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Development and Application of Failure-Based Learning Conceptual Model for Construction Education

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Abstract: ***Recent demands from construction industry have emphasized the capability for graduates to have improved skills both technical and non-technical such as problem solving, interpersonal communication. To satisfy these demands, problem-based learning that is an instructional method characterized by the use of real world problem has been adopted and has proven its effectiveness various disciplines. However, in spite of the importance of field senses and dealing with real problem, construction engineering education has generally focused on traditional lecture-oriented course. In order to improve limitations of current construction education and to satisfy recent demands from construction industry, this paper proposes a new educational approach that is Failure-Based Learning for using combination of the procedural characteristics of the problem-based learning theory in construction technology education utilizing failure information that has the educational value in the construction area by reinterpreting characteristics of construction industry and construction failure information. The major results of this study are summarized as follows. 1) Educational effect of problem-based learning methodology and limitation of application in construction area 2) The educational value of the information on construction failure and limitation in application of the information in construction sector 3) Anticipated effect from application of the failure-based learning 4) Development and application of the failure-based learning conceptual model***

Keywords: Failure-Based Learning; Problem-Based Learning; Construction Failures; Education

I. INTRODUCTION

Nowadays, in the information age of the 21C and the rapidly changing industry circumstances, it is hard to stay competitive only using the knowledge learned in the past. Following the change, construction companies are demanding that graduates should know how to get up-to-date knowledge, apply to solve the problem, and be able to work together (Bernold 2005).

However, the most curriculums in Korea focus on delivering knowledge such as introduction of simple methods of construction, procedure of construction, and matters to be attended to concerning construction technologies. In this situation, it seems that the conventional instructional model usually adopted by most construction engineering education does not meet the demands of 21st-century as it may foster neither the effective, integrative learning of knowledge nor the development of the professional skills and attitudes that may assist in the future engineer's practice, such as autonomous and life-long learning, critical thinking, initiative, creativity, team working skills theory-referenced practice, etc (Luis 2005). Also, former construction education dose not expose to the various related professions and to actual construction as part of academic program.

One of the alternative pedagogical approaches is problem-based learning that is an instructional method characterized by the use of real world problem has been adopted and has proven its effectiveness various disciplines (Johnson 1979, Hmelo 1998, Shon 2008).

In order to improve limitations of current construction education and to satisfy recent demands from construction industry, this paper proposes a new educational approach that is Failure-Based Learning for using combination of the procedural characteristics of the problem-based learning theory in construction technology education utilizing failure information that has the educational value in the construction area by reinterpreting characteristics of construction industry and construction failure information.

II. PROBLEM-BASED LEARNING

Problem-Based Learning is a educational method that was developed by Professor Barrows (2000) in the medical schools in the nineteen seventies. The development background of Problem-Based Learning is to solve the difficulty in diagnosing the patients' conditions for the medical school students who have finished the official education. Problem-Based Learning has been adopted and has proven its effectiveness various disciplines such as engineering, business administration, education, and law as well as medicine (Duch 2001), and it also can cultivate various skills that are not often fostered in the traditional education.

The effect of problem-based learning is developed by the feature of the problem and distinctive process to solve the problem.

Frist, Problem-based learning is initiated by a problem, which are ill-structured and dealing with real-life (Duch 1996). In contrast with the traditional learning process use the problem after introducing contents. Ill-structured

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problem does not contain enough information for solving the problem and has a variety of solution. Jonassen (1997) argued that the feature of ill-structure is a process of structuring argument to seek the solution, and set up a principle and hypothesis.

Second, ill-structured problems should be so complicated as to solve it through working in teams (Jang 2006). That is to say, it helps learner grasp mutual relationship through the process of problem-solving and enlarges their experience. However, complexity of the problem is not simply formed a work responsibility and learner should discuss and synthesize the studied information, then, make a result (Jang 2006).

