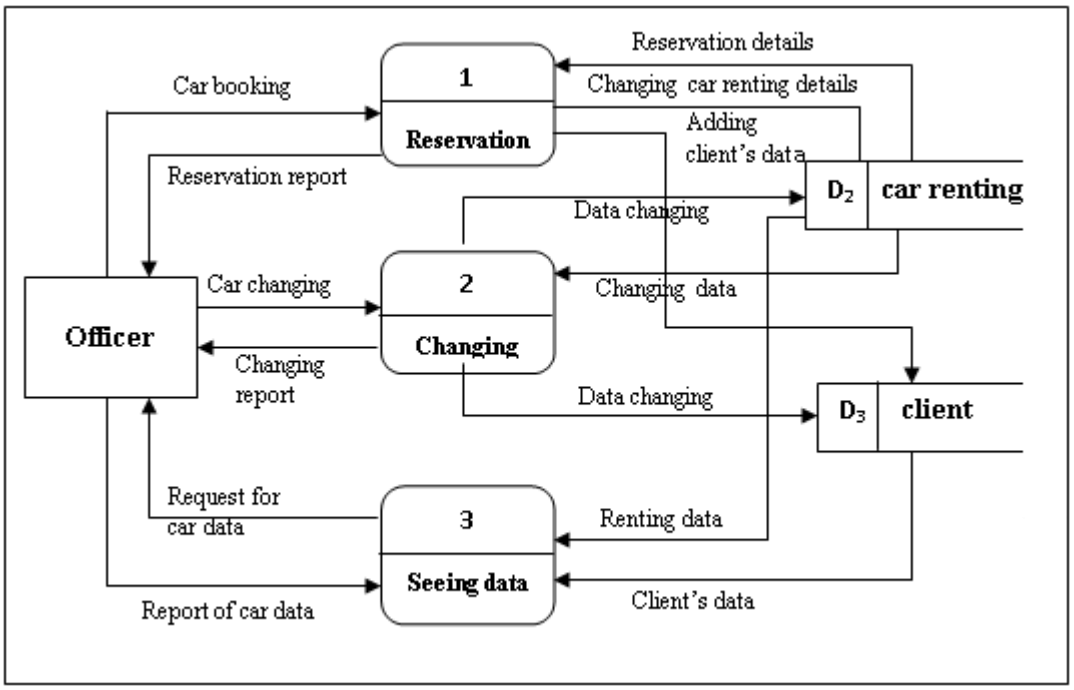

Figure 7. Designing a data flow diagram in the car renting system reconstructed by the learners and creating a new data flow diagram in the new context

6.2 Three types of the cognitive flexibility

Type 1–the learners of this type reach a low level of cognitive flexibility. Learners having the first type of cognitive flexibility recall prior knowledge and compare and contrast the former with the new items. However, type 1 cognitive flexibility is in fact at a low level the only little adaptation is performed. Moreover, learners spent a long time in the adaptation of knowledge to the new situation.

Evidence can be shown from the following interviewing results:

"The solution of car renting problems is like that of renting a dormitory in front of the campus. There are more similar operation processes than with other systems."

"I thought it was similar to renting a dormitory because I compared both the major process, which is renting, and the related external entity in renting which is the client. The components for system design therefore comprise the process and the external entity. From the principle of system design, there must be a similar process, that is, the external entity. Therefore, we compared this before taking into account other systems."

"The reason for choosing dormitory renting was because of the project given in the previous semester of the Database System course. I had to design the database for dormitory renting involving the renting process and setting rental fees. That's why we chose to compare dormitory renting and car renting."

Type 2–Learners of this type reach a moderate level of cognitive flexibility. They possess knowledge or experience related to the problem (Problem domain). They know how to analyze and design the contextual diagram and flow diagram of the data. Their cognitive flexibility corresponds to Spiro and Jehng's theory (1990). However, the required thinking time is not long enough for individuals to adapt the knowledge in a new situation.

