DEVELOPMENT AND APPLICATION OF FAILURE-BASED LEARNING MODEL FOR CONSTRUCTION TECHNOLOGY 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 model

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

1. 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 engineers' 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.

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.

2. PROBLEM-BASED LEARNING (PBL)

Problem-based learning is an active instructional method. It is based on real-life scenario, open-ended and ill-structure problem and provides limited resources to solve the problem.

In contrast with the traditional learning process use the problem after introducing contents, problem-based learning introduces the problem to challenge, motivate, center, and initiate learning (Duch 1996).

The theory of problem-based learning was firstly emerged at the end of the 1969 at medical education in McMaster University. Barrows (2000) identified that necessary solutions are inference and student-centered learning for medical students to solve the problems faced after graduation, then, problem-based learning is was developed to improve the inference and self-leading

studies which are were not enhanced by traditional teaching-learning paradigm.

Originally, although problem-based learning is the learning paradigm in order to resolve the unique problem in medical students, a highly difficult inference, student-centered learning, and problem-solving are required to a variety of area such as engineering, business administration, education, and law as well as medicine (Duch 2001).

The effect of problem-based learning is developed by the feature of the problem and distinctive process to solve the problem. Problem-based learning is initiated by a problem, which are ill-structure and real-life. In comparison, ill-structure 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.

Also, non-structure 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. Problem-based learning should have a real life context. Good problem-based learning's problem should arouse the interest and motive of learner to promote deeper understanding about learning materials. The realism of problem makes learner feel friendliness with the problem and duty 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).

It was observed that the characteristics of problems in PBL and the procedure of PBL for resolving the problems can help produce people who have varied capabilities that are required in the knowledge information society. It was also found through literary research that PBL is the learning model which can be effectively applied to various sectors and learning generations (Shon 2008, Johnson 1979, Hmelo 1998).

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 (Chau 2007, Jose 2010, Quinn 2008, McIntyre 2002).

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.

3. FAILURE -BASED LEARNING (FBL)

3.1 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
Hohns (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. The characteristics of construction industry are that a single 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 fig 1.

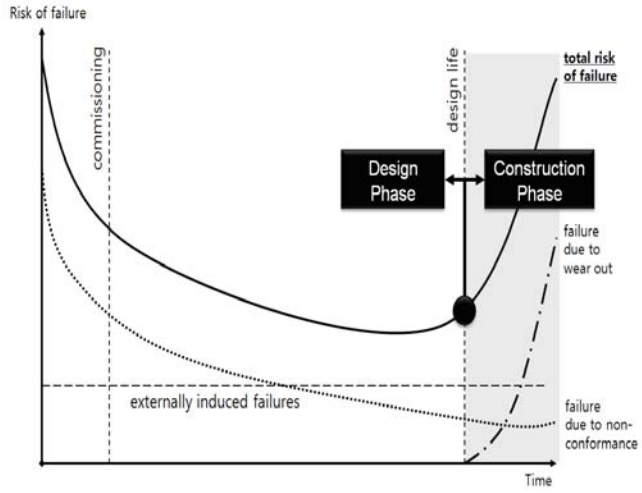


Fig 1. The relationship between time and risk
(Source: adapted from Graham, fig 8.1)

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 2, 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.

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.

3.2 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 (Oswald 1993, Bosela 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 regarding safety as the most important is related with such problems in the education of construction. A project can be performed well without developing a new method in construction industry except possibly in isolated cases. Developing a new technique takes long time. Even though it is developed, pilot construction as well as demonstration study should be performed to apply to the field. Therefore it takes long periods to recover the investment. For this reason, the education of construction is composed of knowledge verified through long time, and performed by delivering theories with lecture-style. 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 equipments, 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 Fig 2 and indirect experiences through thinking does not occur. 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.