Third, The realism of problem used in Problem-Based Learning bring the interests and motivation for the learners to solve the problem and also provides the opportunity to apply the knowledge in the actual practical situation as if they are the person directly involved in the problem(Choi 2005). For these reasons, problem-based learning emphasizes to use real problem (Gallagher and Stepien 1995). Through solving the realistic problem, learners understand the situation which has to resolve and feel that problem-solving is associated with own experience (Dunlap 2005).

However, development of problems which are relevant to the characteristics of PBL was necessary for successful conduct of PBL and it is still difficult to develop PBL problems since each phase of problem development and the difficulties confronted by teachers were not specifically explained through researches and documents even though there had been many preceding researches in the past.

In addition, in case of the construction sector, verification of effect in PBL application was mainly dealt with and the areas of application were focused on the planning - such as designing, structure and construction management - which precedes construction in the field (McIntyre 2002, Chau 2007, Quinn 2008, Jose 2010).

In other words, it was observed that while education which can help understand the causes for failures that occur during the construction phase or after the completion of construction and reflect them in advance during the planning phase is necessary, but the corresponding approach has not yet been tackled.

III. Failure-Based Learning

A. Necessity

A comprehensive definition of "failure" is the following; “an unacceptable difference between expected and observed performance (Leonards 1982).” Afterwards, many researchers defined failure like TABLE 1.

TABLE 1.
Definitions of Failure

Researcher	Definition
Horns (1985)	□ The act of falling short, being deficient, or lacking □unattainment or nonsuccess □ nonperformance, neglect, omission □ bankruptcy □ loss of vigor or strength
Janney (1986)	□ structural failure: the reduction of capability of structural system or component to such a degree that it cannot perform safely its intended purpose □ construction failure: a failure that occurs during construction and they are considered to be either a collapse, or distress, of a structural system
Kaminetzky (1991)	□ A human act: omission of occurrence or performance; lack of success; nonperformance; insufficiency; loss of strength; and cessation of proper functioning or performance

Such construction failures have complex forms caused by various reasons not by a simple technical reason. Therefore, the failures have very ill-structured characteristics. Besides, researches about the basic causes of various failures were conducted. FitzSimon (1985) indicated that 90% of construction failures are caused by the errors in the process, not by lack of technical information. In addition, Andi (2005) addressed that construction failures are practically caused by technical factors, however, the fundamental reasons causing the failures were involved with management, organization and human factors.

These reasons are driven form characteristics of construction industry. For example, a single construction project is massive size, and needs long period and heavy cost. Also the completed buildings are used for long periods. The labor-intensive way is applied in the field to complete the construction. Materials used in the construction industry are affected by the environmental factors such as weather, season, and climate. And effect of the environment varied by physical characteristics of the material. Participants in the construction project are also various and have complexity in that they participate the project with different interests and in different areas and time (Douglas 2007). The problems in management are caused by misunderstanding or overlooking the interconnections among the various factors of construction industry.

Success of project could be completed in the shortest possible time and for the least initial cost by reducing project uncertainty and potential failure factor through design and plan. The construction failures were viewed from the point of risk in the FIGURE 1.

Therefore, it is demanded to understand the complex mechanism of failure in the construction step to prevent the failure in the planning or designing step. Unlike the other engineering, construction manages complex factors to prevent failures by understanding the relationship among various techniques, materials, and natural phenomena rather than develops new products with the application of the theory. As failures occur when the relationship among complex factors are not considered, education with the information of failure in construction is demanded. However, as discussed chapter II, there are few examples about problem-based learning applied to the construction technology education with information of failures. Problem-based learning application in the construction is concentrated only on the structure and planning.