The empirical evidences were illustrated as following: "After comparing the two systems, we had to deconstruct the main system process; that is, renting. This had to be deconstructed into sub-processes. If it is renting play stations, then there are also rental cancelations. Prior knowledge in borrowing and returning books at the people's library can be used. The knowledge in renting a play station can be adapted to borrowing books. The step in renting a play station may involve paying overdue fines. The borrowing process may be different. For renting a play station, no membership is required. You only have to deposit an amount, but you get it back when the machine is returned. For borrowing a book from the people's library, you need to be a member first."

Type 3–Learners proved that they used cognitive flexibility according to Spiro and Jehng's framework (1990). They selected the prior knowledge, then deconstructed and adapted the knowledge to a new problem situation.

The empirical evidence was illustrated by the following interview result: "The deconstructed items were considered and the suitable one was selected for problem solving. For the library system, the items were related and the problem could be solved."

"When we solved the people's library problem, some items were readily usable. Some had to be adapted. For example, we changed from renting play stations to borrowing books in the library. The problems at the library had to be linked through consideration of relationships between components, which were related by information. For example, the information used in process computation is the input which can be derived from external entity, data store or from other processes. The process outcome becomes the process output to be transferred to an external entity, data store, or other processes. For example, for overdue fines, the information is the number of days overdue. The outcome is the fine for the member. When all obtained components are considered, flow data linking is completed."

7. Discussion

The research results showed that the learners were able to solve complex problems applying 3 steps of cognitive flexibility, namely: 1) knowledge selection, 2) knowledge deconstruction, and 3) adapted knowledge reconstruction in order to appropriately apply problem solving solutions in different context. This corresponds to the mechanism of cognitive flexibility defined by Spiro and Jehng (1990). The findings could result from the web-based learning environment model where

problematic situations were designed and called cognitive building, which enhances cognitive flexibility in solving learning problem in 3 steps (Spiro and Jehng, 1990). This help proving opportunity for learners to train how to apply cognitive flexibility to solve problems, sharpening their competence in solving complex problems in other situations.

As for level of cognitive flexibility of the learners were revealed from low level to high level.

Type 1 cognitive flexibility is in fact at a low level. While cognitive flexibility is in accordance with the framework of Spiro and Jehng (1990), only little adaptation is made. Moreover, learners spent a long time in the adaption of knowledge to the new situation. They also had to study more from learning resources and related cases in order to be able to better apply the adapted knowledge. In short, learners require a lengthy period of time to think.

After that they adapted the prior knowledge that they had to solve the new situation problem for renting play stations. As for this type the learners spent a long time in the adaption of knowledge to the new situation. Since only little adaptation of knowledge was performed. They tried to search more information and learn more from the cognitive bank and cognitive flexibility enhancement room for related case. In contrast, Type 1 cognitive flexibility of the learners revealed 3 stages as selected the prior knowledge, then deconstructed and adapted the knowledge to a new problem situation. ตรงนี้

This can be illustrated that the constructivist learning environments help proving information and how to solve the complex problem in other situations for learners in the adapted knowledge reconstruction

This proved that learners were able to adapt their knowledge to new situations many times. They can repeat the process if the reconstruction still does not suit the problems in the new problem. They also took less time to think and adapt and were able to give appropriate reasons. Little time was spent on studying related cases and making alterations.

This correspondent with Spiro'theory of cognitive flexibility that describing on adapted knowledge reconstruction. However, in this study showed mechanism of cognitive flexibility of the learners that they used during the process of learning. Consideration with the three stages, it was seen an operation of them. For example, the adapted knowledge reconstruction stage: the learners had compared the prior knowlege (between borrowing and returning books at the people's library) and(renting play stations) and the new situational problem and then deconstructed into sub-processes.

This can be illustrated how the cognitive flexibility operate functionally. This finding may be beneficial for instructional designer to apply to design learning environment enhancing mechanism of cognitive flexibility.

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