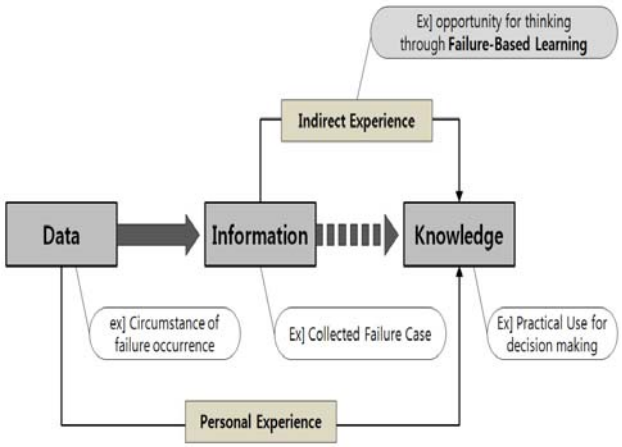


Fig 2. Relations between data, information, knowledge

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.

3.3 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.

4. DEVELOPMENT OF FBL 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 Fig. 3.

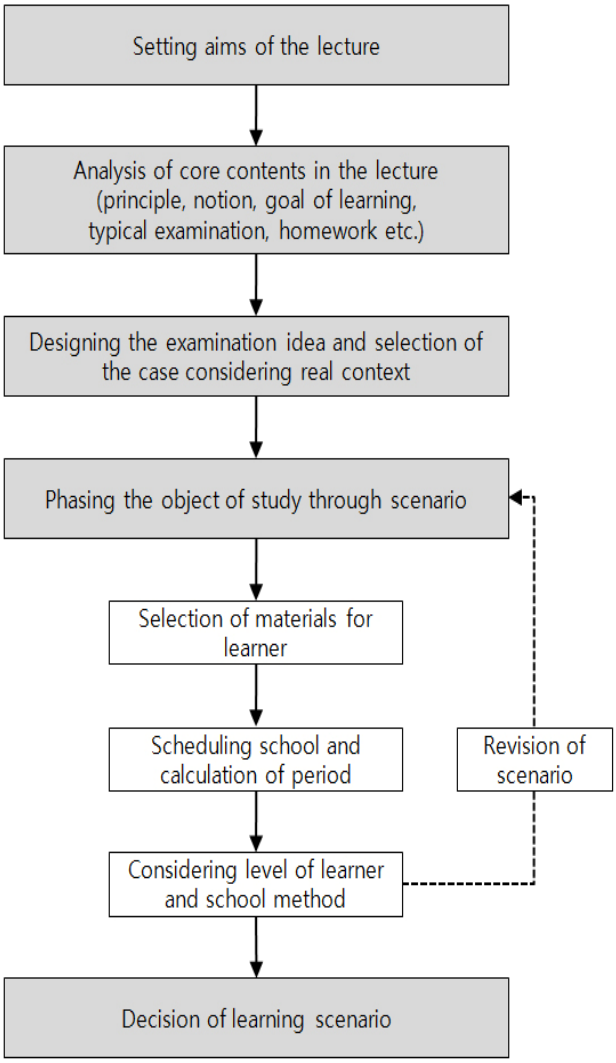


Fig 3. Common problem design principle of PBL

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.

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 failure-based learning model is shown in Fig 4.

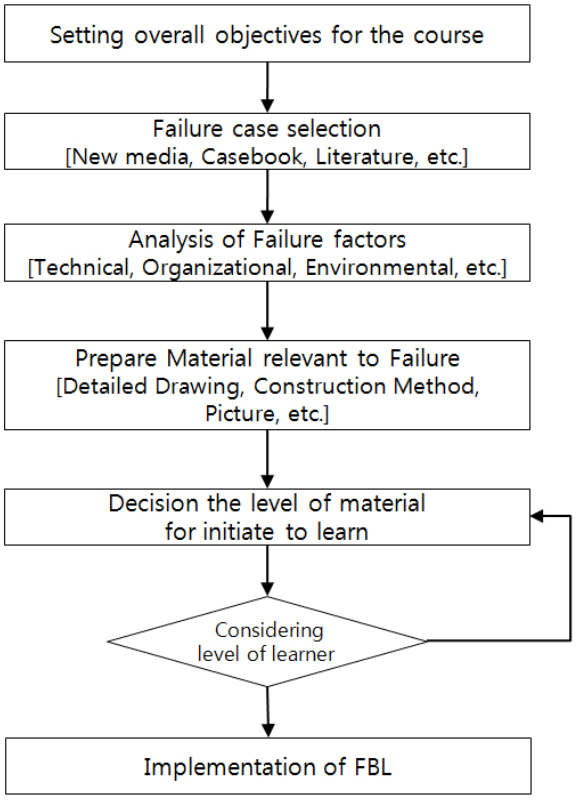


Fig 4. FBL Model

5. APPLICATION OF FBL MODEL

First failure cases are picked in Journal of Performance of Constructed Facilities of ASCE. 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 Table 2.