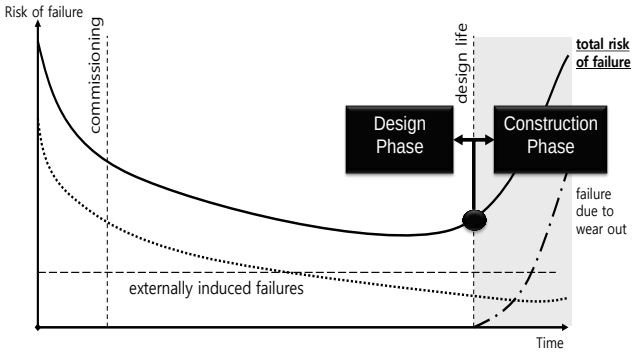

FIGURE 1
THE RELATIONSHIP BETWEEN TIME AND RISK
(SOURCE: ADAPTED FROM GRAHAM(2010), FIGURE 8.1)

Therefore, it is necessary to attempt to apply practical failures occurred in the field to problem-based learning problems. For these reasons, the purpose of this study is to suggest the failure-based learning - which is combination of the procedural characteristics of the problem-based learning theory which has been developed in other area and the information on construction failures that has the educational value in the construction area - for the purpose of resolving limitation of the current construction education.

B. Effectiveness

Education is an essential component of any failure mitigation strategy (Carper 1997). The information of failure would be a valuable supplement in education by giving a chance to integrate failures in the practical experience with the technical theories. However, as a result of the review of preceding researches, to understand the educational values of the information on construction failures, on the forensic engineering which is the typical sector that utilizes construction failures, it was revealed that such researches were chiefly focused on the structure sections (Bosela 1993, Oswald 1993). Although many researchers and site personnel realize that information of construction failure is worth as educational materials and they have developed courses in failure analysis, few civil engineering undergraduates are able to take advantage of them (Delatte 2000, Prevatt 2010). Also, as a result of the review of preceding researches on general construction failures about latent defects, reworks that occurred during construction and occupancy phase, only necessity of education and feedback about failure information has been emphasized except of suggestion of alternative measures (Chong 2006, Love 2008).

Meanwhile, the most curriculums in Korea focus on delivering knowledge such as introduction of simple methods of construction, procedure of construction, and matters to be attended to.

The characteristic of construction industry might cause the reason why lecturing-style education which does not reflect field application is performing. Construction not only takes long periods to complete the product in the field, but also is on-site industry which requires a large scale of equipment, materials and labor. As experiments and practical training in construction education is limited in this reason, the education is performed by lecture-style and on-the-spot study. New employees in the construction industry should perform works in the each step of construction process and should know complex relationship among various factors in the construction field to prevent failure. However, training new employees by delivering knowledge not reflecting prosperities of the field such as introduction of methods or procedure of construction does not clarify how failure, defects, and negligent accident are related with procedure, methods, and material.

To solve limitations of construction education and provide new employees satisfied with demands from industry at the same time, application of failure-based learning which uses failure information as problem-based learning's problems in the education of construction is effective like below.

First, students become interested in the education through construction failure information actually happened.

Second, student will have a chance to have complex consideration about the relationship causing the failure among the theories which are learned or will be learned.

Third, students will feel sympathy with appropriateness for solving problems by the education dealing with examples of failure in the actual field. Also they will feel that solving problems is related with their experiences.

Consequently, students will experience professional's thinking about the contents in the curriculum through solving practical problems. Furthermore, they will understand the professional positions related with the knowledge.

As society is converted to the knowledge-based economy, the importance of knowledge management which forms the basis of competition in business is getting emphasized. Recognition of importance of knowledge management in construction industry is getting increased. Currently various Knowledge Management Systems are introduced and applied in the construction industry.

The reason why the Knowledge Management Systems are required in the construction industry is considered through the characteristics of the construction industry of following two researchers. First, Jung (2001) addressed that knowledge in the field is buried once the project is completed. And Graham (2010) indicated that construction firms have low profitability compared to other sectors because empirical knowledge which is learned by performing the project stays with the individual, rather than being captured by the firms.

Construction firms are introducing various knowledge management systems because they regard effective management and strategic application of knowledge as an important factor for competition in business. However, according to Egbu (2002), satisfaction and frequency of use of the tools recognized as a knowledge management system are rated quite low by users. In case of the failure information which could be utilized in this study, it is collected as various names, fault casebook (T firm), analysis source book of fault case (T firm), experienced

knowledge (D firm), from many domestic firms. However, they are hardly utilized in actual field. Moreover, the information is offered as document or web page with related pictures and simple explanations. Referring to constructivism, these types of information offer inhibits thinking chances to internalize and to reconstruct the complex information. Namely, the methods that offer simple failure information remains in information dimension which was shown in FIGURE 2 and indirect experiences through thinking does not occur.

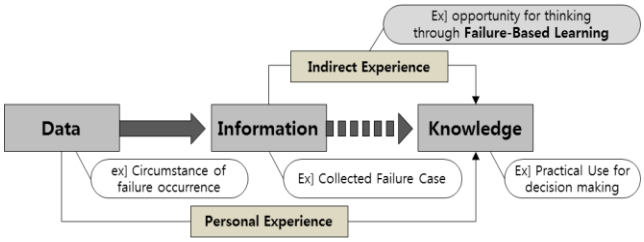

FIGURE 2
RELATIONS BETWEEN DATA, INFORMATION, KNOWLEDGE

Therefore, creating value as knowledge is difficult. Over the left, although firms are accumulating information of various forms which can be converted knowledge, they are not able to utilize effectively. So, the problem that hands-on experiences are accumulated individually is indicated as a character of construction industry.

If firms utilize failure-based learning to solve these vicious circles, failure information which occurred from complex reasons which were performed by firms can be considered deeply.

Furthermore, existing knowledge can be reconstructed and chances to get knowledge can be increased by getting new knowledge and meaningful indirect experiences. When failure-based learning is adapted, firms might have burden to reconstruct failure information and users might have burden to consider in various way. However, these can be a solution process to a part which is spoken as a problem of the school education at construction firm and it can be a meaningful investment to strengthen the firm competitiveness.

C. Availability

Problem-based learning is a learning model that can be effectively adapted to various area and various age groups of learners. However, for the successful problem-based learning accomplishment, problems which fit for the problem-based learning characters should be developed. Although many previous researches about problem-based learning's problem development, the difficulties of the development of problems have not been officially published in detail. So, there are still many difficulties about problem-based learning's problem development. Although general problem-based learning development has those difficulties, failure-based learning which utilized failure information has advantages like below.

First, failure of failure-based learning does not develop problems like problem-based learning. Failure-based learning is the occurred problem by itself. This simple difference makes the adaptation of failure-based learning easy. Second, in case of developing problems, construction failure information includes the failure reasons and surrounding circumstances which has the problem character (reality, non-constructive property) of problem-based learning. Third, if there is a process that analysis relevant failure information rather than contextual development, FLB can be adapted. Lastly, failure information is can be found easily at our surroundings. For example, pollution which is found in buildings which people lives in, collapse or negligent accident announced in news, and fault casebook published from construction firms or governmental institutions can be obtained easily.

IV. DEVELOPMENT OF FBL CONCEPTUAL MODEL

To develop failure-based learning model, problem design principle of four domestic and abroad researchers (Torp and Sage 1998, Duch 2001, Oh 2003, Choi 2005) were observed to search some points which are considered in general problem-based learning model. The considered points suggested by researchers were establishing learning objectives, analyzing learners, laying out problem situations, collecting related data, and correcting scenario. These points were shown comprehensively in FIGURE 3.