Second failure case referred a casebook of construction defects and is concerned with cracks in the roof happened due to expansion of topping concrete and exception of expansion joint. The crack lead to water contaminates interior ceiling finishing. It is applied a variety of flaws to gain the learning objective and instruct waterproofing method in traditional curriculum. It is developed with various failure cases, not using just one case because learning term of the failure-based learning is shorter than typical problem-based learning method. For using the failure-based learning with a casebook of construction defects, learners can figure out the mechanism of the water leak and learn. Analyzed lecture content with failure-based learning model is shown Table 3.

Table 2. Application of FBL using literature source (Angeles 2009)

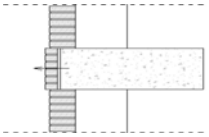
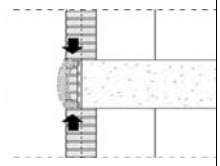
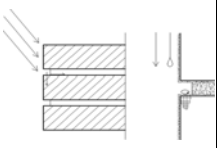
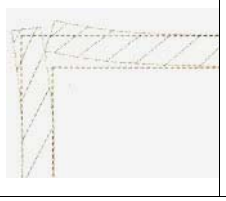
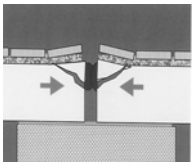
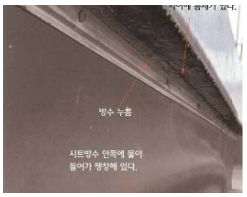
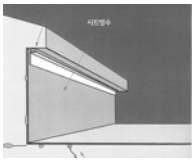
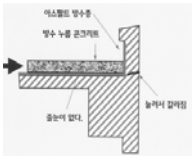
Failure Contents	What to know	Critical Failure Factors	
	1)Function of anchor, installation method, and sort 2) Features and necessity of materials		Horizontal anchor omission and lack of lining mortal thickness and plugging
	1)Matters to be attended to construct veneered brick 2)Necessity of sufficient lining mortal quantity 3)Importance of securement minimum thickness for veneered brick		Flaking veneered brick cause of masonry wall weight
	1)The way of construction of pointed joint and matters to be attended 2) Grasp absorptiveness of masonry brick		Expansion of bricks, mortars, and support can be due to continued exposure to humidity
	1)Function of expansion joint, installing position, and arrangement space 2)Thermal expansion of materials		Lacking expansion joint of long stretches and thermal expansion following degree of isolation

Table 3. Application of FBL using casebook source (Nakazawa 2006)

Failure Contents	What to know	Critical Failure Factors	
	1) Function of expansion joint, materials, properties, construction method, and matters to be attended 2) Property of concrete, mixing proportion, coefficient of thermal expansion, 3) Handling waterproof foundation, rein		Crack is occurred by omission of expansion joint and poor construction.
	1) Materials, mixing, properties, efficiency and construction of concrete and solving the problem 2)Categorization of sheet waterproof, check list, way of adhesion, improved asphalt sheet waterproof, copolymer sheet waterproof		waterproof sheet expansion by omission of parapet drip
	1) Materials, mixing, properties, efficiency and construction of concrete and solving the problem 2) Structural form of roof parapet Waterproof finishes of vertical part of the parapet		Parapet crack is caused by expansion waterproof topping concrete

6. 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.

First, it would be valuable supplement in construction education 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.

Second, 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.

Third, 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.

Lastly, 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. Also, approach of failure-based learning proposed by this paper would be able to apply other engineering area as well as construction.

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.

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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