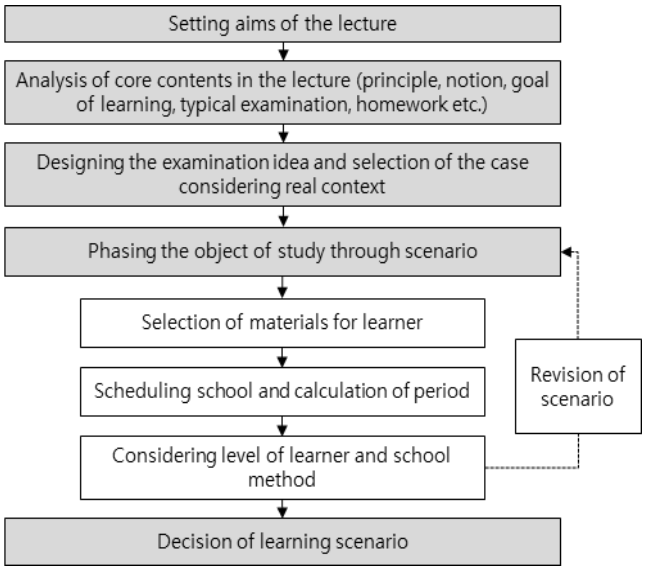

FIGURE 3
COMMON PROBLEM DESIGN PRINCIPLE OF PBL

The process of problem-based learning development is a process of understanding the character of one lecture and the reality of the topic in that lecture. Furthermore, it is a process that trains thorough analysis of learners who solve the problems in the problem-based learning process and practical analysis related problems.

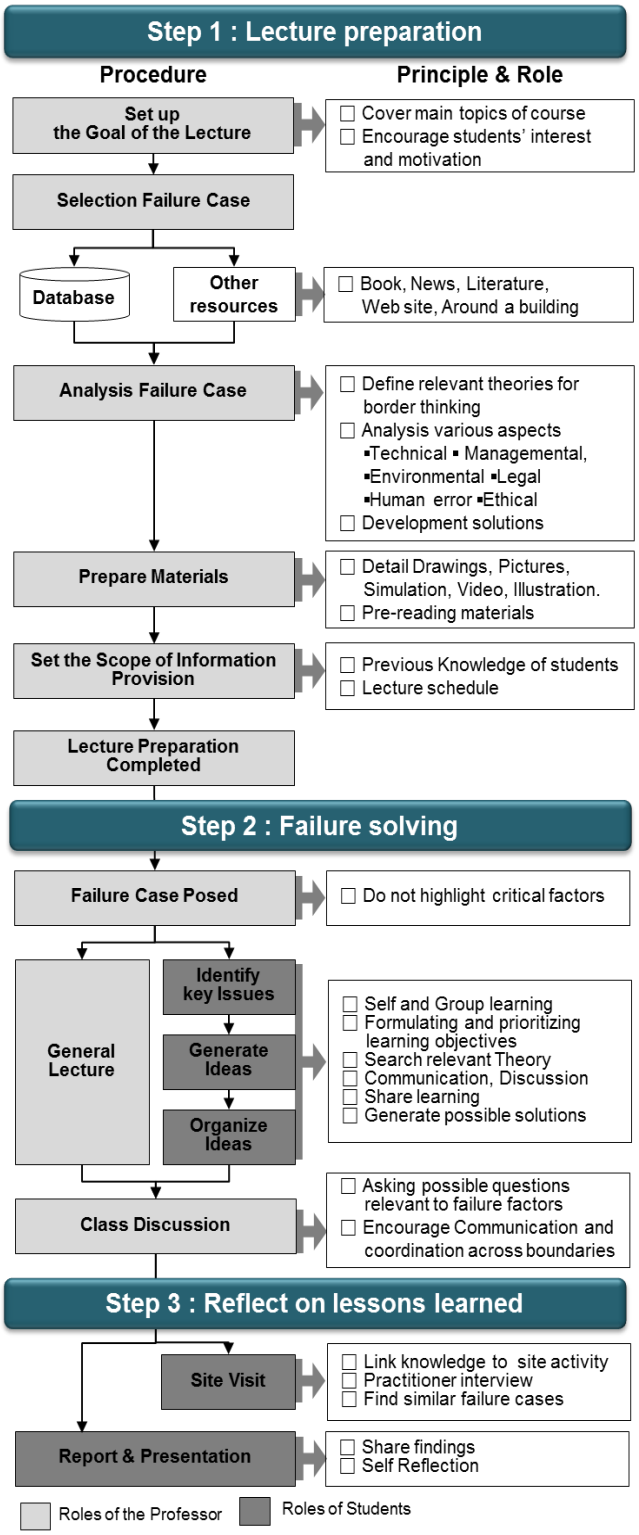

FIGURE 4
DEVELOPMENT OF CONCEPTUAL FBL MODEL

Referring to these considered points; failure-based learning model which fits for the characters of failure information was developed. The most important thing during developing failure-based learning problem is the analyzing the reasons that make failures in various aspects. In relevant subjects, analysis should be focused on which part was the reason of the failure. The object is for learners to assume the failure reasons and to study relevant substances by themselves and to get chances to experience the process of draw the failure reasons with various assumptions.

The organization of the model is divided into 3 steps; first, the lecture preparation by teachers, second, problem solving step by students and third, Reflect on lessons learned by students. Each step of the model suggests the detailed procedures and the principles and roles that need to be considered. The failure-based learning model is shown in FIGURE 4.

V. APPLICATION OF FBL MODEL

In this chapter, through the examples, the key contents of each stage of the model are explained and examined how the actual failure cases can be applied in the lectures.

Failure cases are picked in Journal of Performance of Constructed Facilities of ASCE (Angeles, 2009). This paper identified various types of brick failure was occurred in one building. This failure is not only technical factor, but also inherent environmental factor which is not covered a subject of class in school. This failure is based on complex factor; it is enabled to produce the content helping learner experience complication of the field. Analyzed lecture content with failure-based learning model is shown FIGURE 5.

First, it is the lecture preparation step of the teachers. It contains the selection of cases and analyses. The selected of failure cases need to be able to deal with the main contents of the lecture and should motivate the interests of the students to solve the problem. The example deals with the detachment of the brick walls.

Next, in the case analysis stage needs to analyze the direct causes of the failure and the various aspects. In this example, the bricks were detached where bricks, mortar and the RC slab were united. The reasons of the brick detachment were the difference rate of thermal expansion between bricks and RC slab. The environmental side is also failure factors such as sunlight, temperature and humidity. The technological side is same such as omission of expansion joint that can absorb the thermal expansion of the each material. Such results of the analysis were examined in detail in the class discussion stage.

Second, it is the problem solving step of the students. Before the lecture, the failure case is presented. Through this, the student can continuously be interested in the failure factors during the lecture and can gain opportunities to hypothesize, learn and integrate through the self and group learning actively. After the lecture, the class discussion occurs. The teacher suggests various issues from the case as the topics of discussion. In this case, the materials such as bricks and mortar and the environmental factors, such as external temperature, humidity and sunlight that can affect the materials and the relevance of the physical movement can be the first discussion point.

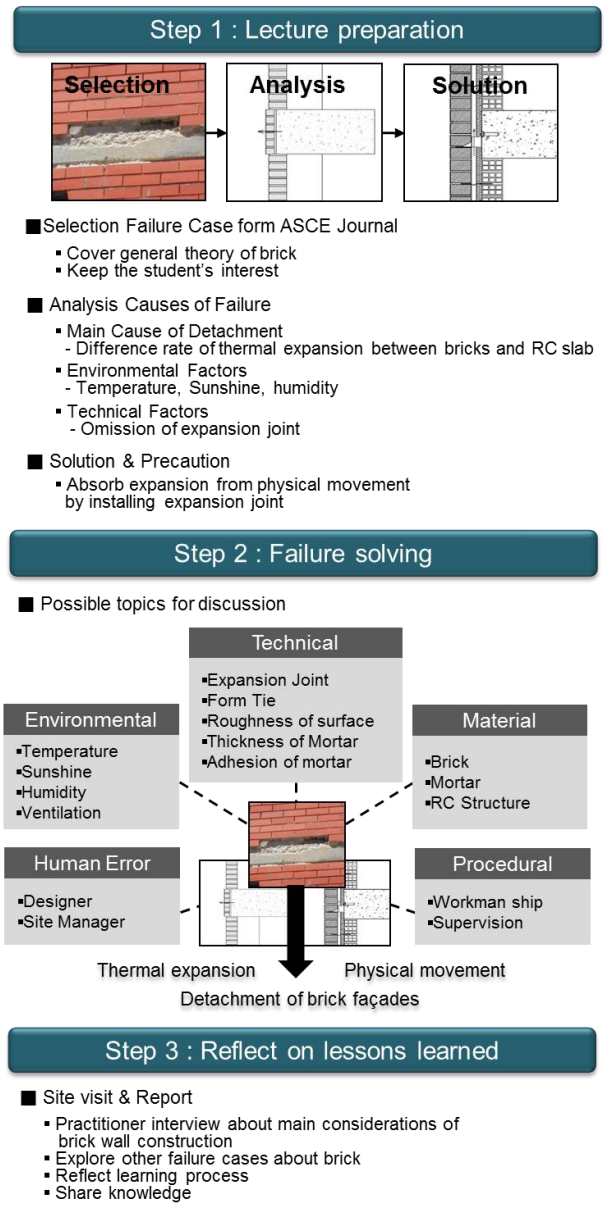

FIGURE 5
APPLICATION OF FBL MODEL

Also, the thickness of the mortar and the adherence, the role of the expansion joint in technological aspect and the workmanship of the laborers can still be discussed. Also, the discussion of the lack of control ability of supervisor and the design faults of the designer for the failure could occur as well. Through various discussions, the general contents of the brick wall lecture and the main contents of other chapters could be connected as well as the ethical aspect of the responsibilities and the roles of the designers and workers can be discussed that cannot be discussed often in the traditional lecture.

Lastly, the student can confirm the learned knowledge through site visits or reports. The students can directly confirm how the learned failure factors are being dealt with on-site and can expand the knowledge on the management factors through the interviews with the site managers. Such results can be reflected and shared with others through reports and presentations.

VI. CONCLUSIONS

The purpose of this study is to suggest the failure-based learning - which is combination of the procedural characteristics of the problem-based learning theory and the information on construction failures that has the educational value in the construction area - for the purpose of resolving limitation of the current construction education.

In addition, to foster the application of the failure-based learning which is a new method for construction education, processes to be considered in the development of the failure-based learning is developed as a model and the procedures for development of the failure-based learning education materials are described simply through the course of actual application.

Failure-based learning using failure information brings valuable effects to educational environment and construction industry. In construction education, this model would be valuable supplement by providing opportunities for thorough consideration on the various complex relationships of the field and giving a chance to integrate failures in the practical experience with the technical theories. Then, from the point of the view of a company, it is able to improve the problem of empirical knowledge which is learned by performing the project stays with the individual, rather than being captured by the firms and the competitiveness of a company can be reinforced through improvement in prevention of failures. Also, the persistently complained difficulty in development of problem-based learning's problems and its approach can be approached with ease by utilizing the failure information as educational contents. Moreover, failure-based learning is anticipated to expand the scope of educational application of the failure information beyond the limitation of the forensic engineering which chiefly focuses on the structure section. After considering above effects, approach of failure-based learning proposed by this paper would be able to apply other engineering area as well as construction.

Although this study has lots of advantages, this study has some limitations and the additional research areas. The development of failure-based learning model and application of course contents through failure-based learning model were based on non-engineering pedagogical theory. Therefore, further research should be conducted about verifying failure-based learning model and scenario that goes as planned and which step of the scenario make faculty and learner feel difficult. And then, the issues of the data storage and analysis will be examined. The database for the cases of failure information needs to be established for the educational utilization. The Database structure that is currently planned will be divided into various categories. Also, using the Case Based Reasoning analysis on the accumulated data, the key issues and solutions or valuable something in similar failure cases can be analyzed. Finally,

the failure data collection issues will be examined. The collection of the failure information is the basic step for the utilization of the failure information. We plan to use the industry-academia cooperation or use social media for further research.

This study intended to resolve the circumstances, in which the failure information cannot be utilized even though the educational value of the information is acknowledged, through the proposal of the failure-based learning. In other words, it was found through the failure-based learning that completely different effects can be expected depending on strategies which delivers and organizes lot of information. This study has its significance from the point of view that it is an attempt in an area in which there was no precedent research, both domestically and internationally.

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